Form 1

REPUBLIC OF NAMIBIA ENVIRONMENTAL

MANAGEMENT ACT, 2007 (Section 32)

APPLICATION FOR **RENEWAL** OF ENVIRONMENTAL CLEARANCE CERTIFICATES

PART A: DETAILS OF APPLICANT

1. Name: (person or business):
   Rössing Uranium Ltd
2. Business Registration / Identity No.
   70/1591
3. Correspondence Address:
   C/o Rössing Uranium Ltd
   Private Bag 5005
   Swakopmund
   Namibia
4. Name of Contact Person:
   Mr. Johan Coetzee
5. Position of Contact Person:
   Managing Director
6. Telephone No.:
   +264 64 520 3400
7. Fax No.:
   +264 64 520 3432
8. E-mail Address: (if any)
   Johan.coetzee@rossing.com.na

PART B: SCOPE OF RENEWAL OF ENVIRONMENTAL CLEARANCE CERTIFICATES

1. The renewal application for environmental clearance certificates is for

THE PROPOSED DESALINATION PLANT OF RÖSSING URANIUM LIMITED

2. Details of the activity(s) covered by the environmental clearance certificate:

[Note: Please attach plans to show the location and scope of the designated activity(s) and use additional sheets if necessary:

Title of Activity:

THE PROPOSED RÖSSING URANIUM MINE DESALINATION PLANT NEAR SWAKOPMUND, ERONGO REGION

Nature of Activity:

Rössing Uranium Limited propose to develop a new desalination plant to supply the mine's water needs.

Location of Activity:

The proposed desalination plant will be approximately 6km north of Swakopmund at the existing Swakopmund Salt Works, see Maps in the SEIA report.

Scale and Scope of Activity:

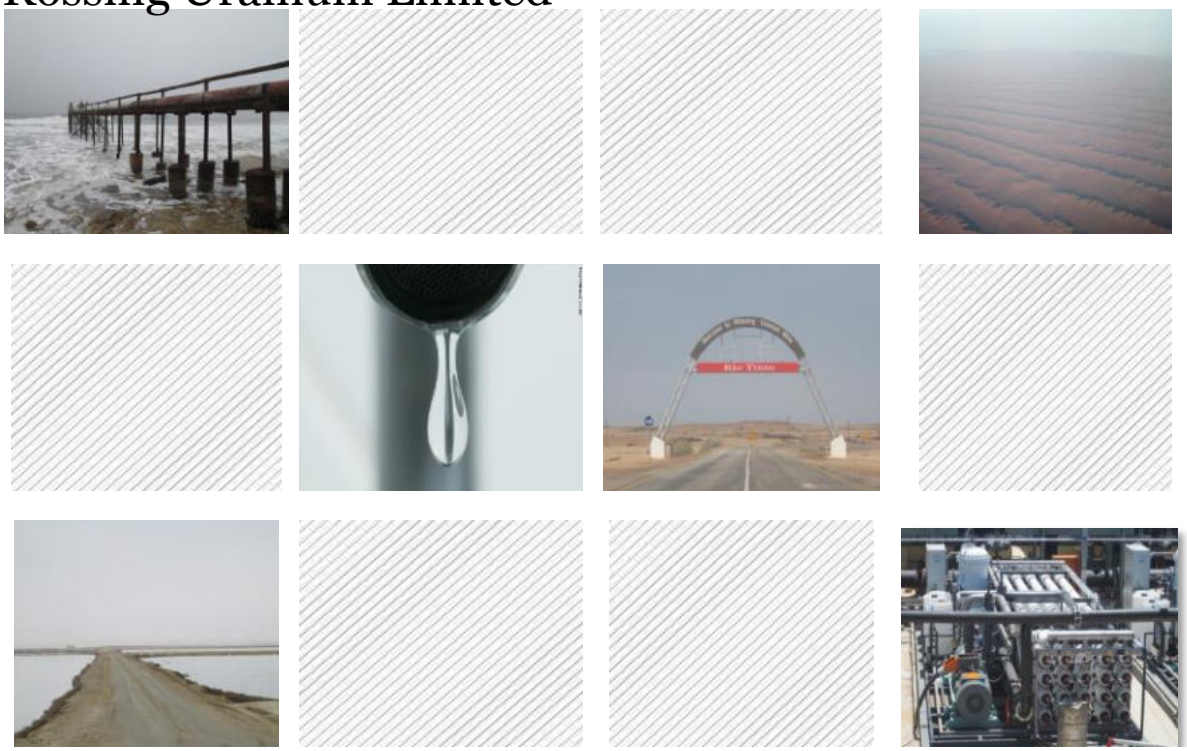
As contained in the relevant Environmental Assessment Report and Environmental Management Plans.

PART C: DECLARATION BY APPLICANT

I hereby certify that the particulars given above are correct and true to the best of my knowledge and belief. I understand the environmental clearance certificate may be suspended, amended or cancelled if any information given above is false, misleading, wrong or incomplete.

Signature of Applicant	**Johan Coetzee** Full name in Block Letters	**Managing Director** Position
On behalf of	**Rössing Uranium Ltd**	Date: **07 July 2025**

Rössing Uranium Limited



SOCIAL AND ENVIRONMENTAL IMPACT ASSESSMENT FOR THE PROPOSED RÖSSING URANIUM DESALINATION PLANT NEAR SWAKOPMUND, NAMIBIA

FINAL SEIA REPORT

PROJECT REFERENCE NO: 110914
DATE: JANUARY 2015

PREPARED BY

aurecon
SLR

ON BEHALF OF

RioTinto
Rössing Uranium
Working for Namibia

PROJECT DETAILS

PROJECT: Social and Environmental Impact Assessment for the Proposed Rössing Uranium Desalination Plant, near Swakopmund, Namibia

AUTHORS: Andries van der Merwe (Aurecon)
Patrick Killick (Aurecon)
Simon Charter (SLR Namibia)
Werner Petrick (SLR Namibia)

SPECIALISTS:
Birds –Mike and Ann Scott (African Conservation Services CC)
Heritage – Dr John Kinahan (Quaternary Research Services)
Marine ecology – Dr Andrea Pulfrich (Pisces Environmental Services (Pty) Ltd)
Noise - Nicolette von Reiche (Airshed Planning Professionals)
Socio-economic - Auriol Ashby (Ashby Associates CC)
- Dr Jonthan Barnes (Design and Development Services CC)[1]
Visual – Stephen Stead (Visual Resource Management Africa)
Wastewater discharge modelling – Christoph Soltau (WSP Group)
Shoreline dynamics - Christoph Soltau (WSP Group)

PROPONENT: Rio Tinto Rössing Uranium Limited

REPORT STATUS: Final Environmental Impact Report

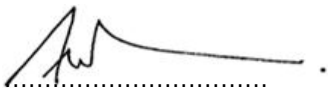
REPORT NUMBER: 9408/110914

STATUS DATE: 27 January 2015

Patrick Killick
Senior Practitioner: Aurecon Environment and Advisory

Simon Charter
Senior Practitioner: SLR Environmental Consulting

Werner Petrick
Director: SLR Environmental Consulting



Andries van der Merwe
Technical Director: Aurecon Environment and Advisory

This report is to be referred to in bibliographies as: Aurecon and SLR. 2014. Social and Environmental Impact Assessment for the Proposed Rössing Uranium Desalination Plant, near Swakopmund, Namibia. Final SEIA Report, Report No. 9408/110914.

Note: All significant changes to the SEIA affected between the draft and final versions of the report are denoted by the underlining of text, as used here.

[1] Dr Jonathan Barnes sadly passed away during the course of the project. The project team would like to acknowledge his contribution and extend our condolences to his family, friends, and colleagues.

TABLE OF CONTENTS

NON-TECHNICAL SUMMARY I

1 INTRODUCTION 1

2 LEGAL FRAMEWORK 4

2.1 The Constitution of the Republic of Namibia (Act 1 of 1990) 4
2.2 Environmental Management Act (Act 7 of 2007) 4
2.2.1 Content of SEIA Report 6
2.3 Water Resources Management Act (Act 24 of 2004) 7
2.4 The National Heritage Act (Act 27 of 2004) 8
2.5 The Soil Conservation Act (Act 76 of 1969) 8
2.6 The National Policy on Coastal Management for Namibia (2013) 8
2.7 The Marine Resources Act (2000) 9
2.8 The Aquaculture Act (2002) 9
2.9 The Integrated Coastal Management Bill (2014) 10
2.10 The National Policy on Human-Wildlife Conflict Management (2009) 10
2.11 Proposed Climate Change Strategy and Action Plan (2009) 10
2.12 The Namibia Vision 2030 11
2.13 COASTAL SEAS 11
2.14 Water Quality Guidelines 12
2.15 Biodiversity Legislation and Policies 15
2.15.1 Rio Tinto Environmental and Sustainability Policies 15
2.15.2 Rössing Uranium Limited Policies 16
2.16 Social Policies 17
2.16.1 The MET Policy on HIV and AIDS 17

3 PROJECT DESCRIPTION 18

3.1 A background to desalination 18
3.2 Project Need and Desirability 22
3.3 Project Overview 23
3.3.1 Pre-construction phase 23
3.3.2 Construction phase 23
3.3.3 Operations phase 28
3.3.4 Decommissioning phase 28
3.4 Project location 28
3.5 Project Components 30
3.5.1 Seawater intake system 34
3.5.2 Seawater pre-treatment system 35
3.5.3 Desalination plant 36
3.5.4 Electrical supply system 39
3.5.5 Product water system and pipeline 40
3.5.6 Effluent treatment and disposal system 41

4 SCREENING OF PROJECT OPTIONS 44

4.1 Trade off study 1 ~ Seawater intake location 45
4.1.1 Site 1: Adjacent the Salt Work's jetty 45
4.1.2 Site 2: Outer shelf 46
4.1.3 Site 3: Yellow shelf 46
4.1.4 Recommendation 46
4.2 Trade off study 2 ~ Brine outfall locations 46
4.2.1 Outfall 1 47
4.2.2 Outfall 2 49
4.2.3 Outfall 3 50
4.2.4 Outfall 4 51
4.2.5 Outfall 5 52
4.2.6 Recommendation 53
4.3 Trade off study 3 ~ Brine discharge method 54
4.3.1 Discharge method 1 ~ Surf zone discharge 55
4.3.2 Discharge method 2 ~ Offshore discharge 56
4.3.3 Discharge method 3 ~ Infiltration Pond 57
4.3.4 Discharge method 4 ~ Beach channel 58
4.3.5 Recommendation 59

4.4 Trade off studies 4, 7 and 9 ~ Seawater delivery systems 60
4.4.1 Trade off study 4 ~ Seawater Channel vs Pipeline 61
4.4.2 Trade-off study 7 ~ Storage options 64
4.6 Trade-off study 9 ~ Seawater Direct to Plant vs Seawater Pond (Combined options) 67
4.6.1 Recommendation 67
4.7 Trade off study 5 ~ Plant location 68
4.7.1 RO Plant site 1 ~ Central site 69
4.7.2 RO Plant site 2 ~ Northern site 70
4.7.3 RO Plant site 3 ~ Eastern Site 70
4.7.4 Recommendation 70
4.8 Trade off study 6 ~ Plant size vs energy 71
4.9 Trade off study 8 ~ plant size vs product water storage 73
4.9.1 Option 1 ~ 8,500m³/d plant 74
4.9.2 Option 2 ~ 9,100m³/d plant 75
4.9.3 Option 3 ~ 10,000m³/d plant 75
4.9.4 Recommendation 76
4.10 Trade off study 10 ~ ProGreen vs traditional 76
4.10.1 Recommendations 77
4.11 Trade off study 11 ~ Seawater intake power supply 77
4.11.1 Option 1: New cable 77
4.11.2 Option 2: Re-use of existing cable 78
4.11.3 Recommendations 79
4.12 Project alternatives assessed in the SEIA 80

5 DESCRIPTION OF THE AFFECTED ENVIRONMENT 84
5.1 Socio-economic Environment 84
5.1.1 The Erongo Region 84
5.1.2 Swakopmund 85
5.1.3 Arandis and Henties Bay 87
5.1.4 The mining economy 87
5.1.5 Guano Production 89
5.1.6 Water Supply and Demand 89
5.2 Physical Environment 92
5.2.1 Surrounding landuses 92
5.2.2 Climate 94
5.2.3 Geology and geomorphology 95
5.2.4 Topography 96
5.2.5 Soils 96
5.2.6 Hydrology 97
5.2.7 Oceanography 97
5.2.8 Visual Character 109
5.2.9 Noise Character 114
5.3 Ecological Environment 123
5.3.1 Flora 123
5.3.2 Avifauna 125
5.3.3 Fauna 133
5.3.4 Marine ecology 134

6 ENVIRONMENTAL ASSESSMENT METHODOLOGY 155
6.1 Considering Cumulative Impacts in Erongo 158

7 IMPACT ASSESSEMENT 161
7.1 Overview of specialist studies undertaken 161
7.2 Overview of the impact assessement 162
7.3 introduction to Assessment Tables 163
7.4 Socio-economic impacts 163
7.4.1 Construction phase 164
7.4.2 Operations phase 165
7.4.3 Decommissioning phase 173
7.4.4 Cumulative impacts 174
7.5 Archaeology and heritage impacts 175
7.5.1 Construction phase 175
7.5.2 Cumulative impacts 177
7.6 Visual impacts 177
7.6.1 Construction phase 185
7.6.2 Operations phase 187

7.6.3 Decommissioning phase 188
7.6.4 Cumulative visual impacts 189
7.7 Noise impacts 189
7.7.1 IFC Guidelines on Environmental Noise 190
7.7.2 SANS 10103 190
7.7.3 Birds and Their Response to Noise 191
7.7.4 Construction phase 194
7.7.5 Operations phase 202
7.7.6 Decommissioning phase 212
7.7.7 Cumulative impacts 213
7.8 Avifauna impacts 213
7.8.1 Construction phase 214
7.8.2 Operations phase 220
7.8.3 Decommissioning phase 226
7.8.4 Cumulative impacts 227
7.9 Marine ecology impacts 228
7.9.1 Marine ecology 228
7.9.2 Construction phase 230
7.9.3 Operations phase 239
7.9.4 Decommissioning phase 262
7.9.5 Cumulative impacts 262
7.10 Shoreline dynamics impacts 263
7.10.1 Construction phase 263
7.10.2 Operations phase 267
7.10.3 Decommissioning phase 272
7.10.4 Cumulative impacts 272
7.11 Other impacts and aspects 273
7.12 Social and Environmental Management Plan 273
7.13 Assumptions, uncertainties and gaps in knowledge 274
7.13.1 Socio-economic 274
7.13.2 Archeology and heritage 274
7.13.3 Visual 274
7.13.4 Noise 275
7.13.5 Avifauna 275
7.13.6 Marine ecology 276
7.13.7 Brine diffusion 276
7.13.8 Shoreline dynamics 277

8 PUBLIC PARTICIPATION 278
8.1 SEIA Programme 278
8.2 Initiation of the public participation process 278
8.3 Meetings 279
8.4 Comment on the Draft Scoping Report 280
8.5 Submission of the Scoping Report 280
8.6 comment on the Draft SEIA Report 281
8.7 Decision and Way Forward 281

9 OPINIONS AND RECOMMENDATIONS 282
9.1 Environmental Assessment Practitioner's opinion on project acceptability 282

10 CONCLUSION 287

11 BIBLIOGRAPHY 289

ANNEXURE A CVS OF THE ENVIRONMENTAL ASSESSMENT PRACTITIONERS .....
ANNEXURE A1 CV for Andries van der Merwe .....
ANNEXURE A2 CV for Patrick Killick .....
ANNEXURE A3 CV for Simon Charter .....
ANNEXURE A4 CV for Werner Petrick .....

ANNEXURE B PUBLIC AWARENESS AND NOTIFICATIONS .....
ANNEXURE B1 Background Information Document .....
ANNEXURE B2 Project meetings presentation .....
ANNEXURE B3 Site Notices .....
ANNEXURE B4 Newsprint Advertisements .....
ANNEXURE B5 Rössing Uranium staff notifications .....

ANNEXURE C PUBLIC ENGAGEMENT AND RESPONSE
ANNEXURE C1 Meeting Minutes with MUN
ANNEXURE C2 Meeting Minutes with Media Focus Group
ANNEXURE C3 Meeting Minutes with Swakopmund stakeholder groups
ANNEXURE C4 Meeting Minutes with Swakopmund public
ANNEXURE C5 Meeting Minutes with MAWF
ANNEXURE C6 Meeting Minutes with NamWater
ANNEXURE C7 Record of discussion with MET
ANNEXURE C8 I&AP Register
ANNEXURE C9 Comments and Responses Report

ANNEXURE D SPECIALIST STUDIES
ANNEXURE D1 Socio-economic impact assessment
ANNEXURE D2 Archaeology impact assessment
ANNEXURE D3 Visual impact assessment
ANNEXURE D4 Noise impact assessment
ANNEXURE D5 Avifauna impact assessment
ANNEXURE D6 Marine ecology impact assessment
ANNEXURE D7 Brine dilution modelling study
ANNEXURE D8 Shoreline dynamics study

ANNEXURE E SOCIAL AND ENVIRONMENTAL MANAGEMENT PLAN

LIST OF FIGURES

Figure 1: SEIA process overview 3
Figure 2: Total global water resource estimates 18
Figure 3: Cumulative desalination capacity of the world 19
Figure 4: The total global installed desalination capacity as of 2009 20
Figure 5: Regions of the world which have implemented desalination plants/facilities 20
Figure 6: Principle of RO and semi-permeable membrane 21
Figure 7: Location of the proposed Rössing Uranium desalination plant in the regional context 29
Figure 8: “Base Case” and optimised SEIA location of the proposed desalination plant in the local context 30
Figure 9: RO Project Process Flow Diagram 31
Figure 10: Detailed process flow diagram 32
Figure 11: Base Case project layout 33
Figure 12: Existing seawater abstraction jetty for the Salt Works 34
Figure 13: RO Plant provisional schematic 37
Figure 14: 11kV power supply route 39
Figure 15: Product water pipeline route 40
Figure 16: Intake location options 45
Figure 17: Brine Outfall Location Options 47
Figure 18: Brine Outfall 1 Concept Layout 48
Figure 19: Brine Outfall 2 Concept Layout 49
Figure 20: Brine Outfall 3 Concept Layout 50
Figure 21: Brine Outfall 4 Concept Layout 51
Figure 22: Brine Outfall 5 Concept Layout 52
Figure 23: Brine discharge methods in spatial concept 55
Figure 24: Salt Works Seawater Intake Channel 61
Figure 25: Schematic layout of the combined pipeline and channel option 62
Figure 26: Option 3 - schematic of pipeline only 63
Figure 27: Storage Option A schematic - no storage 65
Figure 28: Existing oyster pond 65
Figure 29: Example of a storage tank 66
Figure 30: Option 1C schematic – seawater channel with own pond 68
Figure 31: RO Plant site Options 69
Figure 32: Plant size vs return of investment 73
Figure 33: Option 1 Demand-Supply-Storage simulation result 75
Figure 34: Option 2 Demand-Supply-Storage simulation result 75
Figure 35: Option 3 Demand-Supply-Storage simulation result 76
Figure 36: Seawater intake power supply option 1 78
Figure 37: Seawater intake power supply option 2 79
Figure 38: Alternative layouts 83
Figure 39: Constituencies in the Erongo Region 85
Figure 40: Long term town plan for Swakopmund 86

Figure 41: The Dorob National Park 93
Figure 42: Wind roses 95
Figure 43: General view of the Base Case desalination plant site 96
Figure 44: View of the beach areas of the Swakopmund Salt Works area 97
Figure 45: The coastline west of the Salt Works 98
Figure 46: The proposed desalination plant (red rectangle) in relation to the regional offshore seabed sediments 99
Figure 47: Seasonal offshore wave conditions 101
Figure 48: The location in relation to the upwelling cells and the formation zones of low oxygen water 104
Figure 49: Seawater temperatures at Swakopmund recorded between 1988 and 1998 104
Figure 50: Satellite image showing dust plumes being blown offshore from the Namibia coast 106
Figure 51: 'Walk-outs' and mass mortalities of rock lobsters at the central Namibian coast 108
Figure 52: Near shore sulphur eruption 109
Figure 53: Landscape context photograph points overlay onto satellite image 110
Figure 54: Panoramic photograph of Swakopmund town from the renowned Jetty south of the main beach 110
Figure 55: Photograph taken south of the C34 National Road with Swakopmund town in the background 111
Figure 56: Photograph depicting the existing Salt Company (Pty) Ltd structures and salt stockpiles and warehouse 112
Figure 57: The Guano Company structures and the green Correctional Services residence as seen from the C34 road 113
Figure 58: Photograph taken north of the coastline from the existing Swakopmund Salt Work inlet structure 114
Figure 59: Environmental baseline noise sampling locations 117
Figure 60: Pictures of sampling locations 117
Figure 61: 20-minute day-time sample at Location 1, the Swakopmund Salt Works on 20-Aug-14 119
Figure 62: 20-minute night-time sample at Location 1, the Swakopmund Salt Works on 20-Aug-14 120
Figure 63: 3rd octave band frequency spectra at Location 1, the Swakopmund Salt Works 120
Figure 64: 20-minute day-time sample at Location 2, the desalination plant site on 20-Aug-14 121
Figure 65: 20-minute night-time sample at Location 2, the desalination plant site on 20-Aug-14 121
Figure 66: 3rd octave band frequency spectra at Location 1, the Swakopmund Salt Works 122
Figure 67: 20-minute day-time sample at Location 3, Swakopmund on 20-Aug-14 122
Figure 68: 20-minute night-time sample at Location 3, Swakopmund on 20-Aug-14 123
Figure 69: 3rd octave band frequency spectra at Location 2, Swakopmund 123
Figure 70: The Damara Tern 126
Figure 71: Some microhabitats for birds in the Swakopmund Salt Works area 131
Figure 72: Cross-section of the coastal zone showing the typical habitats and morphology 136
Figure 73: Intertidal rocky communities 138
Figure 74: West Coast intertidal beach zonation 141
Figure 75: Benthic macrofaunal genera commonly found in nearshore sediments 143
Figure 76: Phytoplankton and zooplankton associated with upwelling on the Namibian shelf 144
Figure 77: Major spawning areas in the central Benguela region 145
Figure 78: Small pelagic Fish of the area 148
Figure 79: Dead Leatherback Turtle washed up at a beach north of Swakopmund, March 2008 149
Figure 80: Marine mammals 151
Figure 81: Cape Fur Seals 154
Figure 82: Key Observation Points overlaid onto Open Source Satellite Image Map 179
Figure 83: Viewshed of proposed plant and substation structures with a 6m height offset overlay onto Open Source Satellite Imagery Map 180
Figure 84: Existing and probable landscape change of plant Base Case as seen from travelling north on the Henties Bay Road 181
Figure 85: Existing and probable landscape change of Plant Alternative 1 as seen from travelling north on the Henties Bay Road 182
Figure 86: Existing and probable landscape change of Plant Alternative 2 as seen from travelling north on the Henties Bay Road 183
Figure 87: Probable routings of the powerline as seen from Swakopmund north and the Henties Bay Road (Alternative 3) 184
Figure 88: Hearing thresholds of several bird species in comparison with human hearing 192
Figure 89: Masking functions (critical ratios) for 14 species of birds (Dooling R. , 2002) 193
Figure 90: Isopleths of day-time L_{Aeq} (1 hr) during the construction phase 196
Figure 91: Isopleths of the increase in day-time L_{Aeq} (1 hr) during the construction phase 197
Figure 92: Isopleths of night-time L_{Aeq} (1 hr) during the construction phase 198
Figure 93: Isopleths of the increase in night-time L_{Aeq} (1 hr) during the construction phase 199
Figure 94: Minimum distances between to noise sensitive receptors and RO Plant 203
Figure 95: Isopleths of day-time LAeq (1 hr) during the operational phase 206
Figure 96: Isopleths of the increase in day-time LAeq (1 hr) during the operational phase 207
Figure 97: Isopleths of night-time L_{Aeq} (1 hr) during the operational phase 208
Figure 98: Isopleths of the increase in night-time L_{Aeq} (1 hr) during the operational phase 209
Figure 99: Recent flamingo collision incidents 224
Figure 100: The diluted intermediate brine influence area (Option 5 or Base Case) 247
Figure 101: The diluted intermediate brine influence area (Alternative 1) 248
Figure 102: Sand accretion and erosion processes 270
Figure 103: SEIA optimised Layout 285

LIST OF TABLES

Table 1: List of potential activities triggering the need to conduct a SEIA 5
Table 2: Requirements in terms of Environmental Management Act Regulation 30 pertaining to Scoping Phase 6
Table 3: Water quality guidelines for the discharge of a high-salinity brine into the marine environment 13
Table 4: Proposed Special Water Quality Standards for Effluents (DWAF 2014) and expected values before dilution in the brine effluent from the proposed Rössing Uranium desalination plant 15
Table 5: Table of construction activities 25
Table 6: Estimated brine physiochemical profile 43
Table 7: Salt Works channel advantages and disadvantages 62
Table 8: Pipeline and channel advantages and disadvantages 63
Table 9: Dedicated pipeline advantages and disadvantages 63
Table 10: No storage advantages and disadvantages 64
Table 11: Oyster pond storage advantages and disadvantages 65
Table 12: Own pond advantages and disadvantages 66
Table 13: On site tank advantages and disadvantages 66
Table 14: Combined Seawater delivery systems 67
Table 15: Seawater conveyance and storage option combination assessement results 68
Table 16: Site option assessement results 71
Table 17: Plant size vs energy options 72
Table 18: The return on investment periods 72
Table 19: Plant size vs energy assessment results 73
Table 20: Summary of project alternatives assessed in the SEIA process 81
Table 21. Predicted water demand, sources and surplus for the Erongo Coast 91
Table 22: Average diurnal meteorological parameters 95
Table 23: Tide statistics for Walvis Bay 102
Table 24: Summary of sampling locations, times, weather conditions and general acoustic environment 116
Table 25: Summary of sampled baseline noise levels 119
Table 26: Cetacean species present in Namibian waters 151
Table 27: Assessment criteria for the evaluation of impacts 155
Table 28: Definition of significance ratings 156
Table 29: Definition of probability ratings 156
Table 30: Definition of confidence ratings 157
Table 31: Definition of reversibility ratings 157
Table 32: Specialist studies undertaken during SEIA Phase 161
Table 33: Post-mitigation impact significance ratings summary 162
Table 34: IFC noise level guidelines 190
Table 35: Typical rating levels for outdoor noise 190
Table 36: Critical ratio in dB to be exceeded for the detection of pure tones and broadband noise for average bird 194
Table 37: Recommended interim guidelines for the protection of birds from industrial and commercial noise sources 194
Table 38: Sound power levels of activities during the construction phase 195
Table 39: Minimum distances between noise sensitive receptors and the RO Plant 203
Table 40: Sound power levels 's of diesel mobile equipment 203
Table 41: Sound power levels 's for plant equipment 204
Table 42: Sound power levels of general light industrial activities during the operational phase 205
Table 43: Salinity values assumed at the site 277
Table 44: Initiation of public participation process 279
Table 45: Details of stakeholder engagement meetings 279

LIST OF ACRONYMS AND UNITS OF MEASURE

%	Percentage
°C	Degrees centigrade
AIDS	Acquired Immune Deficiency Syndrome
Aurecon	Aurecon Namibia (Pty) Ltd
BID	Background Information Document
cm/s	Centimetres per second
CSIR	Council for Scientific and Industrial Research
dB	Decibels
EAP	Environmental Assessment Practitioner
Gecko	Gecko Namibia (Pty) Ltd
GIS	Geographic Information System
GPS	Global Positioning System

GRP	Glass reinforced plastic
GTZ	German Federal Enterprise for International Cooperation
Ha	Hectare
HDPE	High density poly ethylene
HIV	Human Immunodeficiency Virus
Hz	Hertz
HSEC	Health, Safety, Environment and Community
I&APs	Interested and Affected Parties
IFC	International Finance Corporation
kg	Kilogram
km	Kilometres
km²	Square kilometres
KOP	Key Observation Point: KOPs refer to receptors (people affected by the visual influence of a project) located in the most critical locations surrounding the landscape modification, who make consistent use of the views associated with the site where the landscape modifications are proposed. KOPs can either be a single point of view that an observer/evaluator uses to rate an area or panorama, or a linear view along a roadway, trail or river corridor.
Kpa	Kilopascals
kV	Kilovolt
LAT	Lowest Astronomical Tide
m	Metres
m/s	Metres per second
m²	Square metres
m³/day	Cubic metres per day
MAWF	Ministry of Agriculture Water and Forestry
MET	Ministry of Environment and Tourism
MET: DEA	Ministry of Environment and Tourism: Department of Environmental Affairs and Development
MFMR	Ministry of Fisheries and Marine Resources
mg/ℓ	Milligrams per litre
min	Minutes
Mℓ	Megalitre (1 Megalitre = 1,000 cubic metres)
Mℓ/d	Megalitres per day
Mℓb/a	Million pounds per annum
mm	Millimetres
Mm³	Million cubic metres
Mm³/a	Million cubic metres per annum
NamWater	Namibia Water Corporation
Omdel	Omaruru Delta (Aquifer)
pH	Power of Hydrogen. A figure expressing the acidity or alkalinity of a solution on a logarithmic scale on which 7 is neutral, lower values are more acid and higher values more alkaline. The pH is equal to −log10 c, where c is the hydrogen ion concentration in moles per litre.
RDP	Rössing Uranium desalination plant
RO	Reverse osmosis
RUL	Rössing Uranium Limited
SADC	Southern African Development Community
SEIA	Social and Environmental Impact Assessment
SEMP	Social and Environmental Management Plan
SLR	SLR Environmental Consulting (Namibia) (Pty) Ltd
spp.	Species
t/km²	Tons per square kilometre
UNEP	United Nations Environment Programme
USAID	United States Agency for International Development

NON-TECHNICAL SUMMARY

This non-technical summary provides an overview of the final Social and Environmental Impact Assessment (SEIA) report. The final SEIA report provides a description of the social and environmental baseline, and provides an assessment of the potentially significant social and environmental impacts associated with the project and responds to issues raised by I&APs during the process. The reader is referred to the final SEIA report for greater detail on the information disclosed here.

1. General Introduction

Rio Tinto Rössing Uranium Limited (Rössing Uranium) proposes to develop a new desalination plant, approximately 6km north of Swakopmund at the existing Swakopmund Salt Works, to supply the mine's water needs. SLR Environmental Consulting (Namibia) (Pty) Limited (SLR), in association with Aurecon Namibia (Pty) Ltd (Aurecon), have been appointed to undertake the SEIA process.

Figure 1: Location of the proposed Rössing Uranium desalination plant in the regional context

Rössing Uranium is considering ways to improve the efficiency and overall economic viability of their mining operations near Arandis. The mine currently purchases water through NamWater, via the Areva Desalination Plant, which constitutes a significant overhead cost for the mine. Rössing Uranium have determined that having their own seawater desalination plant, may save costs and lead to a more efficient and resilient mining operation, especially during the current low uranium market prices. It is estimated that the cost of water from the new plant would decrease from the current average of US$4.00/m^3 to less than US$2.50/m^3 at point of supply, thus saving Rössing Uranium upwards of US$3.5 Million per annum (approximately N$40 million per annum).

The cost of US$2.00/m^3 to US$2.50 is widely accepted as a benchmark cost for desalinated water supply. Several years of negotiation attempts have however remained unsuccessful in bringing the current desalination supply cost down to such a level. Progress on the NamWater Mile 6 plant has also been slow and the October 2014 date for completion of that plant has not been met. This leaves the mining community exposed to the current very high desalination water costs, which is the only

alternative supply of water (other than the the supply from the Omdel aquifer), for at least the next five years.

The proposed plant will be designed to have a 10 year operational life, which ties in with the current Rössing Uranium Life of Mine plan. The plant will be designed to produce up to 10,000m^3 (10 Mℓ) of potable water in every 24 hour cycle. The plant would produce approximately 3Mm^3 per annum (or average of 8,200m^3/d), which is consistent with Rössing Uranium's water demand. At full production, the plant will abstract 25,000m^3/d of seawater; produce 10,000m^3/d of drinking water and discharge 15,000m^3/d back to the ocean as concentrated seawater or brine (containing left-over water treatment chemicals).

The project can be divided into the following main components:

- Seawater intake system;
- Seawater pre-treatment system;
- Desalination plant;
- Ancillary structures and infrastructure;
- Electrical supply system;
- Product water system and pipeline; and
- Effluent treatment and disposal system.

The plant will be designed for electrical efficiency since reverse osmosis requires significant electrical power and is the main driver behind product water cost. During the operational phase, the plant will be staffed with an estimated 12 to 18 contract staff and will be operated by Gecko Namibia (Pty) Ltd on Rössing Uranium's behalf. It should take about 18 months to build the plant, following environmental approval from the Ministry of Environment and Tourism (MET). At the end of its life, the plant could be refurbished for ongoing use, or closed, broken down and the site rehabilitated, or possibly sold to another mining operation or NamWater, depending on the needs at that time.

The aim of the SEIA process is to review the relevant legal requirements, undertake the processes as prescribed, identify and investigate potentially significant socio-economic and bio-physical impacts and provide an opportunity for the public and key stakeholders to provide input and participate in the process.

The impact assessment has considered impacts associated with:

- Project design and pre-construction impacts and considerations;
- Construction phase impacts;
- Operational phase impacts;
- Decommissioning phase impacts; and
- Cumulative impacts, taking into consideration existing pressures or impacts on the local socio-economic and biophysical environments.

for

- A Base Case (before and after proposed mitigations);
- Three project alternatives (after proposed mitigations); and
- The No-Go alternative.

Through the investigations, suitable mitigation and management measures have been proposed and carried forward into the Social and Environmental Management Plan (SEMP) which aims to guide responsible environmental management throughout the project lifecycle.

2. Project alternatives

During the scoping/pre-feasibility phase, many design options were considered, but these were reduced down and combined to form a Base Case project and feasible alternatives. The Base Case project and other feasible alternatives, together with the No-Go alternative, have been assessed in this SEIA phase. However, the Base Case project is described in detail in the SEIA Report as it was deemed the best way forward at the commencement of the impact assessment phase and assessed by all the specialists.

A number of feasible alternatives were also considered through the impact assessment. A summarised description of the various alternatives (compared to the Base Case project) with respect to each of the above mentioned project components is provided in the table below and illustrated in Figure 2.

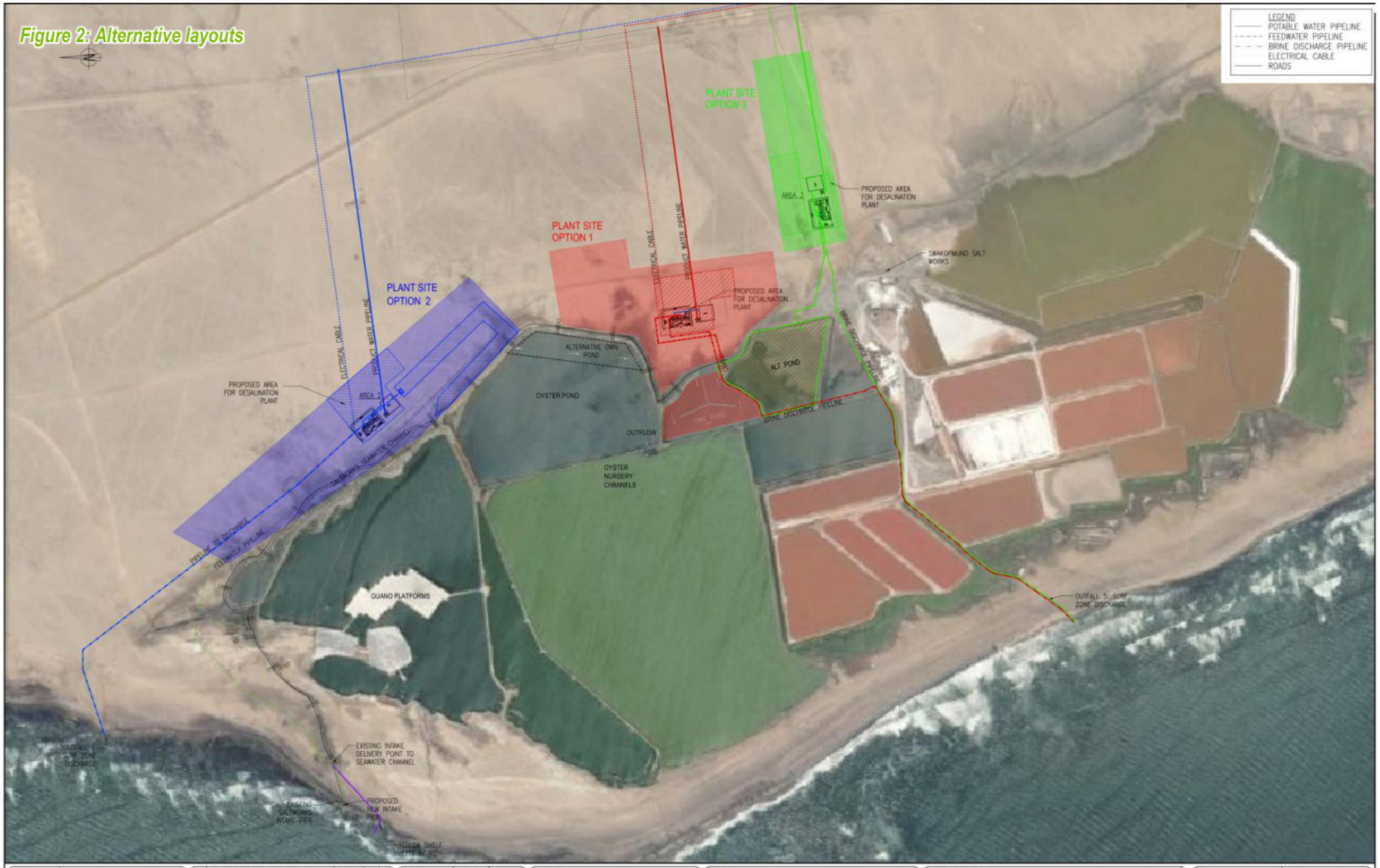
The optimised layout (i.e. SEIA recommended project layout), is described in Section 5 below and a detailed project description of this (SEIA optimised) layout is provided in the SEMP, attached to the SEIA Report as Annexure E.

Table 1: Summary of project alternatives assessed in the SEIA process

Base Case (pre-mitigation) (site 1)	Base Case (post-mitigation) (site 1)	Alternative 1 – Site 2	Alternative 2 – Site 3	Alternative 3 –with overhead power	Alternative 4 -No Go Alternative
RO Plant ~ 10,000m³/d seawater reverse osmosis (RO) plant and associated facilities situated in the centre of site locality 1. The RO plant will house the pre-treatment systems and the various pumps for the product water system. The plant will also house various ancillary facilities (chemical stores, offices, ablutions, roads, parking bays, maintenance areas, spares stores, etc.). The RO plant and associated facilities will be mostly housed within a single warehouse type structure, to protect them from the corrosive coastal air.	Same as base case alternative except that the Plant would be situated in the north / north-eastern area of location 1.	Same as base case alternative except that the Plant would be situated on site locality 2.	Same as base case alternative except that the plant would be situated in site locality 3.	Same as base case	No implementation means no direct environmental impacts. There will however be potentially significant socio-economic opportunity impacts.
Seawater intake system ~ A new seawater intake jetty and associated pumps and pipes will be erected just south of the existing Salt Works intake jetty. Seawater will enter the existing (possibly upgraded) Salt Works seawater intake channel and gravitate around the Salt Works and enter into a new seawater buffer pond located near the RO plant. A new electrical cable will be run from the RO plant around the eastern and northern shores of the salt pans, and provide power to the intake pumps on the new jetty.	Same as base case except that the new seawater intake pond would be situated closer to the RO plant on Site locality 2.	Same as base case except that the new seawater intake pond would be situated closer to the RO plant on Site locality 2.	Same as base case	Same as base case	
Pre-treatment system ~ Sea water abstracted from the buffer pond will be filtered and conditioned ahead of the desalination process. This may involve the use of pre-treatment chemicals or biological processes in combination with physical screens and filters to ensure that the water is free of particulates that could foul the RO membranes, and that the pH is optimum to allow for efficient RO process.	Same as base case	Same as base case	Same as base case	Same as base case	
Product water system ~ clear water from the RO process will then be re-mineralised to meet potable water standards and pumped via an 850m long pipeline, running due east from the plant, into the existing NamWater pipeline running along the eastern side of the Henties Bay Road (C34).	Same as base case	Same as base case	Same as base case	Same as base case	
Brine disposal system ~ Brine (together with filter backwash from the pre-treatment system and chemical cleaning processes) will be pumped from the plant via a new pipeline to ocean discharge (surf discharge) location situated south of the Salt Works bitterns outlet (southern discharge site).	Same as base case alternative except that due to RO Plant site on site 2, the northern discharge (Outfall 1) site becomes preferred due to the shorter pipe length.	Same as base case alternative except that due to RO Plant site on site 2, the northern discharge (Outfall 1) site becomes preferred due to the shorter pipe length.	Same as base case	Same as base case	
Electrical supply system ~ A buried cable would run from the existing Tamarisk substation in the northern parts of Swakopmund, along the C34 toward Henties Bay and then turn due west on a vector to connect with the	Same as base case. However the exact location where the buried cable	Same as base case. However the exact location where the buried cable	Same as base case. However the exact location	Same as base case alternative except that the distribution line	

Base Case (pre-mitigation) (site 1)	Base Case (post-mitigation) (site 1)	Alternative 1 – Site 2	Alternative 2 – Site 3	Alternative 3 –with overhead power	Alternative 4 -No Go Alternative
new mini-substation to be constructed adjacent the RO plant. The cable between the C34 and the plant should follow the same route as the product water pipeline connecting with the NamWater pipeline. Note also that a buried cable will run from the RO plant to the new seawater intake jetty.	would turn west from the Henties Bay Road is located further north.	would turn west from the Henties Bay Road is located further north.	where the buried cable would turn west from the Henties Bay Road is located further south.	from the Tamarisk substation along the C34 to Henties Bay will be above ground as opposed to a buried cable. From the C34 to the plant will remain a buried cable.	

Figure 2: Alternative layouts



3. SEIA process

Prior to the commencement of the proposed desalination project, authorisation is required on the basis of an SEIA report and SEMP. In accordance with this legal framework the SEIA approach included the following:

- The scoping process was conducted to identify the environmental issues associated with the proposed project and to define the terms of reference for the required specialist studies and the SEIA.
- Specialist studies were commissioned in accordance with the relevant terms of reference. The specialists were selected on the basis of their expertise and knowledge of the project area. (Refer to Table 3 below).
- The SEIA report and SEMP was prepared on the basis of the findings of the specialist studies.
- A project specific public participation process was conducted. As part of this process the regulatory authorities and interested and affected parties (IAPs) were given the opportunity to attend information sharing meetings, submit questions and comments to the environmental team, and review the background information document, scoping report and the SEIA report and SEMP. All questions and comments that were raised by the authorities and IAPs have been included and answered in the Comments and Reponse Report, attached to the SEIA Report as Annexure C9.

The following specialist studies were identified in the scoping phase and undertaken during the SEIA phase. These studies have assisted with the investigation and assessment of the key impacts, as well as providing recommendations to reduce and manage those impacts as best as possible:

Table 2: Specislist studies cnducted as part of the assessment phase of the SEIA

SPECIALIST FIELD	SPECIALIST	DESCRIPTION
Socio-economic	Ms. Auriol Ashby (Social) (Ashby Associates CC) and Dr Jonathan Barnes (Economic) (Design and Development Services cc)	Identify and assess the potential Socio-economic impacts associated with the construction and operation of the proposed Rössing Uranium desalination plant.
Heritage and Archaeology	Dr John Kinahan (Quaternary Research Services)	This study will focus on the probable impacts of the proposed project on heritage and archaeological impacts within the footprint of the proposed project.
Visual	Stephen Stead (Visual Resource Management Africa)	Assess the potential visual impact caused by the proposed Rössing Uranium desalination plant.
Noise	Nicolette von Reiche (Airshed Planning Professionals)	Identify and assess the potential noise impacts associated with the construction and operation of the proposed Rössing Uranium desalination plant.
Avifauna	Mike and Ann Scott (African Conservation Services CC)	Identify and assess the potential impacts on local birdlife associated with the construction and operations of the proposed Rössing Uranium desalination plant and associated infrastructure (most notably a possible overhead powerline).
Marine ecology	Dr Andrea Pulfrich (Pisces Environmental Services (Pty) Ltd)	Identify and assess the potential impacts to marine and coastal ecology associated with the construction and operation of the proposed Rössing Uranium desalination plant. The study will rely on the marine discharge and modelling study to be undertaken by WSP.
Brine diffusion modelling	Christoph Soltau (WSP Group)	Assess the marine discharge options and undertake a hydrodynamic modelling exercise to determine the likely movement and dissipation of the discharge plume. Note that this is not an impact assessment but informs the marine ecology impact assessment.
Shoreline dynamics	Christoph Soltau (WSP Group)	Identify and assess the potential impacts that may arise as a result of the construction and operation of the desalination plant's seawater intake, brine outfall and associated structures located on the beach or in the surf on natural coastal processes.

4. Social and environmental impact assessment findings

Through the course of the SEIA process it came to light that the Base Case project layout was situated in a Damara Tern (breeding endemic seabird, globally Near Threatened and also Near Threatened in Namibia) core breeding area and that the desalination plant should move.

With input from the bird specialist, the other specialists identified above, the technical team and Rössing Uranium, various other project layouts (as described in section 2 above) were developed and assessed as part of the SEIA process to arrive at an optimised layout, which is refererred to as the "SEIA optimised layout".

The following table provides a summary of the impact assessment results. This table only shows the post mitigation impact significance ratings.

The following (colour) legend is applicable to the significant ratings in the tables:

Legend	High (-)	Medium (-)	Low (-)	Very low (-)	Neutral	Very low (+)	Low (+)	Medium (+)	High (+)

Table 3: Post-mitigation impact significance ratings summary

Aspect	Phase	Impact Description	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Socio-economic	Construction	Increased traffic and road safety risks.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Reduction in Guano production as a result of disturbance of birds.	Very low (-)	Low (-)	Very low (-)	Very low (-)	Neutral
	Operations	Economic viability of Rössing Uranium Mine.	High (+)	High (+)	High (+)	High (+)	High (-)
		Financial implications for other water users and NamWater.	Medium (-)	Medium (-)	Medium (-)	Medium (-)	Medium (-)
		Financial implications On Langer Heindrich Uranium / Husab.	Low (-)	Low (-)	Low (-)	Low (-)	Low (-)
		Water availability in the region.	High (+)	High (+)	High (+)	High (+)	Low (+)
		Disruptions may result in a lower Guano production rates.	Very low (-)	Low (-)	Very low (-)	Very low (-)	Neutral
	Decommissioning	Bulk water supply options associated with decommissioning.	High (+)	High (+)	High (+)	High (+)	Neutral
Archaeology and heritage	Construction	Loss or damage of archaeological and heritage resources.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
	Operations	No operational phase impacts.	Neutral	Neutral	Neutral	Neutral	Neutral
	Decommissioning	No decommissioning phase impacts.	Neutral	Neutral	Neutral	Neutral	Neutral
Visual impacts	Construction	Intake jetty during construction.	Medium (-)	Medium (-)	Medium (-)	Medium (-)	Neutral
		RO Plant during construction.	Low (-)	Low (-)	Medium (-)	Medium (-)	Neutral
	Operations	Impact of the RO plant and all associated infrastructure.	Low (-)	Medium (-)	Medium (-)	Medium (-)	Neutral
	Decommissioning	Visual impact associated with the decommissioning phase of the project.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
Noise impacts	Construction	Construction noise impact on birds.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Construction noise impact on humans.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
	Operations	Operations phase noise impact on birds.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Operations phase noise impact on humans.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
	Decommissioning	Decommissioning phase noise impact on birds.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Decommissioning phase noise impact on humans.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
Avifauna impacts	Construction	Destruction/modification of Damara Tern breeding habitat.	Low (-)	Very low (-)	Low (-)	Low (-)	Neutral
		Destruction/modification of habitat of other birds.	Low (-)	Low (-)	Low (-)	Low (-)	Neutral
		Physical disturbance to breeding birds, especially Damara Terns.	Low (-)	Very low (-)	Low (-)	Low (-)	Neutral
	Operations	Physical disturbance to breeding birds, especially Damara Terns.	Low (-)	Very low (-)	Low (-)	Low (-)	Neutral
		Physical disturbance to roosting/breeding cormorants.	Very low (-)	Low (-)	Very low (-)	Very low (-)	Neutral
		Collision of birds with power line structures.	Neutral	Neutral	Neutral	Medium (-)	Neutral
		Bird electrocutions on power supply structures.	Neutral	Neutral	Neutral	Medium (-)	Neutral
	Decommissioning	Physical disturbance to breeding birds, especially Damara Terns.	Low (-)	Very low (-)	Low (-)	Low (-)	Neutral
Marine ecology impacts	Construction	Disturbance and destruction of marine biota through alteration and disruption of the coastal zone during construction.	Low(-)	Low(-)	Low(-)	Low(-)	Neutral
		Detrimental effects on marine biota through accidental hydrocarbon spills, concrete works and litter in the coastal zone during construction.	Low(-)	Low(-)	Low(-)	Low(-)	Neutral
		Reduced physiological functioning of marine organisms due to increased turbidity of nearshore waters during excavations.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral

Aspect	Phase	Impact Description	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
		Smothering of benthos through re-deposition of suspended sediments.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Disturbance of shore birds and marine biota through construction noise.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Disturbance and injury of shore birds and marine biota through blasting.	Low (-)	Low (-)	Low (-)	Low (-)	Neutral
		Elimination of benthic communities through loss of substratum in structural footprint.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
	Operations	Loss of marine species through impingement and entrainment.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Potential flow distortion around the discharge outlet.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Reduced physiological functioning of marine organisms due to elevated salinity.	Low (-)	Low (-)	Low (-)	Low (-)	Neutral
		Avoidance behaviour by invertebrates, fish and marine mammals of the discharge area.	Low (-)	Low (-)	Low (-)	Low (-)	Neutral
		Reduced physiological functioning of marine organisms due to elevated temperature.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Reduced physiological functioning of marine organisms due to reduced dissolved oxygen concentrations.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Detrimental effects on marine organisms due to residual chlorine levels in the mixing zone.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Chronic effects on marine organisms due to formation of halogenated by-products.	Low (-)	Low (-)	Low (-)	Low (-)	Neutral
		Reduction in dissolved oxygen concentrations as a result of dechlorination.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Excessive bacterial re-growth in the brine after chlorination.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Detrimental effects on marine organisms through discharge of co-pollutants in backwash waters.	Low (-)	Low (-)	Low (-)	Low (-)	Neutral
		Detrimental effects on marine organisms through discharge of antiscalants in backwash waters.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Detrimental effects on marine organisms or ambient seawater pH through discharge of residual cleaning solutions used periodically for cleaning in place.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Detrimental effects on marine organisms of heavy metals from corrosion processes.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
	Decommissioning	Impacts to marine ecology associated with decommissioning activities.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
Shoreline dynamics impacts	Construction	Intake Jetty: Disruption of coastal processes by marine works.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Intake Jetty: Alteration of beach composition with rock spoil.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Brine outfall: Disruption of coastal processes by marine works.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Brine outfall: Alteration of beach composition with rock spoil.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Brine outfall: Earthworks related flooding or beach erosion.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
	Operations	Intake Jetty: The coastal processes (waves, currents, sediment transport) are affected by the jetty structure.	Low (-)	Low (-)	Low (-)	Low (-)	Neutral
		Intake Jetty: Natural sand movement is impacted by the jetty abutment to shore.	Neutral	Neutral	Neutral	Neutral	Neutral
		Intake Jetty: Wind-blown sand pathways are impacted by the intake structure and pipelines.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Brine outfall: The outfall pipeline causing updrift accretion and downdrift erosion of the beach.	Low (-)	Low (-)	Low (-)	Low (-)	Neutral
		Brine outfall: wind-blown sand pathways on the upper beach are impacted by the brine outfall pipeline.	Neutral	Neutral	Neutral	Neutral	Neutral
		Brine outfall: The high velocity flow from the outfall causes scouring of the sandy seabed.	Low (-)	Low (-)	Low (-)	Low (-)	Neutral
	Decommissioning	Impacts to shoreline dynamics during decommissioning would be comparable with those experienced during the construction phase.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral

MET:DEA asked if the presence of the proposed Rössing Desalination plant and the associated brine discharges would impact on the water quality for the planned Mile 6 NamWater desalination plant. Based on the diffusion modelling, elevated salinity levels should fall back to undetectable levels (i.e. near ambient) within 50m of the diffuser (point discharge), therefore the potential for the Rössing's brine discharges to prejudice water quality for the planned Mile 6 desalination are considered negligible.

5. Opinions and recommendations

In the interest of economic feasibility, Rössing Uranium decided to pursue its own source of desalinated water. Given the current poor uranium market, it is essential that Rössing Uranium implement measures to remain viable and in so doing, avoid the potentially significant regional socio-economic impacts that could arise as a result of its premature closure.

In the Environmental Assessment Practitioner's (EAP's) opinion, three key sensitive aspects were identified during the impact assessment process. The first relates to the projects potential impact on bird life in the area, given that the Mile 4 Salt Works is a recognised Important Bird Area (IBA) and an important breeding area for the Damara Terns (breeding endemic seabird, globally Near Threatened and also Near Threatened in Namibia). The second relates to the potential impacts on marine ecology as a result of the desalination process effuents. The third relates to the potentially significant negative socio-economic impacts if the project does not go ahead and the Rössing mine is forced to close prematurely as a result. Although visual impacts were rated as a medium negative impact because of the nature of the area being unobstructed, we don't consider this to form one of the key aspects to be considered in making a decision.

Regarding the bird aspect, special attention was given to the issue and was pivotal in the project team having to investigate various site locations for the desalination plant and finally informing the development of the "SEIA optimised layout", which is dealt with in the key recommendations to follow, and which seeks to mitigate the potential impact significance to birdlife. It is believed that the operation of the RO plant should not have an unacceptable level of impact to resident birdlife (given the recommended mitigations) however special care should be taken through the construction phase of the project to limit the potential disruption of the local bird assemblages and avoid disturbances to the Damara Terns during their annual breeding period.

Regarding marine ecology, and from a broader viewpoint, the marine ecology impacts associated with the operational phase were found to be within acceptable tolerances. As a result of this, the operational phase marine impacts associated with brine disposal need not factor significantly into the taking of the decision, although operations phase monitoring must be conducted to verify this.

The socio-economic impacts associated with the No-Go alternative and assuming Rössing closes prematurely as a result translates into a significant socio-economic impact for the region that should be avoided, especially now, during a period of depressed uranium market prices.

Other impacts, including noise, visual, and heritage are all within acceptable tolerances and not expected to result in significant impacts, if managed responsibly.

The EAP is of the opinion (subject to the implementation of the recommendations and mitigations measures identified, most notably the key recommendations that follow) that not only could the project go ahead on the basis of the potential environmental impacts, but should go ahead on the basis of the potentially significant socio-economic impacts associated with not going ahead (if an alternative agreement between relevant parties cannot be reached timeously).

- **Key Recommendation 1: SEIA Optimised Layout:** The SEIA assessed three potential site locations (areas) for the RO plant, i.e. site areas (options) 1, 2 and 3 Base Case. Through the assessment, supported by the relevant specialist and technical studies, an optimised project layout took shape which was believed to be a healthy comprise between the technical, financial, and environmental aspects. This layout sees the RO plant shift to the far north or north-eastern corner of site area 1 (away from the core Damara Tern breeding area) but not as far as site option 2, where the RO plant could impact more significantly on the residents of the correctional services accommodation (noise and visual impacts) and tourists (visual impacts) or the birds on the guano platform. Additionally, to use the northern brine discharge point, associated with the above mentioned plant location, as this would route the pipeline away from the Salt Works inter-pond service road network (resulting in less disruption to the Salt Works during construction) and, importantly, the Damara Tern breeding area, but would also see the discharge making use of the derelict concrete Salt Works intake structure, which could mitigate the construction phase impact for the brine discharge. The optimised project layout is shown in Figure 103 at the end of this subsection. All the alternatives except the base case (unmitigated) could be approved by MET, subject to the implementation of all the commitments in the SEMP.
- **Key Recommendation 2: Earthen Berm Enclosure:** This key recommendation is closely linked to the foregoing SEIA optimised layout recommendation. It emerged during the course of the various specialist studies that enclosing the RO plant with a 1.8m to 2m high earthen berm serve a number of impact mitigation functions, as follows:
  - Visual impacts: an earthen berm would act as a visual screen and reduce the visual impacts associated with ground level activities and movements around the plant. The earth berm would also lessen the vertical prominence of the plant when viewed from a distance (provided that the earthen berm ties in with the surrounds). At night the berm would reduce the spillage of light into the adjoining areas, mitigating light pollution related impacts.
  - Noise impacts: an earthen berm would serve as an acoustic barrier and mitigate noise pollution generated at or near ground level and delinking noises from specific movements or activities (i.e. if you can see the bulldozer, the noise seems more intrusive to the receptor.)
  - Avifauna impacts: by reducing the noise and visual disturbances associated with the movement of people, plant and vehicles and associated activities around the RO plant, the potential impact to resident birdlife, most notably the Damara Terms (with their core breeding area located in the area adjacent the SEIA optimised layout) can be maintained within acceptable levels and is expected to have the following benefits:
    - Delinking noises from sudden visible movements, which could otherwise spook birds;
    - Reducing the overall noise level from the plant that could disturb nesting/roosting birds; and
    - Preventing low level light spillage from the RO plant or vehicle headlights around the plant, which would otherwise cause birds to cast a long shadow, increasing their visibility and susceptibility to would be predators.

- **Key Recommendation 3: ProGreen™ Technology**: The ProGreen™ technology is a new approach to desalination in southern Africa. As such the project is approaching the use of technology with precaution and has opted to retain a tried and tested pre-treatment process (i.e. dissolved air floatation (DAF)) and upon which the impact significance rating in the SEIA are based. In the event however that ProGreen™ does perform to full specification and full implementation is realised (i.e. all feedwater is treated to 100% by the ProGreen™ bio-flocculation technology), then this could reduce the potential impacts to marine ecology associated with the co-discharge of various water treatment, conditioning and cleaning chemicals, normally associated with a dissolved air floatation system. In the best case scenario, these impacts would reduce to zero or "Neutral". Note that the ProGreen™ would still produce a sludge that would be co-discharged with the brine effluent arising from the Reverse Osmosis process. The use of this technology is encouraging for the desalination industry and, if proven effective, could have far reaching cumulative environmental benefits for future desalination plants across the subcontinent. Rössing Uranium may even be in a position to investigate the option to discharge the brine into the Salt Works evaporation ponds, which could further reduce the operation phase impacts associated with brine discharge on the marine environment.

6. Way forward

The Final SEIA has been updated where relevant and submitted to MET:DEA for their review and decision whether the proposed desalination project can be implemented or not from an environmental point of view. MET:DEA should provide a record of decision.

Figure 3: SEIA optimised Layout

1 INTRODUCTION

This section provides a brief overview of the project and the legislated SEIA process to be followed and guides the reader as to where certain information may be found within the document.

Rio Tinto Rössing Uranium Limited (Rössing Uranium) has operated an open pit uranium mine in the Erongo Region of Namibia since 1976. As a result of reduced uranium prices, Rössing Uranium is considering ways to enhance efficiency and overall economic viability of their mining operations near Arandis. Rössing Uranium currently purchases water through NamWater, which constitutes a significant overhead cost for the mine. The Erongo Region is a water scarce environment, relying predominantly on the Omaruru Delta (Omdel) aquifer for its supply. The Erongo region is also a centre for growth in Namibia and central to the country's economic vitality. As the demand for water increases, so does the value of water supplied. Rössing Uranium has determined that securing its own water supply, by way of a seawater desalination plant, may save costs and lead to a more efficient and resilient mining operation.

Rössing Uranium is investigating the design, constructing and operating of a new desalination plant, approximately 6km north of Swakopmund, to supply the mine's water needs. SLR Environmental Consulting (Namibia) (Pty) Limited (SLR), in association with Aurecon Namibia (Pty) Ltd (Aurecon), have been appointed as the independent environmental consultants and tasked to undertake the SEIA process for the proposed desalination plant.

The aim of the SEIA process is to identify and investigate potentially significant socio-economic and bio-physical impacts associated with the proposed project and provide an opportunity for the public and key stakeholders to provide input and participate in the process. Lastly, based on the specific nature of the potentially affected environment, specialist input is sourced as required.

This SEIA report is structured as follows:

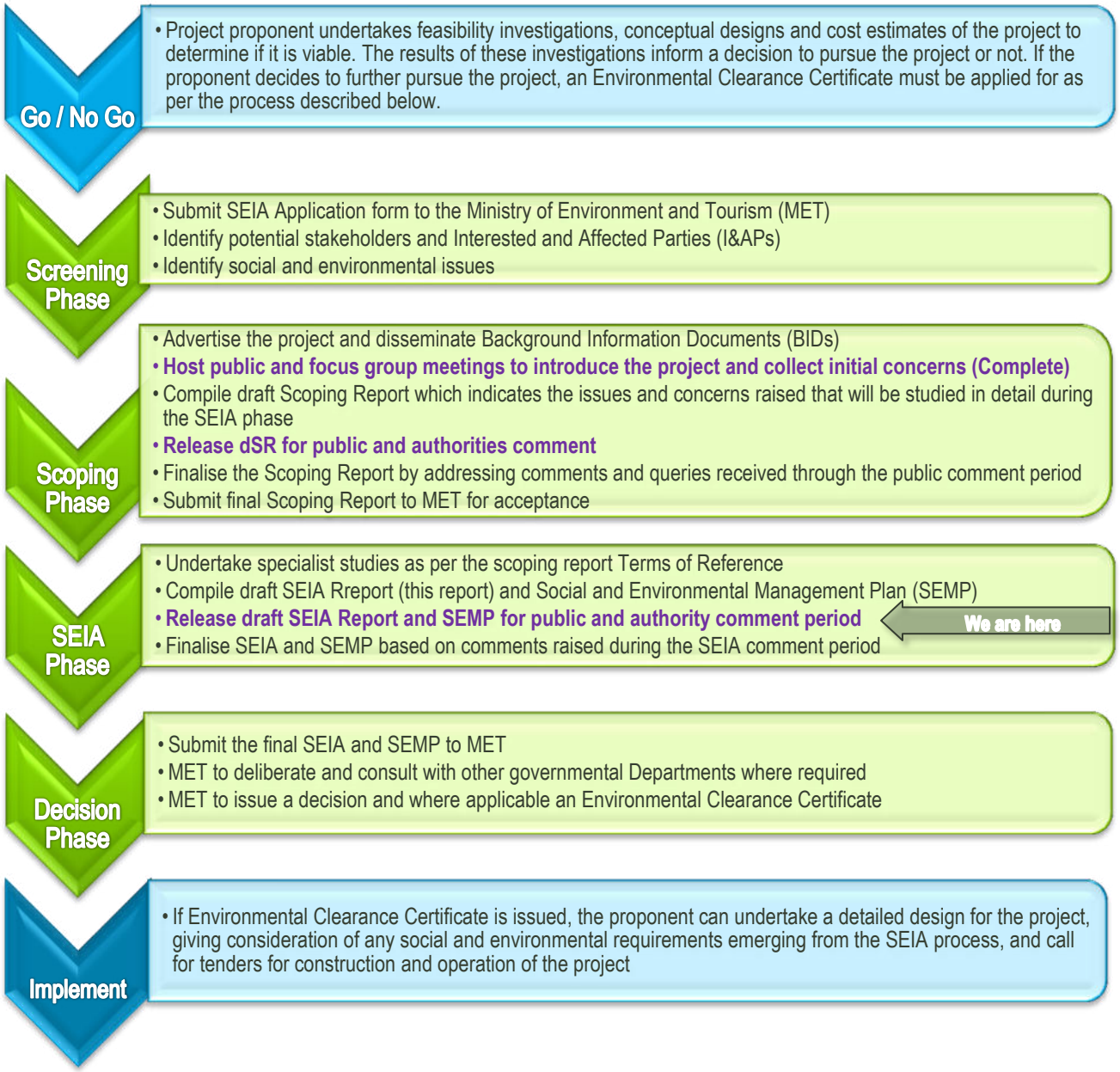
- **Non-technical summary:** This non-technical summary provides an overview of the final Social and Environmental Impact Assessment (SEIA) report. The final SEIA report provides a description of the social and environmental baseline, and provides an assessment of the potentially significant social and environmental impacts associated with the project and responds to issues raised by I&APs during the process. The reader is referred to the final SEIA report for greater detail on the information disclosed here.
- **Section 1:** This section provides a brief overview of the project and the legislated SEIA process to be followed and guides the reader as to where certain information may be found within the document.
- **Section 2:** This section provides an overview of the legislation and policy framework for the SEIA process. The SEIA is being undertaken in compliance with the relevant Namibian environmental legislation, as well as taking into account international best practice for impact assessments. The SEIA involves a public participation process which is aimed at providing stakeholders and the general public the opportunity to become involved and raise concerns or make comments about the proposed project. This is considered fundamental to ensure the integrity of the environmental assessment process. Much of the legislation outlined below has applicability from a biophysical perspective. While certain relevance is highlighted, such documents are relevant on a variety of levels.
- **Section 3:** This Chapter aims to provide a description of the project and the workings of the key project components. In addition, the project need and desirability has also been described.

- **Section 4:** This chapter provides an overview of the options considered in the scoping phase and the feasible alternatives assessed in the impact assessment phase and provides reasons why some options were retained and some were screened out.
- **Section 5:** This section provides an overview of the social and environmental characteristics of the study area at present, which forms the basis for the assessment of the potential impacts.
- **Section 6:** The section provides the assessment methodology employed in this impact assessment and which was used by the various specialists in the determination of impact significance ratings. Using a common methodology assists with ensuring consistency in impact rating across the various specialist disciplines.
- **Section 7:** This section provides an assessment of the impacts (by various specialists) identified and described in the Scoping phase of the SIEA associated with each of the alternatives, provided under subsection 4.12, for each of the construction, operation, and decommissioning phases of the project. Also provided here are the specialists' recommendations regarding the mitigation measures that should be implemented to manage direct impacts and reduce the severity of the negative impacts and enhance the benefit of the positive impacts. This section also touches on cumulative environmental impacts or issues that the project links with.
- **Section 8:** In terms of Section 21 of the EIA Regulations a call for open consultation with all interested and affected parties (I&APs) at defined stages of the EIA process are required. This entails participatory consultation with members of the public by providing an opportunity to comment on the proposed project. Public participation in this project was undertaken to meet the specific requirements in accordance with the international best practice.
- **Section 9:** This section details project specific and noteworthy recommendations revealed through the SEIA process that the environmental assessment practitioner wishes to highlight as the most pertinent issues.
- **Section 10:** This section briefly concludes the report and touches on a few key procedural aspects going forward.

In terms of the Environmental Assessment Policy of 1995; and the Environmental Management Act (Act 7 of 2007) and the associated Environmental Impact Assessment (EIA) Regulations of Government Notices 28, 29, and 30 promulgated on 6 February 2012, the activities required for the construction of the proposed desalination plant requires an Environmental Clearance Certificate from the competent authority, namely the Department of Environmental Affairs at the Ministry of Environment and Tourism (MET:DEA). On completion of the SEIA process a final SEIA Report will be submitted to the MET:DEA, who are required to take an informed decision as to whether the project may proceed on social and environmental grounds.

The SEIA process is undertaken in accordance with the above mentioned EIA Regulations. A flow diagram below provides an outline of the SEIA process that is being followed, with opportunities to participate in the process highlighted in bold font. More details regarding the Public Participation Process is provided in Section 7.11.

Figure 1: SEIA process overview



2 LEGAL FRAMEWORK

This section provides an overview of the legislation and policy framework for the SEIA process. The SEIA is being undertaken in compliance with the relevant Namibian environmental legislation, as well as taking into account international best practice for impact assessments. The SEIA involves a public participation process which is aimed at providing stakeholders and the general public the opportunity to become involved and raise concerns or make comments about the proposed project. This is considered fundamental to ensure the integrity of the environmental assessment process. Much of the legislation outlined below has applicability from a biophysical perspective. While certain relevance is highlighted, such documents are relevant on a variety of levels.

2.1 THE CONSTITUTION OF THE REPUBLIC OF NAMIBIA (ACT 1 OF 1990)

There are two clauses contained in the Namibian Constitution that are of particular relevance to sound environmental management practice, viz. Articles 91(c) and 95(l). In summary, these refer to:

- Guarding against over-utilisation of biological natural resources;
- Limiting over-exploitation of non-renewable resources;
- Ensuring ecosystem functionality;
- Protecting Namibia's sense of place and character;
- Maintaining biological diversity; and
- Pursuing sustainable natural resource use.

The above therefore commits the State to actively promote and sustain environmental welfare of the nation by formulating and institutionalising policies to accomplish the abovementioned sustainable development objectives.

2.2 ENVIRONMENTAL MANAGEMENT ACT (ACT 7 OF 2007)

In giving effect to Articles 91(c) and 95(l) of the Constitution of Namibia, general principles for sound management of the environment and natural resources in an integrated manner have been formulated. This resulted in the Environmental Assessment Policy of 1995. To give statutory effect to this Policy, the Environmental Management Act (Act 7 of 2007) was gazetted on 27 December 2007 in, Government Gazette No. 3966. Part 1 of the Environmental Management Act describes the various rights and obligations that pertain to citizens and the Government alike, including an environment that does not pose threats to human health, proper protection of the environment, broadened *locus standi*[2] on the part of individuals and communities, and reasonable access to information regarding the state of the environment.

[2] *The right or capacity to bring an action or to appear in a court, from Latin: a place for standing.*

Part 2 of the Act sets out a number of principles of environmental management, as follows:

- Renewable resources shall be utilized on a sustainable basis for the benefit of current and future generations.
- Community involvement in natural resource management and sharing in the resulting benefits shall be promoted and facilitated.
- Public participation in decisions affecting the environment shall be promoted.
- Fair and equitable access to natural resources shall be promoted.
- Equitable access to sufficient water of acceptable quality and adequate sanitation shall be promoted and the water needs of ecological systems shall be fulfilled to ensure the sustainability of such systems.
- The precautionary principle and the strategy of preventative action shall be applied.
- There shall be prior environmental assessment of projects and proposals which may significantly affect the environment or use of natural resources.
- Sustainable development shall be promoted in land-use planning.
- Movable and immovable cultural and natural heritage, including biodiversity, shall be protected and respected for the benefit of current and future generations.
- Generators of waste and polluting substances shall adopt the best practicable environmental option to reduce such generation at source.
- The polluter pays principle shall be applied.
- Reduction, reuse and recycling of waste shall be promoted.
- There shall be no importation of waste into Namibia.
- Promotion of the coordinated and integrated management of the environment.
- The Minister of Environment and Tourism was enabled to give effect to Namibia's obligations under international environmental conventions.
- Sustainable Development Commission and Environmental Commissioner have been provided for.

As the organ of state responsible for the management and protection of its natural resources, the MET:DEA is committed to pursuing these principles of environmental management.

The recently gazetted regulations promulgated in terms of the Environmental Management Act, identify certain activities which could have a substantially detrimental effect on the environment. These listed activities require Environmental Clearance from the competent environmental authority, i.e. MET:DEA, prior to commencing. The following activities identified in the regulations apply to the proposed project:

Table 1: List of potential activities triggering the need to conduct a SEIA

ACTIVITY	DESCRIPTION OF RELEVANT ACTIVITY	RELEVANCE
Activity 1 (b) ~ Energy generation, transmission and storage activities	The construction of facilities for the transmission and supply of electricity.	A new 11kV powerline will link to the plant to the substation near Swakopmund.
Activity 7.8 ~ Agriculture and aquaculture activities	The introduction of alien species into local ecosystems.	A new biological treatment process (ProGreen™ ®), that prevents the need for chemical pre-treatments, may be used. This system / plant may be seeded with foreign microorganism species (to be confirmed).
Activity 8.1 ~ Water Resource Developments	The abstraction of ground or surface water for industrial or commercial purposes.	Seawater will be abstracted to supply the plant.

ACTIVITY	DESCRIPTION OF RELEVANT ACTIVITY	RELEVANCE
Activity 8.5 ~ Water Resource Developments	Construction of dams, reservoirs, levees and weirs.	A new pond may be constructed near the Swakopmund Salt Works to serve as a stilling basin and abstraction point. This is not in a river system, but rather an extension of the existing Swakopmund Salt Works seawater ponds.
Activity 8.6 ~ Water Resource Developments	Construction of industrial and domestic wastewater treatment plants and related pipeline systems.	The desalination plant may undertake effluent treatment (or conditioning) prior to discharge to the ocean.
Activity 8.12 ~ Water Resource Developments	The release of brine back into the ocean by desalination plants.	The desalination plant will discharge brine back to the ocean.
Activity 9.1 ~ Hazardous substance treatment, handling and storage	The manufacturing, storage, handling or processing of a hazardous substance defined in the Hazardous Substances Ordinance, 1974.	The desalination plant may store chlorine gas for the pre-treatment of seawater.
Activity 9.2 ~ Hazardous substance treatment, handling and storage	Any process or activity which requires a permit, licence or other form of authorisation, or the modification of or changes to existing facilities for any process or activity which requires an amendment of an existing permit, licence or authorisation or which requires a new permit, licence or authorisation in terms of a law governing the generation or release of emissions, pollution, effluent or waste.	The discharge of the brine back into the ocean requires an effluent discharge permit from the Ministry of Agriculture, Water and Forestry (MAWF). Any sewage discharged into municipal sewerage systems would also have to be included in the effluent discharge permit.
Activity 10.1 ~ Infrastructure	The construction of- (a) oil, water, gas and petrochemical and other bulk supply pipelines; and (e) any structure below the high water mark of the sea.	(a) the project requires the construction of a seawater pipeline from the intake structure to the plant and the construction of a product water pipeline from the plant to the NamWater tie in point. (e) The construction of the seawater intake systems and brine outlet may result in construction activities below the high water mark.

2.2.1 Content of SEIA Report

Section 15(2) of the gazetted impact assessment Regulations requires specific content to be addressed in the Assessment Report. Table 2 below provides the required contents of an Assessment Report (as per the Regulations) and assists the reader to find the relevant information in this report.

Table 2: Requirements in terms of Environmental Management Act Regulation 30 pertaining to Scoping Phase

REG #:	REGULATION	REFER TO:
15(2)	An assessment report must contain all information that is necessary for the Environmental Commissioner to consider and to make a decision on the application, and must include -	-
15(2)(a)	- the curriculum vitae of the EAP who compiled the report;	Annexure A
15(2)(b)	- a detailed description of the proposed listed activity;	Section 3 (pg. 18)
15(2)(c)	- a description of the environment that may be affected by the activity and the manner in which the physical, biological, social, economic and cultural aspects of the environment may be affected by the proposed activity;	Section 5 (pg. 84) & Section 7 (pg. 165)
15(2)(d)	- a description of the need and desirability of the proposed listed activity and identified potential alternatives to the proposed listed activity, including advantages and disadvantages that the proposed activity or alternatives may have on the environment and the community that may be affected by the activity;	Section 3.2 (pg. 22) & Section 4 (pg. 40)
15(2)(e)	- an indication of the methodology used in determining the significance of potential Effects;	Section 6 (pg. 155)
15(2)(f)	- a description and comparative assessment of all alternatives identified during the assessment process;	Section 4 (pg. 40) & Section 7 (pg. 161)

15(2)(g)	- a description of all environmental issues that were identified during the assessment process, an assessment of the significance of each issue and an indication of the extent to which the issue could be addressed by the adoption of mitigation measures;	Section 7 (pg.161)
15(2)(h)	- an assessment of each identified potentially significant effect, including -	Section 7 (pg.161)
15(2)(h)(aa)	~ cumulative effects;	
15(2)(h)(bb)	~ the nature of the effects;	
15(2)(h)(cc)	~ the extent and duration of the effects;	
15(2)(h)(dd)	~ the probability of the effects occurring;	
15(2)(h)(ee)	~ the degree to which the effects can be reversed;	
15(2)(h)(ff)	~ the degree to which the effects may cause irreplaceable loss of resources; and	
15(2)(h)(gg)	~ the degree to which the effects can be mitigated;	
15(2)(i)	- a description of any assumptions, uncertainties and gaps in knowledge;	
15(2)(j)	- an opinion as to whether the proposed listed activity must or may not be authorised, and if the opinion is that it must be authorised, any conditions that must be made in respect of that authorisation; and	Section 9 (pg. 282)
15(2)(k)	- a non-technical summary of the information.	Non-Technical Summary (pg. i)

2.3 WATER RESOURCES MANAGEMENT ACT (ACT 24 OF 2004)

This Act provides a framework for managing water resources based on the principles of integrated water resources management. It provides for the management, development, protection, conservation, and use of water resources. Relevant principles of the Act include, *inter alia*:

- Equitable access for all people to safe drinking water is an essential basic human right to support a healthy productive life;
- Harmonisation of human water needs with the requirements of environmental ecosystems and the species that depend on them, while recognising that the water resource quality for those ecosystems must be maintained;
- Promotion of the sustainable development of water resources based on an integrated water resources management plan which incorporates social, technical, economic, and environmental issues;
- Development of the most cost effective solutions, including conservation measures, to infrastructure for the provision of water; and
- Promotion of water awareness and the participation of persons having interest in the decision-making process should form an integral part of any water resource development initiative.

This Act is relevant since the project will abstract seawater and discharge effluent back to the ocean, with product water being entered into the NamWater system. In terms of the Act "water source" is defined as “water from a watercourse, an aquifer or the sea, and includes meteoric water” while "water resource" includes a “watercourse, an aquifer and the sea and meteoric water” and thus the provision of the Act apply to seawater abstraction.

The consequence is that Rössing Uranium will have to obtain a licence to abstract and use seawater and will have to comply with the various provisions of the Act set out in Part VIII of the Act (Sections 32 to 45). Section 32 prohibits the abstraction or use of water without a licence and significantly specifically states that the term “abstract water” includes the abstraction of marine water for any purpose (Section 32(1)). The required Water Use License will be applied for by Rössing Uranium independently and as a separate process to the SEIA.

There are a number of requirements which must accompany the application to abstract water. Of particular importance is Section 33(3)(c) which stipulates that an application for a licence to abstract and use water must be accompanied by a number of requirements including “an environmental impact analysis of the proposed abstraction of water upon the environment and existing water users and water resources” .

Part XI of the Act (Sections 56 to 71) which deals with Water Pollution Control is relevant to the proposed desalination plant in light of the brine discharges back to the ocean. The opening section stipulates that a person may not discharge effluent directly or indirectly to any 'water resource' (defined to include the sea as seen above) unless such person is in compliance with a permit issued in terms of Section 60. The term "effluent" is defined to mean "…any liquid discharged as a result of domestic, commercial, industrial or agricultural activities". Section 59 gives details on the information required for an effluent discharge permit.

It should be noted that this may be repealed by the new Water Resources Management Act (Act 11 of 2013), which has been accepted by parliament but not yet promulgated. Under the new act, Rössing Uranium may be required to register as a water services provider in terms of Section 41, which reads:

> *41 (1) A person may not operate as a water services provider without holding a licence as a water services provider issued by the Minister under this Act that authorises the person -*
> *(a) to distribute water to end-consumers; and*
> *(b) to operate a water treatment facility.*

Under the new Act, a combined abstraction and discharge licence may also be applied for in terms of Section 47, as follows:

> *47. The Minister may, with the consent of the applicant concerned, grant a combined licence to abstract and use water and to discharge effluent if the requirements prescribed by this Act for a separate licence for each type of work or activity are complied with.*

Rössing Uranium acknowledges the requirements in terms of the new Act and will adhere to these as required after promulgation.

2.4 THE NATIONAL HERITAGE ACT (ACT 27 OF 2004)

The Act makes provision for the protection and conservation of places and objects of heritage significance and the registration of such places and objects. The National Heritage Council has been established to identify, conserve, manage, and protect places and objects of heritage significance.

2.5 THE SOIL CONSERVATION ACT (ACT 76 OF 1969)

The Act makes provision for the prevention and control of soil erosion and the protection, improvement and conservation of soil, vegetation and water supply sources and resources, through directives declared by the Minister.

Care is to be taken in identifying any potential impacts on soil, vegetation, water supply sources and resources by firstly trying to avoid these impacts. Where they can't be avoided, management measures should be implemented to reduce the significance of the impact(s).

2.6 THE NATIONAL POLICY ON COASTAL MANAGEMENT FOR NAMIBIA (2013)

The policy aims to "provide a framework to strengthen governance in Namibia's coastal areas to realise long-term national goals defined in Vision 2030 and the more specific targets of National Development Plans, namely sustainable economic growth, employment creation and reduced

inequalities in income". One of the objectives of the policy is to provide a foundation for improving the quality of life of coastal communities while doing so responsibly. The proposed project is therefore in line with this policy as it aims to increase water security.

2.7 THE MARINE RESOURCES ACT (2000)

This Act aims to provide for the conservation of the marine ecosystem and the responsible administration, conservation, protection and promotion of marine resources on a sustainable basis; for that purpose to provide for the exercise of control over marine resources; and to provide for matters connected therewith.

Part VI of the Act, namely the harvesting of marine resources, has particular reference as follows:

Part VI: 32 Prerequisites to harvesting:

(1) No person shall in Namibia or in Namibian waters harvest any marine resource for commercial purposes, except under a right, an exploratory right or a fisheries agreement.

Where "harvest" means (a) searching for, catching, taking or attempting to catch or take any marine resource; (b) placing, or having fishing gear in the sea or using it on the sea shore or on an island; (c) engaging in any other activity that can reasonably be expected to result in the locating, catching or taking of marine resources; (d) undertaking any operations at sea or on an island in preparation for any activity mentioned in (a), (b) or (c);

And where "marine resources" means all marine organisms, including, but not limited to, plants, vertebrate and invertebrate animals, monerans, protists (including seaweeds), fungi and viruses, and also includes guano and anything naturally derived from or produced by such organisms.

Whilst the desalination plant aims to avoid incidental harvesting ("taking") of an marine biota ("marine resource") through a number of design interventions (since this is undesirable for plant operation), which enter the system as part of the seawater intake, some uptake of marine biota is unavoidable, especially where those species are of the microbial spectrum and suspended in the sea water. The incidental "harvesting" of "marine resources" is however not being undertaken for "commenrcialcommercial purposes" and in terms of Section 33 of the Act is therefore exempt from having to apply for a right under the Act. "Commercial purposes" with respect to harvesting marine resources means (a) with the intention of selling, bartering, pledging or otherwise disposing of, or delivering or offering to do any of the things mentioned in this paragraph in respect of such resources; (b) using purse seine, trawl or long line, or such other fishing or harvesting methods as may be prescribed; or (c) exceeding the limits prescribed for the harvesting of marine resources for own use. The potential impact of entrainment and impingmentimpingement of marine biota has nevertheless been considered in this impact assessementassessment and any resulting decision.

2.8 THE AQUACULTURE ACT (2002)

The Act aims to regulate and control aquaculture activities; to provide for the sustainable development of aquaculture resources; and to provide for related matters.

Section 35 of the Act states that a person may not, unless authorized in writing to do so by the Minister, conduct any business or undertaking other than aquaculture in aquaculture development zones.

Currently, the area surrounding the proposed location for the desalination plant is not proclaimed as an Aquaculture Development Zone. Nevertheless, aquaculture is regarded as a priority development objective in terms of the National Development Plan and the NACOMA SEA identified the area just north of the Saltworks as a potential development area for land-based aquaculture (refer to section 2.11). Also, Namibia's Vison 2030 predicts a large growth in the aquaculture industry by 2030, particularly in the Erongo and Karas Regions. Namibia has an excellent mariculture potential as a result of ocean conditions and the Benguela upwelling. As a result, the protection of marine areas that could potentially support such an aquaculture industry is of national and strategic importance. The release of desalination effluent has the potential to negatively impact on the suitability of an area from an aquaculture standpoint and must therefore be considered.

However, given that the Rössing desalination plant would be a small scale desalination plant discharging effluent directly into the active and high energy surf zone (where traditional mariculture would not be possible), and is expected to influence an area of between 25m and 45m from the point of discharge (i.e. still within the surf zone), it is not anticipated fors the plant to negatively impact on the suitability of the surrounding area for mariculture development, provided the plant is operated per design specification. Also, as a result of the north trending longshore current, this desalination will not impact on the area between Mile 4 and the Mile 4 Saltworks (up current), which is identified as an area of aquaculture potential according to a NACOMA report Similarly, the presence and operation of the desalination plant is not expected to negatively impact on the oyster farming operations currently underway in the adjoining Swakopmund Salt Works evaporation ponds.

2.9 THE INTEGRATED COASTAL MANAGEMENT BILL (2014)

Once enacted the bill aims to establish a system of integrated coastal management in Namibia in order to promote the conservation of the coastal environment, maintaining the natural attributes of the coastal landscapes and seascapes, and ensuring the sustainable development and use of the natural resources within the coastal zone that is also socially, economically and ecologically justifiable. Furthermore it aims to define the rights and duties in relation to coastal areas; to determine the responsibility of the organs of state in relation to the coastal areas; to control pollution in the coastal zone, development of the coastal environment and other adverse effects on the coastal environment; to give effect to Namibia's international obligations in relation to coastal matters; and to provide for related matters connected therewith.

2.10 THE NATIONAL POLICY ON HUMAN-WILDLIFE CONFLICT MANAGEMENT (2009)

The aim of the policy is to manage human-wildlife conflict efficiently and effectively, for example the destruction of water supply infrastructure.

The location of the project near the Dorob National Park and Important Bird Area of the salt pans necessitates the need to address potential conflicts between humans and wildlife during the construction-, operational- and decommission phases.

2.11 PROPOSED CLIMATE CHANGE STRATEGY AND ACTION PLAN (2009)

The purpose of this document is to put Namibia's commitment to achieving its Millennium Development Goals into action. The plan list, *inter alia*, the following guiding principles:

- Sustainable development and ensuring environmental sustainability;
- Sustainable and equitable use of natural resources; and
- Human rights-based development.

The project therefore addresses some of the above as it will increase water security, as well as provide a medium-term integrated water supply system that would ensure sustainable utilisation of the available resources.

2.12 THE NAMIBIA VISION 2030

The principles that underpin Vision 2030[3], a policy framework for Namibia's long-term national development, comprise the following:

- Good governance;
- Partnership;
- Capacity enhancement;
- Comparative advantage;
- Sustainable development;
- Economic growth;
- National sovereignty and human integrity;
- Environment; and
- Peace and security.

Vision 2030 states that natural environments are disappearing quickly. Consequently the solitude, silence and natural beauty that many areas in Namibia provide are becoming sought after commodities and must be regarded as valuable natural assets. Vision 2030 emphasises the importance of promoting healthy living which includes that the majority of Namibians are provided with safe drinking water. The importance of developing wealth, livelihood, and the economy is also emphasised by Vision 2030. This includes infrastructure provision like transport, communication, water, and electricity. This development will improve the viability of the Rössing Uranium mine, a significant employer and contributor to the local economy. Rössing Uranium's desalination plant will also inadvertently free up much needed water in the Erongo region which can be applied to alternative social and developmental objectives in the region.

2.13 COASTAL SEAS

Two Namibian coastal Strategic Environmental Assessments (SEAs) were undertaken between 2006 and 2008, i.e. one for the northern regions of Kunene and Erongo and another for the southern regions of Karas and Hardap. These draw on international experience and were undertaken at a time of mounting production sector pressures within Namibia. Being an initiative of the Namibian Government through MET, the two SEAs seek to inform political and technical decision makers at local, regional and national levels.

The 2008 "SEA for the coastal areas of the Erongo and Kunene Regions" compiled by the Namibian Coast Conservation & Management Project (NACOMA) is aimed at ensuring informed decisions on

[3] *Derived from Namibia's Green Plan drafted by MET in 1992 and followed by the sequence of National Development Plans.*

issues related to biodiversity conservation, land use planning and socio-economic development planning in the Kunene and Erongo coastal regions.

According to the NACOMA SEA for this region, the Mile 4 Saltworks comprises a private nature reserve of 400 ha in which no conflicts seem to exist between the waterbird concentrations, the salt extraction, oyster production and guano scraping at the Saltworks. The SEA further notes that in line with the Namibian Wetland Policy the current seemingly sustainable activities should be monitored and any new development should be subject of environmental impact assessment (as has been carried out for the proposed project).

In addition, the area just north of the Saltworks has been identified as a potential development area for land-based aquaculture by Ministry of Fisheries and Marine Resources. It is therefore important that the proposed desalination activities do not prevent and/or impact potential future aquaculture activities to the north of the Saltworks.

2.14 WATER QUALITY GUIDELINES

The Water Resources Management Act (Act 24 of 2004) does not contain any target values for water quality associated with brine effluent. These will form part of the regulations associated with the new Water Act and will be implemented at a future date. As far as can be established, South Africa is the only southern African country that currently has an official set of water quality guidelines for coastal marine waters. In terms of policy, legislation and practice South Africa's operational policy for the disposal of land-derived wastewater to the marine environment (DWAF 2004 a-c) is thus of relevance. Specifically, environmental quality objectives need to be set for the marine environment, based on the requirements of the site-specific marine ecosystems, as well as other designated beneficial uses (both existing and future) of the receiving environment. The identification and mapping of marine ecosystems and the beneficial uses of the receiving marine environment provide a sound basis from which to derive site-specific environmental quality objectives (Taljaard *et al*. 2006). To ensure that environmental quality objectives are practical and effective management tools, they need to be set in terms of measurable target values, or ranges for specific water column and sediment parameters, or in terms of the abundance and diversity of biotic components. The South African Water Quality Guidelines for Coastal Marine Waters (DWAF 2005) provide recommended target values (as opposed to standards) for a range of substances, but these are not exhaustive. Therefore, in setting site-specific environmental quality objectives, the information contained in the DWAF guideline document is supported by additional information obtained from published literature and best available international guidelines (e.g. ANZECC 2000; World Bank 1998; EPA 2006). Recommended target values are also reviewed and summarized in the Benguela Current Large Marine Ecosystem (BCLME) document on water quality guidelines for the BCLME region. Recommended target values extracted from these guidelines are provided in Table 5 below.

As required by the Water Resources Management Act 24 of 2004, the Namibian Department of Water Affairs and Forestry is in the process of compiling regulations for water quality standards for effluent disposal to ground, groundwater and surface waters, including territorial coastal marine waters. To meet this objective, a set of Special Water Quality Standards for effluents has been proposed. Although not specifically stipulated as such, these appear applicable to effluent discharges into fresh water sources only. Nonetheless, for the sake of completeness, the proposed Special Water Quality Standards are presented in Table 4, with values for the combined brine and waste stream (before dilution) from the proposed Rössing Uranium desalination plant being provided for comparison. Should DWAF enforce these standards at a point discharge in the marine environment without taking cognizance of the dilution of the brine effluent in the mixing zone (see Section 3.5.6 below), etc. an application for an exemption permit will need to be submitted.

Table 3: Water quality guidelines for the discharge of a high-salinity brine into the marine environment

DETERMINANT /VARIABLE	SOUTH AFRICA (DWAF 2005)	AUSTRALIA/NEW ZEALAND (ANZECC 2000)	WORLD BANK[A] (WORLD BANK 1998)	US ENVIRONMENTAL PROTECTION AGENCY (EPA 2006)
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	The maximum acceptable variation in ambient temperature is ± 1°C	Where an appropriate reference system is available, and there are sufficient resources to collect the necessary information for the reference system, the median (or mean) temperature should lie within the range defined by the 20%ile and 80%ile of the seasonal distribution of the ambient temperature for the reference system.	< 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.	
Salinity[b]	33 – 36 psu	Low-risk trigger concentrations for salinity are that the median (or mean) salinity should lie within the 20%ile and 80%ile of the ambient salinity distribution in the reference system(s). The old salinity guideline (ANZECC 1992) was that the salinity change should be <5% of the ambient salinity.	-	
Total residual Chlorine	No guideline, however, deleterious effects recorded for concentrations as low as 2 – 20 µg/ ℓ. A conservative trigger value is <2 µg/ℓ.	3 µg Cl/ℓ 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)[c]	0.2 mg/ℓ at the point of discharge prior to dilution	Long-term and short-term water quality criteria for chlorine in seawater are 7.5 µg/l and 13 µg/l, respectively
Dissolved oxygen	For the west coast, the dissolved oxygen should not fall below 10 % of the established natural variation. For the south and east coasts the dissolved oxygen should not fall below 5 mg/ℓ (99 % of the time) and below 6 mg/ℓ (95 % of the time)	Where an appropriate reference system is available, and there are sufficient resources to collect the necessary information for the reference system, the median lowest diurnal DO concentration for the period for DO should be >20%ile of the ambient dissolved oxygen concentration in the reference system(s) distribution. The trigger value should be obtained during low flow and high temperature periods when DO concentrations are likely to be at their lowest.		
Nutrients	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 (see above)	Default trigger values of PO_4-P: 100 µg/ℓ NO_x-N: 50 µg/ℓ NH_4^+-N: 50 µg/ℓ for the low rainfall southern Australian region (Table 3.3.8 in ANZECC 2000)		
Chromium	8 µg/ℓ (as total Cr)	Marine moderate reliability trigger value for chromium (III) of 10	0.5 mg/ℓ (total Cr) for effluents from	1 100 µg/ℓ for highest

DETERMINANT /VARIABLE	SOUTH AFRICA (DWAF 2005)	AUSTRALIA/NEW ZEALAND (ANZECC 2000)	WORLD BANK[A] (WORLD BANK 1998)	US ENVIRONMENTAL PROTECTION AGENCY (EPA 2006)
		µg./ℓ with 95% protection Marine high reliability trigger value for chromium (VI) of 4.4 µg/ℓ at 95% protection.	thermal power plants	concentration at brief exposure without unacceptable effect 50 µg/ℓ highest concentration at continous exposure without unacceptable effect
Iron		Insufficient data to derive a reliable trigger value. The current Canadian guideline level is 300 µg/ℓ	1.0 mg/ℓ for effluents from thermal power plants	
Molybdenum		Insufficient data to derive a marine trigger value for molybdenum. A low reliability trigger value of 23 µg/ℓ was adopted to be used as indicative interim working levels.		
Nickel	25 µg/ℓ (as total Ni)	7 µg/ℓ at a 99% protection level is recommended for slightly-moderately disturbed marine systems.		74 µg/ℓ for highest concentration at brief exposure without unacceptable effect 8.2 µg/ℓ highest concentration at continous exposure without unacceptable effect

[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 (=ΔS of approximately 1 psu). Scientific studies have shown that effects on marine biota are primarily observed for increases of >4 psu above ambient level. ΔS 1 psu and 4 psu have been chosen for assessment purposes.

[c] In case of chlorine "shocking", which involves using high chlorine levels for a short period of time rather than a continuous low-level release, the target value is a maximum value of 2 mg/ℓ 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/ℓ (The same limits would apply to bromine and fluorine.).

Table 4: Proposed Special Water Quality Standards for Effluents (DWAF 2014) and expected values before dilution in the brine effluent from the proposed Rössing Uranium desalination plant

DETERMINANT	UNIT	PROPOSED SPECIAL WATER QUALITY STANDARDS FOR EFFLUENTS	COMBINED BRINE AND WASTE STREAM (BEFORE DILUTION)
Turbidity	NTU	<5	10
Colour		<10%	
Suspended solids	mg/l	<25 mg/l	50
TDS	mg/l	<500 mg/l above the intake potable water quality	63,000
pH		6.5- 9.5	7.5 - 8
Temp	C	± 1°C of ambient	(+) 2 - 4
Nitrate as N		< 15 mg/l (as N)	
Nitrite as N	mg/l	<2 mg/l	0.4 - 0.75
Fluoride (F)	mg/l	< 1 mg/l	2
Na	mg/l	<50mg/l above the intake potable water quality	20,000
Ca	mg/l	Not specified	750
Mg	mg/l	Not specified	2,500
K	mg/l	Not specified	900
Chloride as Cl	mg/l	<40mg/l above the intake potable water quality	38,000
Alkalinity as $CaCO_3$	mg/l	Not specified	
Hardness as $CaCO_3$	mg/l	Not specified	
Sulphate as SO4	mg/l	<20mg/l above the intake potable water quality	5,000
Iron as Fe	mg/l	<200 µg/l	4 - 5

2.15 BIODIVERSITY LEGISLATION AND POLICIES

The following legislation and policies, aimed at biodiversity conservation and management, may also be relevant for the proposed project:

- Convention on Biological Diversity (2000);
- Convention to Combat Desertification (1997);
- RAMSAR Convention (1975);
- United Nations Framework Convention on Climate Change (1992); and
- Climate Change Policy (draft).

2.15.1 Rio Tinto Environmental and Sustainability Policies[4]

The following policy statement is provided on the Rio Tinto web page and provides a brief overview of their sustainability policies.

"Sustainable development is commonly defined as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs'. While it cannot be achieved by one organisation on its own, Rio Tinto believe that our business can make an important contribution to the ongoing, global transition to sustainable development.

[4] *Source: http://www.riotinto.com/sustainabledevelopment2012/strategy/our_sustainable_development_strategy.html*

Because Rio Tinto recognises a responsibility to all their stakeholders and to the wider world, our commitment to sustainable development is integrated into everything we do. Rio Tinto operations give us the opportunity to bring long-lasting positive change to the communities, regions, and countries where we work, and the metals and minerals are transformed into end products that contribute to higher living standards.

To build and protect Rio Tinto's reputation, there is a relentless focus on embedding and living these values – accountability, respect, teamwork, and integrity – and on deepening sustainable development capabilities.

Rio Tinto must maintain safety as our absolute priority – eliminating workplace fatalities, and continuing to reduce incident, injury, and illness rates towards our goal of zero harm. Recognising that strong leadership is essential for achieving our safety goals, we will continue to improve our leaders' engagement around safety risks.

Rio Tinto's approach to sustainable development and business integrity are, we believe, competitive advantages for us. They help us gain access to high quality resources and business development opportunities. In addition they allow us to attract talented people, engage with communities, reduce environmental impacts, manage risks effectively, and decrease operating costs. This enables us to give more confidence, and deliver higher returns, to our stakeholders".

Key policy aims are to:

- "Wherever possible we prevent, or otherwise minimise, mitigate and remediate, harmful effects of the Group's operations on the environment.
- Excellence in environmental performance is essential to our business success. Compliance with all environmental laws and regulations is the foundation on which we build our environmental performance.
- Rio Tinto develops Group wide standards and builds systems to identify, assess and manage environmental risk to achieve continuous improvement in environmental performance.
- Rio Tinto businesses, projects, operations and products should contribute constructively to the global transition to sustainable development.
- Rio Tinto contributes to sustainable development by helping to satisfy global and community needs and aspirations, whether economic, social or environmental. This means making sustainable development considerations an integral part of our business plans and decision making processes".

2.15.2 Rössing Uranium Limited Policies

In order to accomplish Rössing Uranium's vision and commitment to social responsibility and sustainability, Rössing Uranium will:

- Commit to operate Rössing Uranium's business with respect and care for both the local and global environment in order to prevent and mitigate residual pollution;
- Be in full compliance with all applicable legislation, standards and requirements;
- Provide adequate training and resources to employees, contractors and visitors; and
- Enhance biodiversity protection by assessing and considering ecological values and land-use aspects in investment, operational and closure activities.

2.16 SOCIAL POLICIES

2.16.1 The MET Policy on HIV and AIDS

The relevance of this policy for the proposed project stems from the fact that construction activities may involve the establishment of temporary construction workforce. Experience with other construction projects in a developing-world context has shown that, where construction workers have the opportunity to interact with local community, a significant risk is created for the development of social conditions and behaviors that contribute to the spread of Human Immune-deficiency Virus (HIV) and Acquired Immune Deficiency Syndrome (AIDS).

In response to the threat the pandemic poses, MET has developed a policy on HIV and AIDS. This policy, which was developed with support from United States Agency for International Development (USAID) and German Federal Enterprise for International Cooperation (GTZ) (a German Development Fund), provides for a non-discriminatory work environment and for workplace programs managed by a Ministry-wide committee.

3 PROJECT DESCRIPTION

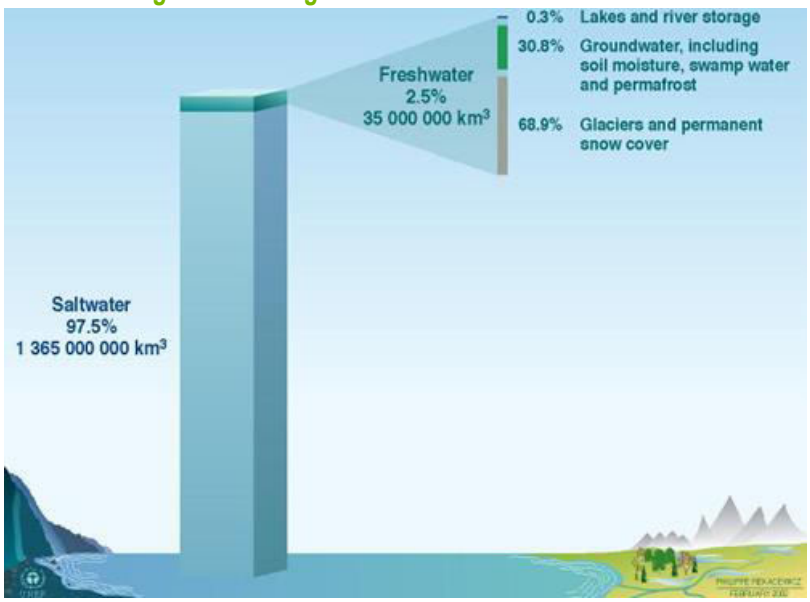
This Chapter aims to provide a description of the project and the workings of the key project components. In addition, the project need and desirability has also been described.

3.1 A BACKGROUND TO DESALINATION

As the global human population expands so does the pressure on the environment to provide adequate quantities of clean water for ecological, domestic, industrial, and agricultural purposes. Global water supplies are rapidly approaching upper supply limits and in many countries where resources are already overexploited, resulting in significant impacts to both social and biophysical environments. The number of people affected by water scarcity is expected to grow from approximately half a billion in 1995 to over four and half billion by 2050. Increasing human population drives ongoing industrial and agricultural development and urbanisation, amongst other water intensive pursuits. This situation is compounded by growing environmental problems such as desertification, soil erosion and deforestation, loss of wetlands and other impacts which either reduce the supply potential or increase the demand potential.

This background reveals the growing need to seek and implement alternative water supply strategies in order to secure adequate fresh water and cater for future demand without causing irreparable harm to existing fresh water resources. The world's total water resources are comprised of 97.5% saltwater and only 2.5% freshwater. Of the 2.5% freshwater, a mere 0.3% is available in lakes and rivers, 30.8% is found as groundwater (which includes soil moisture, swamp water and permafrost), and the remaining 68.9% is locked up as ice as glaciers and areas covered permanently in snow (Figure 2).

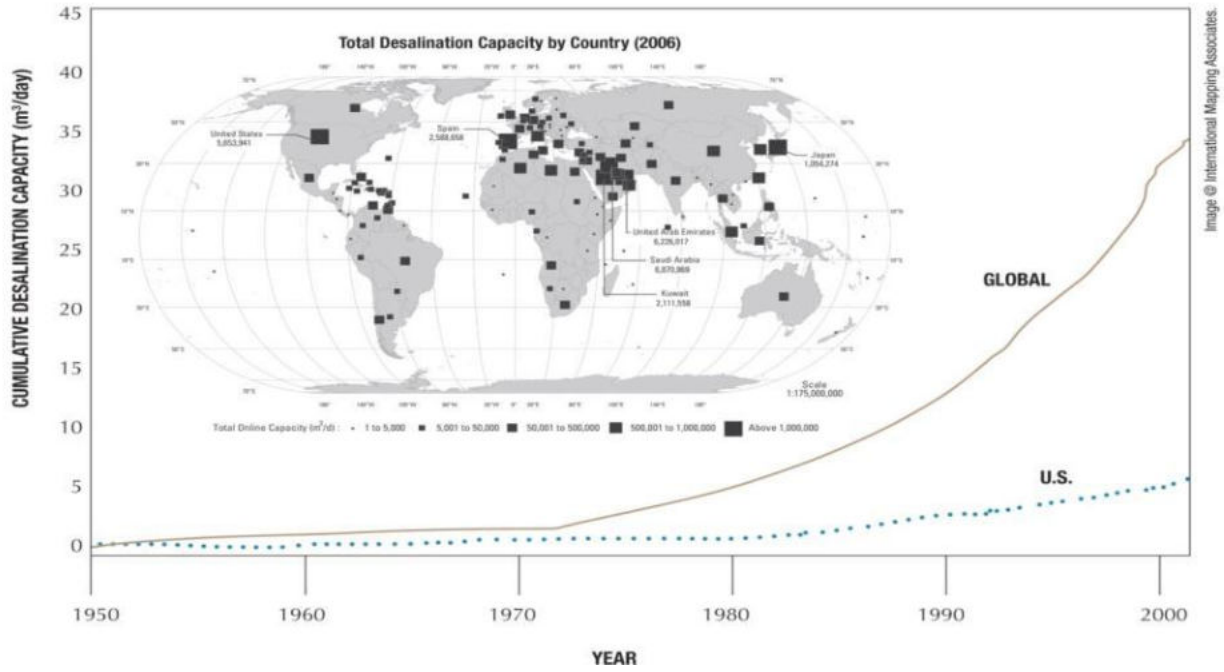
Figure 2: Total global water resource estimates[5]



[5] Source: UNEP. 2010.

Desalination of saltwater therefore provides a means to access a vast supply of water from the world's oceans. Consequently there has been an increasing interest and investment into desalination since its conception. Many coastal areas, arid and/or island nations have had to resort to desalinated water for potable and development needs as demand currently outstrips the supply of traditional freshwater resources. The regions and rate of growth in the desalination industry between 1950 and 2006 are depicted in Figure 3. With the rapid growth and development of the desalination industry, the technology has undergone continual refinement, becoming more energy and cost efficient as the technology matures. Desalination is able to provide safe, high quality water at virtually any quantity, provided the required energy requirements can be met. Not only is water available during drought periods, but it also alleviates pressures on other traditional freshwater resources[6].

Figure 3: Cumulative desalination capacity of the world[7]



Desalination has emerged as one of the leading alternative water supply strategies internationally. The technology has been used on a small scale on ships and submarines; however it is now increasingly being used on a larger scale to provide potable water for human consumption. The technology has been around since the mid-twentieth century, and has become common practise in some of the more populous and arid regions of the world. Regional centres, where desalination plants are prominent include the Mediterranean Sea, the Red Sea, the Caribbean, and the coastal areas of China and Australia[8]. Figure 4 provides an indication of the the total global installed desalination capacity as of 2009 and Figure 5 illustrates regions of the world which have implemented desalination plants/facilities.

[6] *Source: UNEP, 2008.*
[7] *Source: UNEP, 2008.*
[8] *Source: UNEP, 2008.*

Figure 4: The total global installed desalination capacity as of 2009

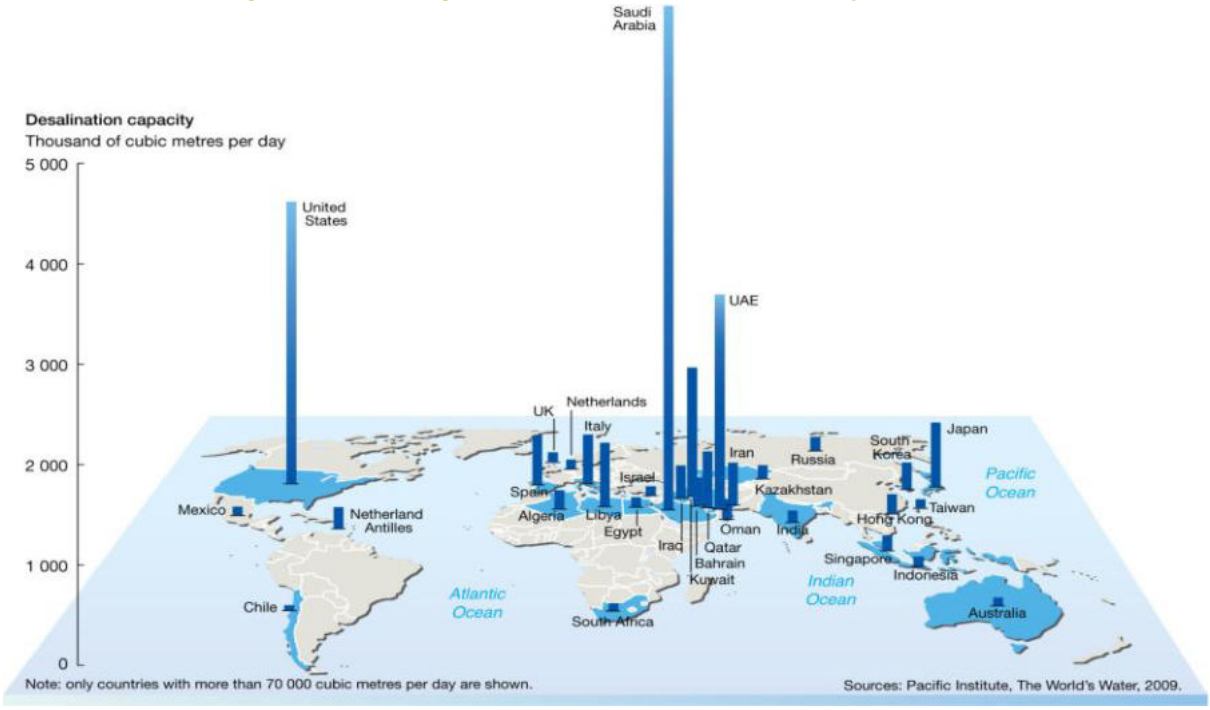
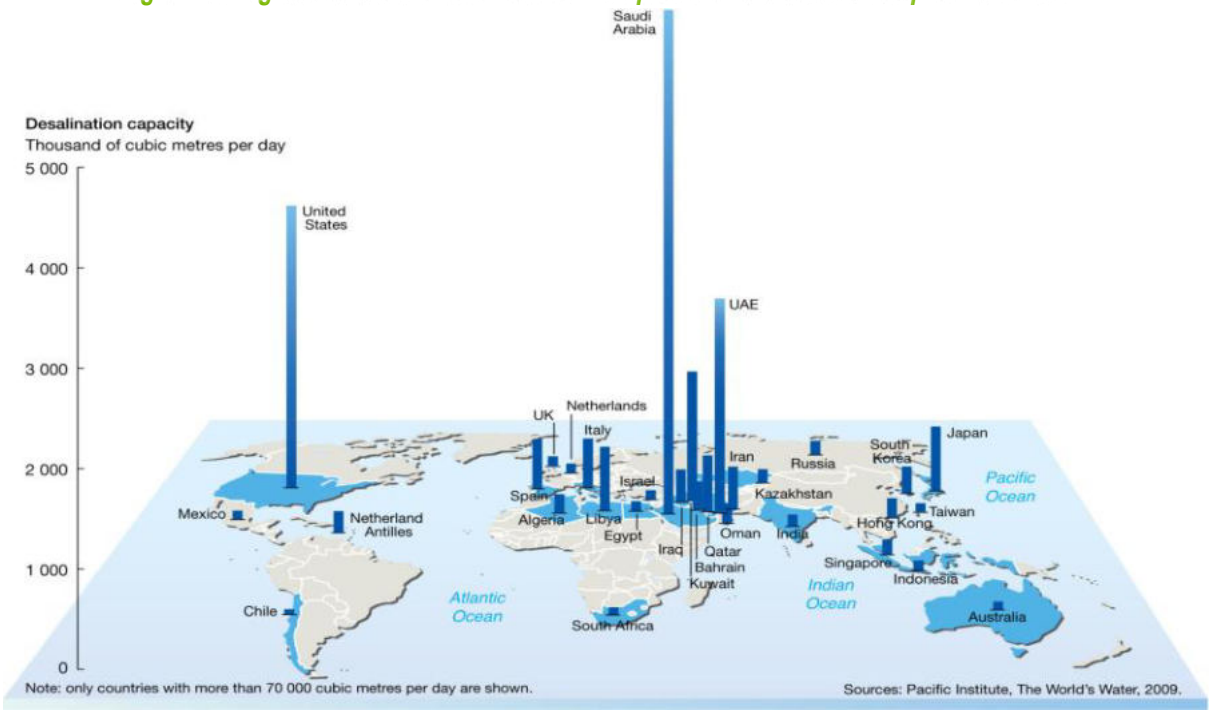


Figure 5: Regions of the world which have implemented desalination plants/facilities[9]



Desalination offers a number of socio-economic, environmental and public health benefits resulting in the technologies having undergone rapid and extensive development, and is now considered a mature technology. There are a number of desalination plants in operation across southern Africa, and they are likely to become more prevalent in future as traditional freshwater systems reach their upper supply limits.

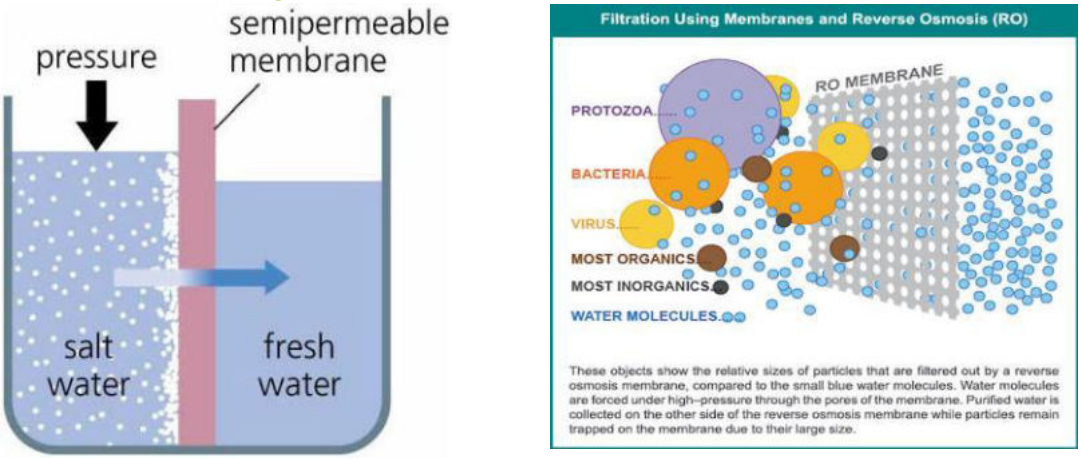
[9] *Source: Pacific Institute. 2010.*

Desalination refers to a suite of processes, whereby clean water is separated from polluted, brackish or sea-water by effectively removing the dissolved mineral salts and other impurities. The process separates the feed water into two streams, one clean water stream, and one containing all dissolved matter removed. The effluent stream typically has the same chemical make-up as the original feed water only that the minerals and impurities are at a concentrated level.

The technology that will be employed by the Rössing Uranium desalination plant is referred to as reverse osmosis (RO). The process purifies water by removing dissolved mineral salts and other impurities from seawater[10], making it suitable for human consumption. Desalination technology is now being used increasingly as a means of providing fresh water for human consumption in regions with a scarcity of water resources or where the demand for potable (drinking) water is exceeding traditional freshwater supplies.

Seawater is abstracted from the ocean and pumped to the desalination plant where it is placed under pressure in the presence of a semi-permeable membrane. This pressurisation process can be energy intensive. As a result of the high pressures exerted on the seawater, water molecules escape through the semi-permeable membrane, leavening behind the impurities such as mineral salts and dissolved organic matter, as shown in Figure 6. This is mostly as a result of the physiological size of the water molecule as in comparison with the impurities it adheres to. The pressure applied is enough to break the chemical bonds and overcome osmotic pressure and is why it is referred to a RO.

Figure 6: Principle of RO and semi-permeable membrane[11]



The freshwater or permeate produced by the RO process, which represents approximately 40% of the feed water, is devoid of almost all impurities. This results in the water becoming aggressively corrosive as it attempts to reform molecular bonds with substances in its environment. In this form it can be damaging to municipal and domestic water reticulation infrastructure, including pipework and pumps due to its strong oxidative chemistry, and is unfit for human consumption. To address this, permeate must undergo a re-mineralisation process to reduce these corrosive characteristics and make it suitable for distribution and human consumption. Alternatively, permeate can be pumped to reservoirs where it is allowed to dilute with fresh water from other water sources (containing more impurities) as a means of diluting and reducing these oxidative characteristics.

The brine or highly concentrated seawater left behind, consists of about 60% of the total seawater intake volume and contains all the impurities and mineral salts that were unable to pass through the

[10] *Note: Desalination technologies are also employed for the treatment of brackish water, the recycling of wastewater and treatment of effluents.*
[11] Source: http://images.yourdictionary.com/reverse-osmosis *and http://sfwater.org/detail.cfm/MC_ID/13/MSC_ID/377/C_ID/5163/ListID/1*

membrane during the RO process. The brine is typically discharged back to the ocean and allowed to dilute back to ambient levels. Other concentrate disposal options include deep well injection into aquifers (not affecting aquifers used for other purposes), land application, evaporation ponds, brine concentrators and zero liquid discharge technologies.

3.2 PROJECT NEED AND DESIRABILITY

As of the 1st of November 2013, Rössing Uranium has been receiving water from the desalination plant built by Areva at Wlotzkasbaken. For years, it has been known to both NamWater and the mines in the Central Coastal Area that the Omdel underground aquifer has been depleting and that this would be unable to sustain the coastal towns and the mines at the current rate of abstraction.

When the Trekkopje mine was built by Areva, Areva were required to provide their own desalination plant, as they would not be able to obtain water from the Omdel aquifer. The permissible Omdel aquifer abstraction was formally reduced on 31 October 2013 by the Ministry of Agriculture, Water, and Forestry (MAWF) from 9Mm^3 to 4.5Mm^3. Therefore, as from the 1st of November 2013, all the mines in this region were transferred to desalinated water supply from the Areva plant.

The desalinated water from the Areva plant is extremely expensive. The water is purchased on a take or pay arrangement on unfavourable commercial terms, the only terms to which NamWater, the country's official water distributor, was prepared to enter into a back to back arrangement between the mines and Areva for this water supply.

The Areva desalination plant was built to serve a capacity of 20Mm^3 per annum, with a power feed equivalent to provide electricity for 40Mm^3. The three mines currently in operation and development require in total 6Mm^3 per annum, and the demand will grow to approximately 10Mm^3 per annum over the next three years. The smaller off-take therefore has to cover the fixed charges and related finance charges to a plant that has been over-specified for the present situation.

The production of desalinated water at between US$2.00/m^3 and US$2.50 is widely accepted as a benchmark cost for desalinated water. Several years of negotiation attempts between Rössing Uranium and the key stakeholders have however remained unsuccessful in bringing the cost of water into this cost envelope. Progress on the NamWater Mile 6 plant has also been slow. The original plan was for an October 2014 completion date for this (Mile 6) plant. However, to date, the implementation of this plant has not commenced. This leaves the mining community exposed to the current very high desalination water costs, which is the only alternative supply of water (other that the the supply from the Omdel aquifer), for at least the next five years.

Rössing Uranium's off-take is approximately 3Mm^3 per annum. Therefore it effectively carries half the cost of this plant. In 2012 (the last full year on aquifer water), Rössing Uranium's water cost was N$39 million. In 2014 (the first full year on desalinated water), the cost for water is expected to be N$129 million.

Where Rössing Uranium manages to take its full allocation of water in terms of the take or pay arrangement, the average cost of the water is approximately between US$4.00/m^3 and US$4.50/m^3 (inclusive of conveyancing costs). However, in the two months where Rössing Uranium suffered curtailed operations due to an unfortunate leach tank failure, the effective unit cost of water became approximately US$9.00/m^3.

This is a commercially unsustainable situation and needs to be rectified in order for Rössing Uranium to remain globally competitive.

Rössing Uranium is therefore proposing to build, own, and operate a desalination plant, designed to a much lower capacity than the Areva plant. It is expected that the total cost of water for Rössing Uranium will then decrease to between US$2.00/$m^3$ and US$2.50/$m^3$ at point of supply.

A modular solution is being proposed, following an initial concept study that was done by Gecko Namibia (Pty) Ltd (Gecko). It is intended to proceed with this venture, utilising Gecko as project managers for the feasibility study.

The proposed desalination plant will have immediate commercial benefits, as it will be catering for a much smaller capacity. The plant will also be under Rössing Uranium's control, providing supply surety. Since the desalination plant will be modular, it would be easy to increase or decrease capacity in line with Rössing Uranium's requirements that may vary from month to month, without having to incur a take or pay penalty.

As described in the socio-economic assessment (secion 7.4 of this report), without an intervention to ensure that water can be secured at a reasonable cost, the impact on operating costs may render the continued operation of the Rössing mine unfeasible, forcing a premature closure and resulting in a range of undesirable and significant negative socio-economic impacts, affecting not only Rio Tinto (as the mine owner) but the various communities of the Erongo Region and the Namibian economy as a whole.

3.3 PROJECT OVERVIEW

This subsection provides the reader with a description of what is likely to occur if the project receives clearance from MET:DEA and Rössing Uranium moves forward with the project. The key activities occurring in each phase of the project are briefly described below.

3.3.1 Pre-construction phase

During this phase, Rössing Uranium and their consultants would commence with the detailed planning and design phase. The findings in this SEIA (and also any conditions contained in the MET:DEA environmental clearance) would be considered and catered for in the detailed design. During the period tenders will be released and an eligible contractor/s appointed to undertake the various construction activities. This period should take approximately 3 months before construction will commence.

During this time Rössing Uranium would also resolve any outstanding legal requirements and permits (i.e. a licence to abstract and use seawater, an effluent discharge permit and a licence to operate as a water services provider) which are required to operate the plant. During the period Rössing would also negotiate and secure agreements for use of the property and any services agreements i.e. use of the NamWater pipeline for transference of product water, Erongo RED for the supply of electricity, Swakopmund Municipality for the disposal and treatment of sewage and solid waste, etc.

3.3.2 Construction phase

The construction of the desalination plant can only commence after receipt of environmental clearance from MET:DEA. The construction phase of the project is expected to last approximately 18 months in duration. However, due to the strategic financial significance of the project to the Rössing mine it is possible that the project could be accelerated, bringing the total build time down to around 12 months. At the peak of construction the project is expected to employ approximately 50 persons (10 Skilled, 25 semi-skilled and 15 unskilled). Where these construction staff are not from the area it is most likely that they will take up residence in Swakopmund for the duration of the project. The various project components are described in greater detail in subsection 3.5 to follow.

The contractor would commence by establishing the various works areas and temporary construction areas, including a construction yard. The main construction yard would be located adjacent to the main RO plant and smaller construction yards or laydown areas would be established at the Seawater intake Jetty and the Brine outfall. The existing Salt Works road will also be upgraded to cater for the construction and operations phase of the facility. The construction yards would be temporarily fenced for safety and security purposes. Housed in the these areas would be container offices, ablution facilities, workshop containers, employee recess areas, general materials stockpiling, fuel and oil stores, and laydown areas and parking for vehicles, plant and equipment.

In the case of the brine outfall and seawater intake, enough area will need to be set aside for the construction of storage and construction of the steel lattice jetty framework and for the connection of pipeline stings which need to be constructed as a single length, and pulled into their final positions, either on the jetty, or into a excavated trench through the beach and intertidal zone. The marine works component is the most challenging aspect of the build as it requires construction in the intertidal zone placing people and equipment in a precarious and unpredictable environment. To enable this work the contractor may need to extend a working platform (using beach sand and rock) out into the surf and drive steel piles to protect the work area from waves, enabling plant, equipment and people access to these areas for the construction of these structures.

Construction of the RO plant would involve routine construction processes, commencing with site clearance, placement of concrete foundations and plinths onto which the building walls and various items of plant, equipment and pipelines would attach. The RO plant building would then be erected and at the same time the various components making up the desalination plant (including the modular RO trains, pumps, compressors and chemical storage tanks) would be imported onto site and affixed to the concrete plinths or the building structure, where after the contractor would commence with the tying in of the components through an involved network of pipes and electrical connections. One of the larger tasks associated with the construction of the RO plant will be the construction of the various concrete holding tanks and the ancillary structures, including the various chemical storage and dosing areas, which must all be equipped within suitable bunded storage facilities. The chlorine storage facility for example is a specialized and sealed storage area, containing a number of safety features including chorine gas detection systems and alarms. The construction of the RO plant building will also involve the construction of a Mechanical Control Centre (MCC), office space, ablution facility and conservancy tanks, kitchen area, first aid station, workshop and spares storages areas and any other facilities that may be required for the operation of the plant.

The remainder of the construction work involves the trenching and burying of various pipelines and electrical cables between the key components.

A summary of construction activities is provided in Table 5. The “x’s” in the table indicate which activities may be associated with the construction of the various project components. The project components are described in more detail in section 3.5 below.

Most construction processes (with the exception of marine works) are common and well understood and good repository of environmental best practices have been developed to manage these processes to reduce excessive environmental damage. The SEMP developed for this project and attached here as Annexure E incorporates these generic mitigation and management measures, and if implemented affectively, can significantly reduce the environmental impact of construction activities to minimal levels.

Table 5: Table of construction activities

Activity		Intake structures	Intake channel	Plant	Ponds	Discharge structures	Powerline and substation	Water pipeline
A1	Earthworks: Clearing and bulldozing activities		X	X	X		X	X
A2	Earthworks: Soil excavation and trenching		X	X	X		X	X
A3	Earthwork: Stockpiling of soil and other material		X	X	X		X	X
A4	Earthworks: Drilling, pile driving and blasting activities (Take note that blasting activities are not envisaged at this stage. However, conservatively, blasting were included and assessed in this SEIA, should small blast occurrences be required).	X				X		X
A5	Backfill of material	X	X	X	X	X	X	X
A6	Civil works: Foundation excavations	X		X		X	X	
A7	Building activities	X	X	X		X	X	
A8	Storage and handling of material: sand, rock, cement, chemical additives in cements	X		X		X		
A9	Water utilization	X	X	X	X	X	X	X
A10	Mixing of concrete (batch plant) and concrete work (casting)	X	X	X		X	X	
A11	Operation and movement of construction vehicles and machinery	X	X	X	X	X	X	X
A12	Refuelling of equipment	X	X	X	X	X	X	X
A13	Use of cranes			X				

Activity		Intake structures	Intake channel	Plant	Ponds	Discharge structures	Powerline and substation	Water pipeline
A14	Erection and destruction of scaffolding			X			X	
A15	Building of shutters			X			X	
A16	Installing re-enforcement Steel	X		X		X	X	
A17	Handling, storage and disposal of hazardous waste • Empty paint containers • Cements bags • Chemical additives (for cement) containers • Contaminated PPE and other (with hydrocarbons, etc). • Redundant concrete	X	X	X	X	X	X	X
A18	Handling, storage and disposal of non-hazardous waste • Steel off-cuts • Domestic waste • Wood off-cuts • Grinding wheels • Other construction waste	X	X	X	X	X	X	X
A19	Transportation of hazardous material	X		X	X	X	X	X
A20	Transportation of non-hazardous material	X	X	X	X	X	X	X
A21	Handling and storage of Hazardous material • lubricants • Paints • Gas (welding) • Cement • Chemical additives for cement	X	X	X		X	X	

Activity		Intake structures	Intake channel	Plant	Ponds	Discharge structures	Powerline and substation	Water pipeline
A22	Install water pipelines	X		X		X		X
A23	Install of electricity lines (above and/or below ground)	X	X	X	X	X	X	
A24	Use of electricity generators	X		X		X	X	
A25	Install transformers and substations	X		X		X	X	
A26	Install parking bay for trucks			X				
A27	Manage construction site	X	X	X	X	X	X	X
A28	Painting, grinding and welding	X	X	X	X	X	X	
A29	Provision and operation of water washing and toilet facilities	X	X	X	X	X	X	X
A30	Appointment of contractors, labourers, etc. • Civil contractor • Structural contractor • Electrical contractor	X	X	X	X	X	X	X

3.3.3 Operations phase

The proposed desalination plant can produce up to 10,000m^3/d of potable water in every a 24 hour cycle. Water production times and rates will vary depending on demand at the mine, peak and off-peak electrical demand periods (and associated electrical rates), routine maintenance shutdowns, breakdowns and upset conditions (i.e. ocean storms or red tide conditions). The production rate for the plant should however average at 8,200m^3/d or approximately 3Mm^3 per annum. At peak production the plant will abstract up to 25,000m^3/d of seawater, produce 10,000m^3/d of potable water and discharge 15,000m^3/d back to the ocean as brine. The plant will be designed to optimise electrical efficiency and will be equipped with energy recovery systems to further improve the electrical efficiency and performance of the plant. The approximate footprint of the desalination plant is 200 x 100m, however larger areas have been considered initially to allow for flexibility (Trade-Off Study Report 5: Optimum Plant Location, 2014). The various project components are described in greater detail in subsection 3.5 to follow.

During the operational phase, the plant will be staffed with an estimated 12 to 18 contract staff working on a shift basis or as required to satisfy water production objectives at any given time. It is likely that the plant will be operated by Gecko under an Operation and Maintenance Contract with Rössing Uranium.

3.3.4 Decommissioning phase

At a conceptual level, decommissioning can be considered a reverse of the construction phase with the demolition and removal of the majority of infrastructure and activities very similar to those described with respect to the construction phase.

The plant will be designed to have a 10 year operational life, which coincides with the current Rössing Uranium Life of Mine plan. At the end of the design life period, the plant may be refurbished for continued operation, upgrade, or may be decommissioned, broken down and the site rehabilitated, or sold as a going concern to another mining house or NamWater, depending on the situation and needs at that time. Given that the plant will be producing water to potable water standards and will already be tied in with the existing NamWater system, decommissioning of the plant would seem to be a wasted opportunity.

3.4 PROJECT LOCATION

The desalination plant will be located within the northern extremities of the Swakopmund Local Authority area, positioned on the eastern side of the evaporation ponds within the Swakopmund Salt Works, and situated approximately 6km north of Swakopmund. The plant will be situated on Erf 4007 Swakopmund Extension 10, which is currently zoned for mining (salt). The Swakopmund Salt Works is registered as a private nature reserve and thus compatibility with conservation objectives will remain an important consideration of which the resident birdlife is the key aspect.

The preliminary or “Base Case” project (i.e. conceptual project as envisaged at the completion of the pre-feasibility stage) that was assessed as part of this SEIA process, is as follows (refer to Figures 22, 23 & 26):

- The coordinates of the plant are 22°35'27.88"S and14°31'32.32"E (indicated with the blue dot in the Figures below).
- The seawater intake location is approximately 160m south of the existing seawater intake structure for the Swakopmund Salt Works.

- The brine discharge is located 230m south of the present bitterns discharge site and located at a rock outcrop within the shallow surf zone.

However, as an outcome of the SEIA process, after assessing various alternative project layouts, the location of the plant must be moved further north (indicated with the red dot in Figure 8 below), and away from the core Damara Tern breeding area, also resulting in a different brine discharge location, north of the intake structure, referred to as the "optimised SEIA layout". Refer to sections 4 and 10 for more details regarding the different layouts and the optmised site layout.

The site can be accessed off the C34 between Swakopmund and Henties Bay via the existing Swakopmund Salt Works roads. The following maps place the project in a regional and local context.

Figure 7: Location of the proposed Rössing Uranium desalination plant in the regional context

Figure 8: "Base Case" and optimised SEIA location of the proposed desalination plant in the local context

3.5 PROJECT COMPONENTS

The project can be divided into the following main components, which are described in greater detail under respective headings to follow and conceptually shown inFigure 11 to follow:

- Seawater intake system;
- Seawater pre-treatment system;
- Desalination plant;
- Ancillary structures and infrastructure;
- Electrical supply system;
- Product water system and pipeline; and
- Effluent treatment and disposal system.

These components are described in further detail below, in terms of design, capacity and footprint, etc.

Please note that the description relating to the project layout provided here refers to the "Base Case" project layout and was deemed the best way conceptual forward at the commencement of the impact assessment phase.

However, as mentioned in section 3.4, a number of feasible alternatives were also considered through the impact assessment (refer to sections 7 and 9). A summarised description of the various alternatives (compared to the Base Case project) with respect to each of the above mentioned project components is provided in section 4.12. The optimised layout (i.e. SEIA recommended project layout), is provided in Section 9 below and a detailed project description of this (SEIA optimised) layout provided in the SEMP, attached here as Annexure E.

Figure 9 below provides an overview of the RO process, treatment chemicals, and waste stream associated with the plant. Figure 10 provides a detailed process flow diagram and provides additional detail on the RO internal components and processes, not shown in Figure 9.

Figure 9: RO Project Process Flow Diagram

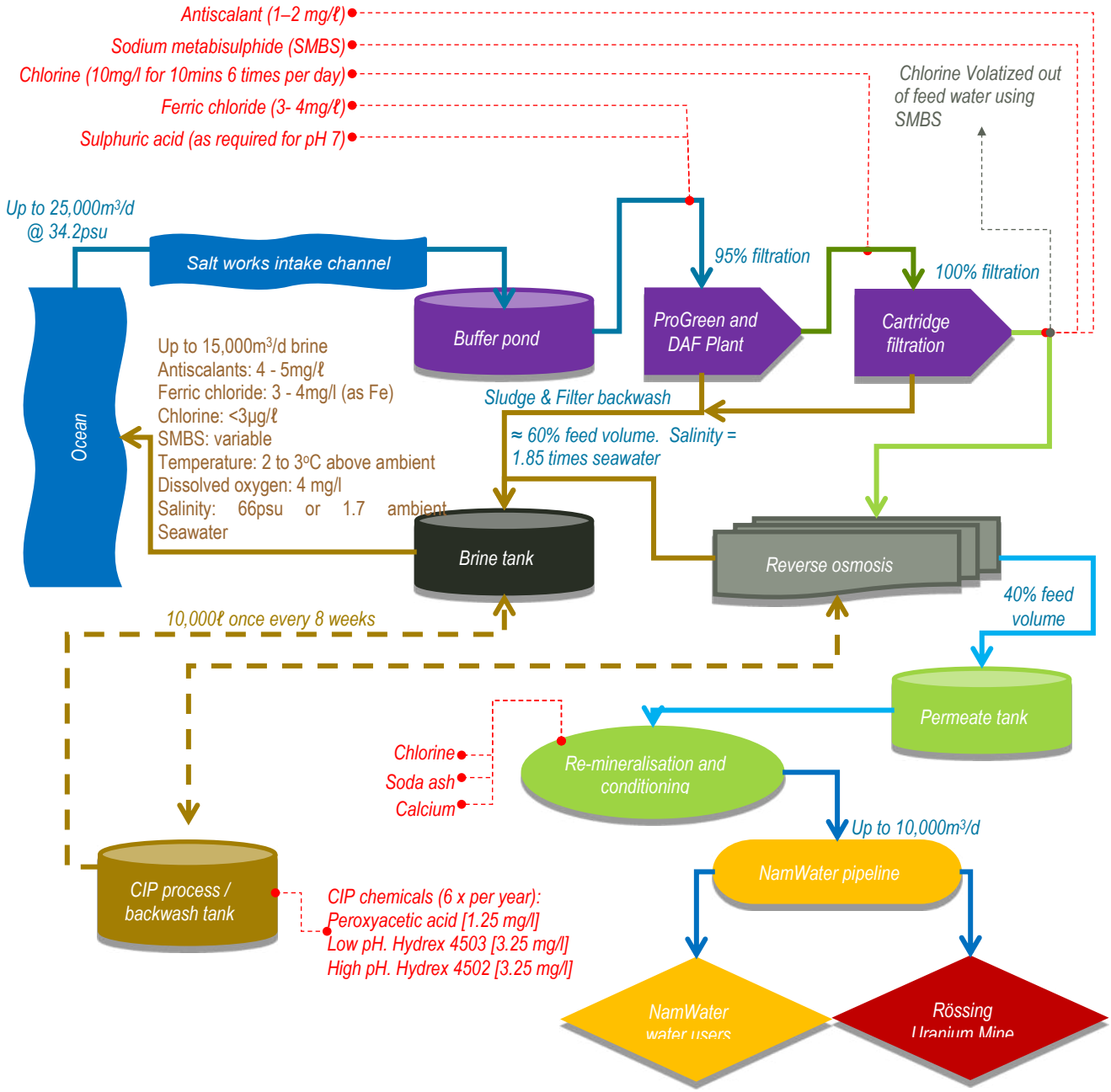
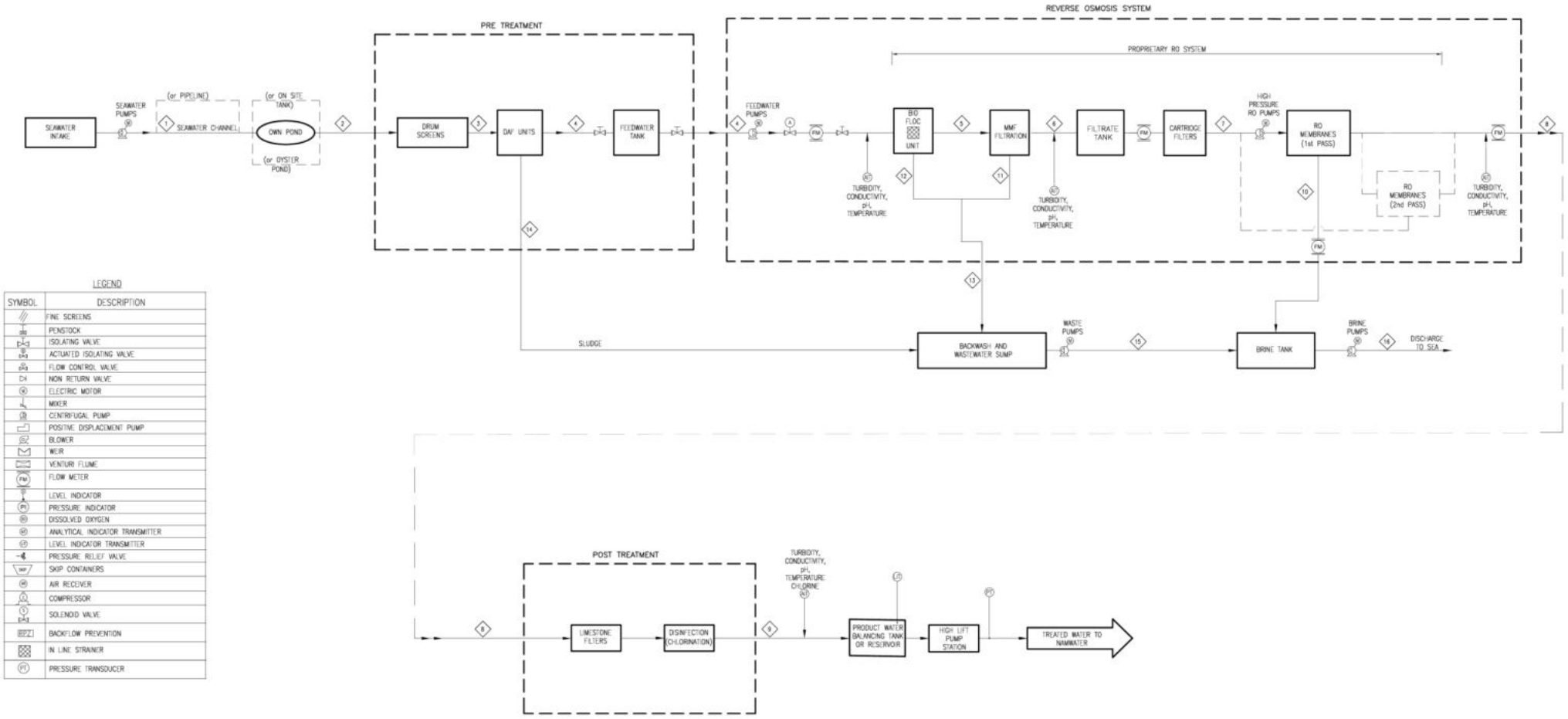


Figure 10: Detailed process flow diagram[12]



LINE NO.		1	2	3	4	5	6	7	8	9	10	11	12
DESCRIPTION		SEAWATER (GROSS)	SEAWATER (NETT)	SCREENED WATER	FEED WATER	PRE TREATED WATER	FILTERED WATER	RO FEED WATER	RO PERMEATE	PRODUCT WATER	BRINE	FILTER BACKWASH	BIOFLOC BACKWASH
FLOW	MAXIMUM (m3/h)	1 220	1 044	1 044	1 044	1 023	1 009	982	417	417	565	27	14
	DESIGN (m3/h)	1 220	1 044	1 044	1 044	1 023	1 009	982	417	417	565	27	14
	HRS/DAY	21.33	24	24	24	24	24	24	24	24	24	24	24
	PEAK DAY (Ml/d)	26.04	25.05	25.05	25.05	24.55	24.23	23.57	10.02	10.02	13.55	0.65	0.33
PIPE	SIZE	5m base W	DN600	DN500	DN500	DN500	DN500	DN500	DN350	DN350	DN400	DN100	DN100
	MATERIAL	Channel	HDPE/GRP	HDPE/GRP	HDPE/GRP	HDPE/GRP	HDPE/GRP	HDPE/GRP	HDPE/GRP	HDPE/GRP	HDPE/GRP	uPVC	uPVC
	EXISTING OR NEW	Existing	New	New	New	New	New	New	New	New	New	New	New
PROPERTIES	FLUID TYPE	Seawater	Seawater	Seawater	Seawater	Seawater	Seawater	Seawater	Demin water	Potable water	Brine	Filter backwash	Bio backwash

LINE NO.		13	14	15	16	17	18	19	20	OTHER	A	B	C
DESCRIPTION		COMBINED BACKWASH	DAF SLUDGE	PRETREAT MENT WASTE	WASTE WATER								
FLOW	MAXIMUM (m3/h)	41	21	62	627								
	DESIGN (m3/h)	41	21	62	627								
	HRS/DAY	24	24	24	24								
	PEAK DAY (Ml/d)	0.98	0.50	1.48	15.04								
PIPE	SIZE	DN100	DN100	DN150	DN400								
	MATERIAL	uPVC	uPVC	uPVC	HDPE/GRP								
	EXISTING OR NEW	New	New	New	New								
PROPERTIES	FLUID TYPE	Backwash	DAF sludge	Wastewater	Brine & waste								

[12] *Source: Royal HaskoningDHV, 26-09-2014, drawing number: CPT_0188_1_104*

Figure 11: Base Case project layout

3.5.1 Seawater intake system

The seawater abstraction system would involve a shallow water direct abstraction system, with relatively simple screens around the pump intakes to prevent the abstraction of marine creatures and flotsam. An abstraction location 160m south of the existing Salt Works jetty has been identified and meets the various technical, financial and environmental requirements. This site is located at a natural shore perpendicular shelf (which provides a good foundation for the intake jetty) that extends some 40m from the 0m mean sea level contour line. The intake screens would be located on the seaward side of the shelf within a depression area. The fixed screen opening has been specified to be 100mm with a maximum intake velocity of 0.15m/sec to minimize impingement/entrainment of marine biota. This area is protected from large waves by submerged shelves on its seaward side. The shelf's level is just above mean sea level, which allows construction of a large portion of the jetty to be less tide dependent, potentially reducing construction downtime (Trade Off Study Report 1: Intake Site Selection, 2014).

A set of pumps and pipes placed on a new jetty would abstract water from the shallow surf zone. The jetty would be similar in concept to that already used by the Swakopmund Salt Works, only upgraded to meet current Rössing HSEQ and engineering standards, and shown here in Figure 12.

Figure 12: Existing seawater abstraction jetty for the Salt Works

Two low-lift, high-volume pumps and parallel 650mm diameter pipelines (one duty and one standby) would abstract up to ~25,000m^3/d of seawater from the ocean and drain into the existing Swakopmund Salt Works seawater canal system and gravitate to the new seawater buffer pond near the RO Plant. The canal extends around the northern and eastern most sides of the Swakopmund Salt Works pond complex. The seawater canal is a gravitational system and seawater would flow approximately 3.1km from the intake to the ponds nearest to the desalination plant. From here the seawater would enter into a new, purpose built seawater buffer pond and would then be abstracted directly and piped a short distance to the desalination plant's pre-treatment facilities.

Using the canal and a new pond system as part of the seawater intake system is expected to have the added benefit of reducing the suspended solids load in the seawater and provide a higher quality and more homogenous (biological, physical and chemical) feed water quality than a direct abstraction from the sea. To achieve a target reduction of approximately 50% in suspended solids concentration, it is estimated that 24 hours of retention time at the peak design flow rate should be provided. Further reductions in suspended solids can be achieved with longer retention times, and

the proposed modification of the existing pond layout can achieve an estimated 42 hours feedwater retention (Trade-Off Study Report 4,7 & 9: Seawater Pipeline vs Seawater Channel, 2014).

The system will also provide operational storage and a buffer against sudden changes in ocean conditions, such as red tide, sulphur eruptions and ocean storms. The limitation of a shallow seawater intake is that it results in potential downtime for the seawater pumps when water levels drop below accessible levels during low tide events. The recommended intake option is therefore based on flows up to 339ℓ/s and downtime of up to 3.5 hours per day. Therefore allowing at least 4 hours of storage, to achieve continuous transfer of seawater to the plant, is considered prudent (Trade-Off Study Report 4,7 & 9: Seawater Pipeline vs Seawater Channel, 2014).

It should be noted that prior to using the canal and pond it will need to be dredged and modified to ensure it is capable of accommodating the maximum daily volumes, whilst continuing to service the needs of the existing Swakopmund Salt Works operations. The upgrading of the channel would involve cleaning out deposited sand and sediments in a 3-5 metre wide, 300mm deep central slot, and trimming and stabilising side slopes where necessary (Trade-Off Study Report 4,7 & 9: Seawater Pipeline vs Seawater Channel, 2014). A final benefit of the canal and pond system is that it may slightly increase the temperature of the feed water which improves the efficiency of the desalination process.

3.5.2 Seawater pre-treatment system

Pre-treatment of the feed water aims to limit RO membrane fouling. An accumulation of one or more foreign substances on the surface of a membrane will result in a loss of rate of flow through the membrane. This results in the need for higher operating pressures to achieve the specified water production which in turn results in an increased energy consumption and associated cost. Membrane fouling generally occurs through one of the following:

- Precipitation of inorganic salts (scaling) due to super-saturation;
- Deposition of silt or other suspended solids;
- Interaction of organics with the membrane; and
- Biological fouling caused by excessive microbial growth.

Seawater abstracted from the buffer pond will pass through a series of fine sieve screens to remove larger particulates and debris still present in the buffer pond. The feed water is then subjected to a bio-flocculation and Dissolved Air Filtration (Dissolved Air Flotation) process to remove finer particulate matter and colloids. In this process, chemical flocculants (ferric chloride at a rate of 3-6mg/ℓ, resulting in a waste discharge concentration of 3-4mg/ℓ (as Fe) in the brine discharge) are added to the feed water and then it is aerated, and air bubbles cause the flocs (a loosely clumped mass of fine particles) to float to the surface where they can be skimmed from the surface. The sludge is then pumped to the brine tank where it mixes with brine before being discharged back to the ocean.

A new bio-flocculation pre-treatment technology, ProGreen™, will form part of the pre-treatment process. This system is a proprietary bio-flocculation pre-treatment step similar to a membrane bio-reactor (MBR) and employs a biological process, similar to those widely employed in existing wastewater treatment plants, to pre-treat the feed water and has the potential to significantly reduce or eliminate the need for standard pre-treatment and Clean-In-Place chemicals. For more information on this technology please view the IDE ProGreen™ promotional video or visit the IDE ProGreen™ webpage.

The feed water may also be conditioned using sulphuric acid which is used to correct the pH and ensures flocculation occurs at an optimised rate. Ferric chloride coagulates optimally at around pH

7.0 and by correcting the pH the optimal dosing rates can be achieved which reduces the overall chemical demand and chemical residue in the discharges.

Chlorine gas may be used to eliminate biological contaminants in the feed water and reduce biological growth in the pipes and pumps of the desalination plant and various holding tanks. The preferred process will not use continuous application of chlorine because the bio-flocculation process (part of the ProGreen™ system) relies on biological action and would be destroyed by a biocide. However, shock doses of chlorine, i.e. 10mg/ℓ for 10mins may be introduced infrequently at certain points for controlling bio-growth (e.g. at media filters, and at a maximum frequency of about 6 times a day or every 4 hours of operation). Prior to entering the RO trains (or module), the water is treated with sodium metabisulphite (SMBS) and, potentially, antiscalants. Chlorine is detrimental to the RO membranes and so the SMBS is used to neutralise any free chlorine before coming into contact with the RO membranes. An antiscalant may also be added to reduce the build-up of deposits inside the RO units or on the membrane itself which could lead to fouling of the membrane and reducing operational efficiencies.

The concentration of chlorine in the brine water discharges is expected to be low and within relevant standards due to the application of SMBS. Chlorine gas would be stored in 1-ton drums within a purpose built storage facility meeting the requirements for hazardous installations (i.e. leak detection systems and alarms, shut-off valves, specialist safety equipment and secondary containment, amongst other requirements).

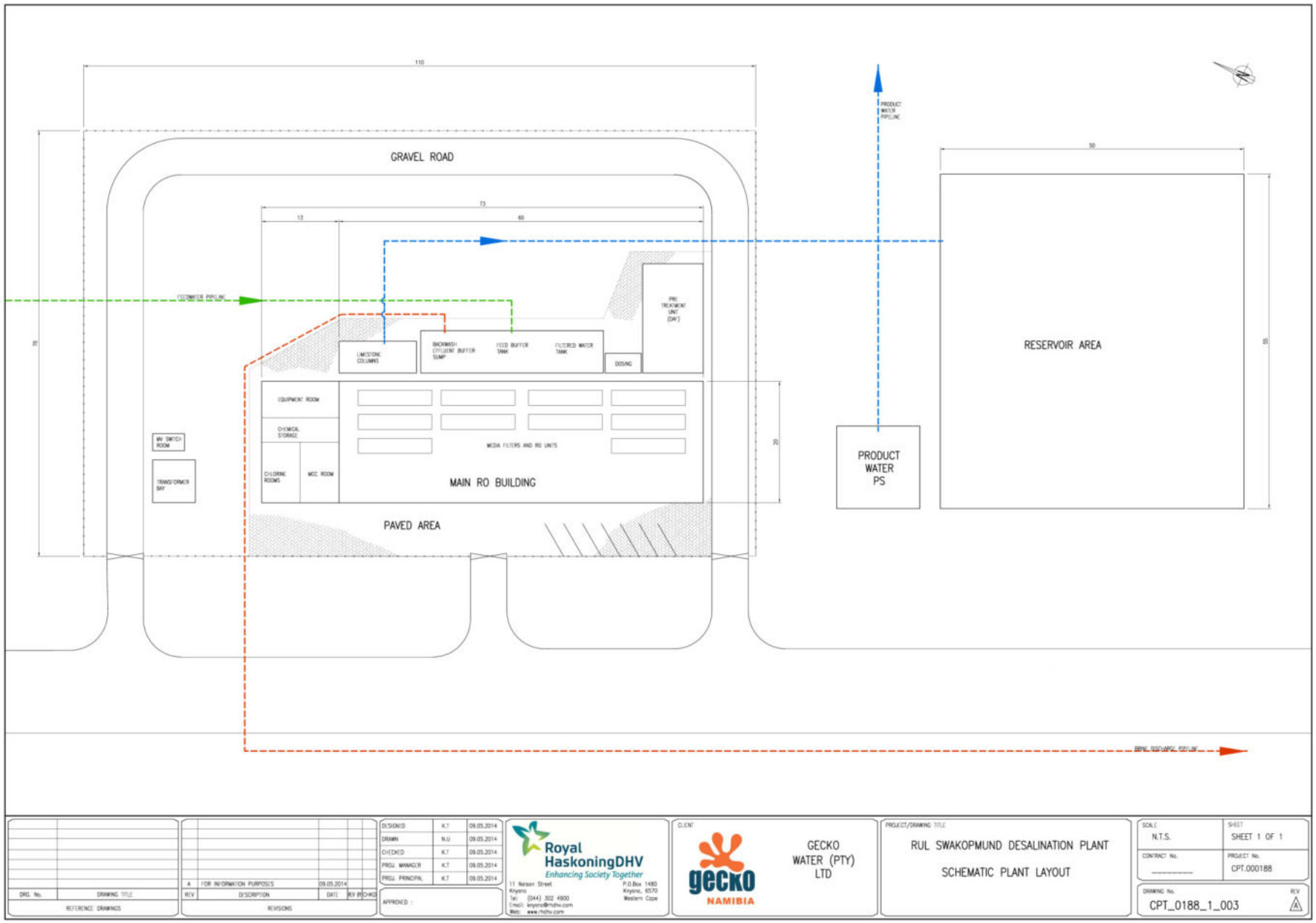
The RO trains are also fitted with disposable cartridge filters upstream of the RO membranes which will filter the feed water to the micro scale just prior to desalting.

3.5.3 Desalination plant

In the Base Case scenario the desalination plant would have been situated on the eastern side of the Swakopmund Salt Works ponds in the center of Site Alternative 1 (as shown in Figure 11). A different location is however recommended as an outcome of the SEIA process (refer to section 10 and the SEMP), avoiding the core Damara Tern breeding area.

The desalination plant complex itself (including the pre-treatment and post-treatment systems and all associated infrastructure) is likely to have a permanent footprint of less than 5ha, all inclusive. This excludes any additional footprint area associated with the upgrading and modification of the canal and new buffer pond. The desalination plant will be approximately 60m by 20m (1,200m^2) by 6m high, while the post treatment and pre-treatment plants, and storage tanks would be located adjacent to the plant building. The equipment room, offices, and chemical storage room would also be housed in a 13m by 20m (260m^2) by 6m high building that is connected, or is immediately adjacent, to the main plant building. A provisional schematic of the RO plant layout is provided in Figure 13.

Figure 13: RO Plant provisional schematic



The desalination plant will represent the most significant of the structures associated with the project. The plant will take the form of a large enclosed structure (to protect the various equipment and processes against the corrosive sea breezes). The plant will house the following, within an enclosed security fenced area with a gate to control access:

- Pre-treatment systems;
- Post-treatment systems;
- A series of RO trains with associated filters, piping, pumps and valves, access ladders gangways, cleaning and maintenance facilities, energy recovery systems, etc.;
- Feedwater, product water, and brine/waste buffer tanks;
- Clean In Place systems, tanks, and associated facilities;
- Water treatment chemical storage areas and dosing equipment;
- Electrical and mechanical control centre;
- Spares and maintenance stores and workshop area
- Offices, ablutions, kitchen, parking, sewerage, communications (possibly overhead telephone lines) and solid waste storage facilities and other amenities; and
- The 6m wide, and approximately 800m long, existing salt and gravel access road intersecting with the C34 is proposed to be upgraded to provide safe access to the proposed plant.

3.5.3.1 Sewage and solid wastes

Permanent ablutions will be established as part of the RO plant complex. Sewage and grey water collected from kitchen sinks and elsewhere in the facility will be collected in conservancy tanks. The conservancy tanks will be pumped out on an as needed basis and the sewage delivered to the existing Swakopmund waste water treatment plant for processing.

The operations phase is not expected to generate significant volumes of waste and will be restricted to mostly domestic waste and chemical containers and packaging. Where possible the chemical storage containers will be returned to the supplier for reuse or disposal. Any residual waste will be collected from rubbish bins around the facility and moved to a central waste storage area and, when required, delivered to an approved landfill site for final disposal.

3.5.3.2 Clean In Place System

Even with good quality feed water, good pre-treatment practices, and the proposed cleaning systems (including the ProGreen™ technology); the RO membranes may experience fouling and may lose efficiency over time. The ProGreen™ technology claims to not require a CIP (Clean in Place) process and uses a patented in-line direct osmosis (DOC) cleaning flushing system using permeate water only, however, since this is the first time this technology is being used in the southern African context, the applicant wishes to keep the option for CIP process in the SEIA application.

To overcome membrane fouling, each RO membrane may be cleaned about once every six to eight weeks (in conventional plants) to ensure operational efficiency is maintained. The cleaning chemicals used for the RO membranes constitute mainly high and low pH solutions prepared by adding caustic soda or acid to product water. Small amounts of surfactant or chelating agent (e.g. citric acid) may also be added to the CIP mix. These solutions are then passed through the RO membranes a number of times, alternating between the high and low pH solutions. Once complete spent CIP solutions released into the brine over a period of 12 hours where they mix with one another (which has a pH neutralising affect), the brine, the sludge, and multimedia filter filtrate, and are discharged into the ocean. The waste from this intermittent process would be fed back into the brine discharge system over a time period, for example up to 12 hours, to achieve suitable dilutions.

The following CIP chemicals will be found in the following estimated concentration in the brine discharge during release:

- Peroxyacetic acid (eg. Hydrex 4203) – approximately 6 x per year [1.25 mg/ℓ]
- Low pH CIP solution (eg. Hydrex 4503) – approximately 6 x per year [3.25 mg/ℓ]
- High pH CIP solution (eg. Hydrex 4502) – approximately 6 x per year [3.25 mg/ℓ]
- Preservative (eg. Hydrex 4301) – approximately 2 x per year [6 mg/ℓ]

Note that the concentrations of the spent CIP chemicals in the brine can be decreased by increasing the time period of release of each batch from the suggested 12 hours to meet any dilution requirements and avoid toxicological effects on marine biota (if required).

3.5.4 Electrical supply system

The desalination plant and associated facilities will be powered via a new 11kV underground cable running from the existing Tamarisk substation, located 6km away along the C34 on the outskirts of Swakopmund. The cable will run alongside the C34 towards Henties Bay in an existing electrical servitude. The cable will cross the C34 and follow the new product water pipeline route in a westerly direction to the new transformer and substation building adjacent the RO plant complex. The power line route is shown in Figure 14.

Figure 14: 11kV power supply route

The Tamarisk substation is currently able to provide more than 3MW of electricity, which is adequate for the purposes of the desalination plant. The desalination plant is expected to consume approximately of 1.5MW at full production.

The new seawater intake system will be fitted with two low-lift high-volume pumps that will pump the seawater to the buffer ponds. The proposed pumps are two 45kW that typically operate in a duty/ standby configuration. The electrical equipment will however be designed to allow for simultaneous operation of the two pumps (Trade-Off Study Report 11: Electrical Supply To The Seawater Intake, 2014). A new ~3km long 11kV underground cable (a 25mm², 3 core, 6.35/11kV PILC cable) would run from the plant, alongside the existing Salt Works' canal to provide electrical supply to the seawater intake. The cable would be placed within a dedicated trench of 600mm (w) x 1000mm (d). Cable markers to indicate the position of the new MV cable will be installed at each turning point along the route. The cable will terminate in a new small building close to the new intake jetty, similar to the existing Swakopmund Salt Works intake mini-substation building located near the intake jetty.

During plant operation, the plant will mainly only be run during standard and off-peak times, as a means to improve the cost efficiency and avoid overloading of the regional electrical supply at these critical times.

3.5.5 Product water system and pipeline

Product water produced by the desalination process will be pumped via a new 400mm diameter pipeline (steel, ductile iron and GRP piping are being considered) to intersect with the existing 700mm diameter NamWater pipeline that runs alongside the C34, approximately 850m to the east of the site.

Figure 15: Product water pipeline route

Water will need to be inserted into the NamWater pipeline at a pressure that is compatible with the system. Prior to insertion, the product water will be pH corrected, re-mineralised (using soda ash and calcium) and chlorinated to the relevant potable water standards and will form part of the NamWater supply. Rössing Uranium will then be supplied with the equivalent volume of treated water by NamWater from the Swakopmund Base Reservoirs.

3.5.6 Effluent treatment and disposal system

Brine is the saltwater concentrate remaining on the upstream side of the RO membrane, after the separation process. The brine stream contains higher concentrations of salts and other impurities than are found in the intake water (since a portion of pure water has been removed), and which must be disposed of in an acceptable way. Due to the chemical makeup of the brine water, essentially a concentrate of the source water, the brine is commonly returned to the ocean where it is rapidly diluted, returning to ambient concentration over time. It is calculated that the brine needs to be diluted 18 times in order to meet the guideline standards at the edge of the mixing zone[13]. The will be achieved by discharging the brine (174 ℓ/s at 6.14m/s) under pressure through a 190mm diameter single port diffuser aimed horizontally and toward the oncoming surf. The velocity of the brine release causes rapid mixing with the receiving water and then the surf and ocean currents augment further mixing and dilution. The brine will also contain traces of the water treatment chemicals that were introduced during the pre-treatment phase. This is typically regarded as one of the more significant environmental issues associated with desalination plants.

The desalination plant's peak product water capacity will be 10,000m^3/d. This will require a seawater feed of approximately 25,000m^3/d, with 15,000m^3/d of brine to be discharged back to the sea. This brine flow translates to 174ℓ/s. The brine (which is approximately 1.85 times the saline concentration of seawater after the reverse osmosis stage) would be mixed with the filter backwash, CIP backwash (every 6 – 8 weeks) and sludge from the Dissolved Air Flotation and / or ProGreen™ pre-treatment processes before being returned to the ocean, resulting in a final estimated brine concentration of about 1.70 times that of ambient seawater salinity.

In the Base Case scenario the brine would have been discharged as follows:

Discharged brine would have been piped 2.25km from the desalination plant via a buried 400mm diameter HDPE pipe. The pipe would follow the existing road network through the Swakopmund Salt Works to the existing Swakopmund Salt Works bitterns discharge area, as shown in Figure 11Figure 11. The final, approximately, 40m of pipeline on the seaward side of the high-water mark would have been encased in concrete and is located a natural rock outcrop situated 230m south of the present bitterns discharge. The pipeline with a single diffuser would terminate just seaward a rock outcrop in a natural deep spot below low water level. The diffuser would be located approximately 1.6m below the mean sea level or 0.6m below the lowest astronomical tide waterline (Trade-Off Study Report 3: Brine Discharge Methods, 2014). The purpose of the diffuser port would be to concentrate the flow into a high velocity jet in order to attain good initial mixing of the effluent with the ambient receiving waters and preventing it from sinking and accumulating in seabed depressions. Brine is denser than the ambient receiving waters and would sink to the seabed under gravitational forces, not taking into account any external turbulent mixing mechanisms (e.g. waves and currents). Subsequently, the

[13] For each litre of effluent brine discharged from the RO plant, 17.7 litres of seawater must be mixed with the brine in order to dilute the brine to within 1.8g/l of the ambient receiving water salinity. According to the South African Marine Water Quality Guidelines (Department of Water Affairs and Forestry, 1995), the target value for salinity should range between 33.0g/l and 36.0 g/l. For this study the value of 36g/l is assumed. Thus, the difference in concentration between the published guidelines (36g/l) and the ambient salinity (34.2g/l) is 1.8g/l. As such, it is assumed that a dilution of the effluent brine in the near field to a level of 1.8 g/l above ambient is acceptable.

heavy brine would typically be transported away from the source by bottom gravity currents due to a sloping bathymetry.

As a result of the SEIA findings, the recommended brine discharge location is however moved to a position north of the intake system (still in the surf zone), avoiding the core Damara Tern breeding area. Details of this optimised SEIA brine discharge location is provided in sections 4.12 and 10 of this report as well as the SEMP.

Discharging the brine into the surf zone relies on the turbulence and mixing caused by energetic wave conditions, the long shore and cross shore currents and tidal exchanges which will aid with the expected rapid mixing, dilution and distribution of the brine discharges. This has been confirmed through the near-field dilution modelling undertaken as part of the SEIA process. The dilution modelling found that the results of the intermediate mixing indicate a general influence area of approximately 30m to 40m (mixing zone) from the effluent discharge point under varying water levels and coastal processes. The surf zone discharge is considered to be a viable option for brine effluent disposal within the parameters detailed in the dilution modelling study.

The discharge pipe should be fitted with a suitable diffuser system at its seaward end to ensure rapid and efficient dilution of the effluent with the receiving water, thereby reducing plume footprints near the seabed and minimising impacts on marine ecology. The design of the diffuser and discharge rates would meet the requirements of the South African Marine Water Quality Guidelines and the Operational Policy for the Disposal of Land-derived Water containing Waste to the Marine Environment insofar as they are applicable to this type of installation.

Table 6 lists the expected composition of the brine effluent and the typical cleaning reagents and pre-treatment chemicals to be discharged should standard conventional RO technology be implemented. The brine effluent at the maximum plant capacity is anticipated to have a temperature of between 2–4° Celsius above the ambient average seawater temperature, a salinity of 66 g/ℓ or psu (based on the maximum feed-water salinity of 34.2 g/ℓ or psu), a density of 1,049 kg/m^3, and with a maximum effluent flow of ~10,000m^3/day.

Table 6: Estimated brine physiochemical profile

Description	Units	Quantity
Feed-water Intake (average)	m^3/d	23,600
Feed-water Intake (instantaneous)	m^3/d	26,100
Average brine discharge (average)	m^3/d	13,550
Average brine discharge (instantaneous)	m^3/d	15,000
Average Co-discharge (Pre-treatment and Media Filtration Backwash – intermittent and discharged over 24 h)	m^3/d	1,338 (in 24 h)
Instantaneous Co-discharge (Pre-treatment and Media Filtration Backwash – intermittent and discharged over 24 h)	m^3/d	1,483 (in 24 h)
Co-discharge (CIP rinse water for conventional RO system – 6 x per year only and assumed to be discharged over 12 h)	m^3/d	202 (in 12 h)
Discharge velocity	m/s	~6
Salinity	mg/ℓ psu	66,000 66
Change in temperature	°C	2 - 4
pH		7.3 – 8.2
Suspended Solids (average)	mg/ℓ	8 - 12
Phosphonate antiscalant for conventional RO system	mg/ℓ	4 - 5
Chlorine – for conventional RO system	mg/ℓ	0.002
Sodium bisulphate (SMBS)	mg/ℓ	3 – 3.5
Spent CIP solution in waste flow (6 x per year and blended in over 12 hours)[14] • Peroxyacetic acid • Low pH cleaner • High pH cleaner	mg/ℓ 0.003 0.01 0.01	
Preservative (sodium metabisulfite) in waste flow (twice a year)	mg/ℓ	6.0
Coagulant: Ferric Chloride ($FeCl_3$) will precipitate into Ferric Hydroxide, which will be removed as a solid.	mg/ℓ	3-4
Discharges from preferred option (IDE Progreen™ system) • CIP rinse water Co-discharge • Phosphonate antiscalant • Chlorine • Sodium bisulphate (SMBS)	n/a	n/a

With reference to the Table 6 above, it is intended that the project will implement a bio-flocculation pre-treatment technology (i.e. ProGreen™ technology) as described in section 3.5.2. This means, in a best case scenario, that there would be no CIP solution; Phosphonate antiscalant; Chlorine; or SMBS contained in the effluent stream (brine). In the worst case scenario, this system will run in parallel or as an additional pre-stage to the more traditional dissolved air floatation flocculation system, and would potentially serve to reduce the volume of pre-treatment DAF chemicals. Given the uncertainties around the integration, use and ultimate success of the technology under local conditions, a pre-cautionary approach has been adopted and the SEIA assessment (refer to section 7.9 of this report) is based on a DAF only treatment process, which is the worst case for this plant (i.e. if ProGreen™ works the marine impacts will be less than those presented in the SEIA). The information provided in the foregoing Table is for a DAF pre-treatment based RO plant and is not adjusted for ProGreen™.

[14] Note: in the event that the ProGreen™ technology does not fulfill the operational requirements and a CIP process is required, the CIP chemicals will be co-discharged in the concentrate for a period of 12 hours every 6 to 8 weeks (Note that these concentrations can be reduced by slowing the bleed rate of the CIP chemicals into the brine, which should be determined following a whole effluent toxicity test).

4 SCREENING OF PROJECT OPTIONS

This chapter provides an overview of the options considered in the scoping phase and the feasible alternatives assessed in the impact assessment phase and provides reasons why some options were retained and some were screened out.

At the scoping phase, the project was at a very early conceptual design stage and the proponent's technical consultants, with input from the Social and Environmental Team, were investigating a variety of options for each of the project components.

A summary of the alternatives that were considered during the conceptual design stage were presented in the Scoping Report, together with the advantages and disadvantages associated with the various options.

The project description provided in Section 3 is referred to as the Base Case project. The Base Case project refers to the conceptual project as envisaged at the completion of the pre-feasibility stage and augmented by a number of trade-off studies which are described in the section below (taking the various options described in the Scoping phase into consideration).

What follows is a description of all the options that were considered in the trade off studies and reasons why some were screened out due to technical, financial, operations and maintenance, legal and regulatory or Health, Safety, Environment and Community (HSEC) limitations, rendering these options either unfeasible or bearing no additional benefit or variation to a preferred option.

Only feasible design alternatives have been carried forward into the SEIA phase for detailed assessment.

The project's technical team, with input from the SEIA team, undertook the following trade-off studies and comparatively assessed a number of options, as shown hereunder in brackets:

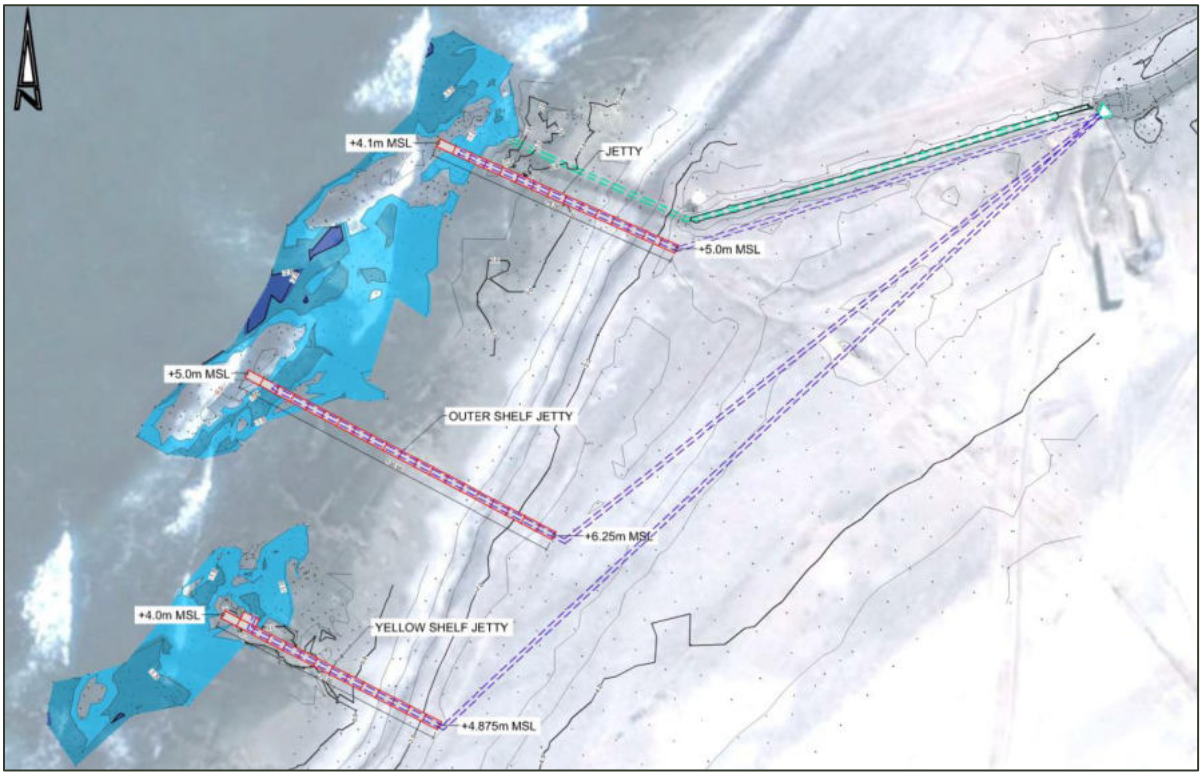
- Trade-off No. 1 – Seawater Intake Location (3 options considered);
- Trade-off No. 2 – Brine Outfall Location (5 options considered);
- Trade-off No. 3 – Brine Disposal Method (4 options considered);
- Trade-off No. 4 – Seawater Channel vs Pipeline (3 options considered);
- Trade-off No. 5 – Plant Location (3 options considered);
- Trade-off No. 6 – Plant Size vs Energy Efficiency (3 options considered);
- Trade-off No. 7 – Seawater Storage Pond Capacity (4 options considered);
- Trade-off No. 8 – Plant Size vs Product Water Storage (3 options considered);
- Trade-off No. 9 – Direct Seawater Feed vs Seawater Pond (12 option were considered);
- Trade-off No. 10 - Pro-Green technology vs conventional RO (2 options were considered); and
- Trade-off No. 11 – Electrical Supply to Seawater Intake (2 options considered).

4.1 TRADE OFF STUDY 1 ~ SEAWATER INTAKE LOCATION[15]

Three alternative intake sites were identified and assessed (preferred in bold text):

- Site 1: At the existing jetty – directly south of the existing Salt Works intake jetty;
- Site 2: Outer shelf – approximately 100 m south; and
- Site 3: Yellow shelf – approximately 160 m south.

Figure 16: Intake location options



The aim of the trade-off study is to establish the merits and feasibility of the three intake locations and comparatively weight them against each other. A suitable concept design was developed for each site. Overall, a similar design philosophy was applied to ensure that a comparative assessment between sites could be made.

The local and site specific marine conditions, i.e. waves, water levels, currents, sand transport and marine growth were assessed. This formed the baseline for assessing the sites from a technical, financial, operation and maintenance and health and safety / environmental compliance perspective. The highest weighting was given to the technical aspects (60%), with financial second (25%). The sites were fairly homogenous in physiological character and therefor the other assessment criteria were seen as less of a differentiator and were therefore assigned a lower weighting.

4.1.1 Site 1: Adjacent the Salt Work's jetty

Although Site 1 has a good rating in terms of financial considerations, it does not satisfy the identified list of technical requirements adequately. It falls short with regards to supply of water, has limited through flow of water and does not provide sufficient space and water depth to incorporate both the Salt work's and the plant's intakes.

[15] *(Trade Off Study Report 1: Intake Site Selection, 2014)*

4.1.2 Site 2: Outer shelf

Site 2 is technically superior to the other alternatives. It has good supply of water, through flow past the intakes, limited risk of clogging and can be expanded if required and has a sufficient water depth. The technical advantages are, however, set against the higher construction cost and required constructability efforts. The intake screen location is further from land and exposed to higher wave conditions. It also requires more construction in the wet, which will increase construction difficulty and downtime, and hence cost. An expanded wet works programme is also likely to impact more significantly on marine ecology.

4.1.3 Site 3: Yellow shelf

Site 3 is located at a natural shore perpendicular shelf that extends some 40m from the 0m mean sea level line on shore. The shelf's level is just above mean sea level, which allows most construction work to be done with very limited tidal wet work and associated downtime which makes this more cost effective than Site 2. Site 3 is technically less superior to Site 2 and three main risk items have been identified, i.e. clogging of the screen due to excessive kelp particles, elevated levels of suspended sand if the upper beach accretes over time, and a potential limited supply of water. These risks could be adequately addressed by extending the jetty at Site 3 some 15m forward. This will marginally increase the construction costs.

4.1.4 Recommendation

Site 3, Yellow shelf, is recommended as the preferred site due to its cost effectiveness (overall 79.1% rating). Site 2, Outer shelf, is the second preferred site (overall rating 77.1%). The only disadvantage of Site 2 is the cost.

4.2 TRADE OFF STUDY 2 ~ BRINE OUTFALL LOCATIONS[16]

Five brine outfall locations were identified and assessed (preferred in bold text):

- Outfall 1: Northern Outfall (using the derelict Salt Works intake site);
- Outfall 2: 170m North of Salt Works intake jetty;
- Outfall 3: 920m South of Salt Works intake jetty;
- Outfall 4: Salt Works Bitterns discharge; and
- Outfall 5: Southern Outfall (230m south of Salt Works Bitterns Discharge).

[16] *(Trade-Off Study Report 2: Brine Outfall Locations , 2014)*

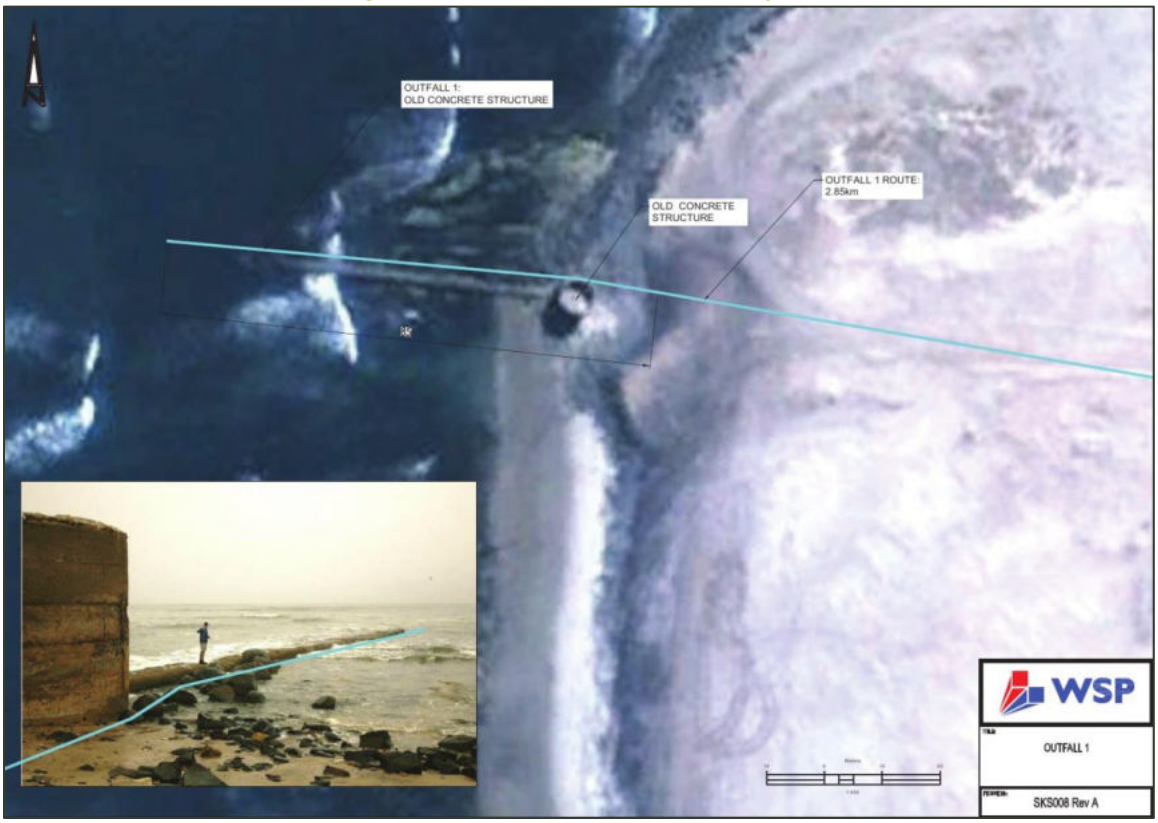
Figure 17: Brine Outfall Location Options

The proposed desalination plant will produce an instantaneous flow of 15,000m^3/day of brine continuously. Trade-off study 3 concludes that a surf zone discharge (below the spring low water mark) is the recommended method for brine disposal. Five potential brine outfall locations were identified, as introduced above and described in greater detail below.

4.2.1 Outfall 1

Outfall 1 is located 900m north of the existing seawater intake, at the Salt work's old concrete intake structure. This structure consists of a concrete tower and concrete encased pipe extending approximately 60m into the sea. It is envisaged that the concrete encased brine pipeline would be installed directly next to and using the existing concrete intake pipeline structure extending into the surf zone, as portrayed in Figure 18.

Figure 18: Brine Outfall 1 Concept Layout



Technically, the site is reasonably well exposed to waves, but is partly sheltered behind the small headland on the edge of a small shallow rocky embayment. Wave breaking action is comparatively gentle (spilling breakers). Due to this, the waves approach the location at a slightly oblique angle. These obliquely approaching waves cause a strong longshore current, which would facilitate the dispersion of brine.

Outfall location 1 is situated on a rocky shoreline exposed to reasonably strong longshore currents, and thus unlikely to be buried by sand deposit. This site has a distinct advantage above others when considering construction effort, health and safety, visual impact and impact on shoreline dynamics. This advantage is due to the utilisation of the existing concrete structure. Out of a constructability point of view the existing structure will provide easy access to most of the pipeline length, create a solid wave protection barrier, and act as formwork on one side and a sound foundation to connect other formwork to. Due to this the construction is expected to be relatively easy and quick as compared with the other locations. A brine discharge at this location would result in a minimal additional visual impact because of the presence of the existing structure and its similarity to the proposed design. The reduced wet works programme and brownfield nature of the site also makes it attractive from the environmental perspective.

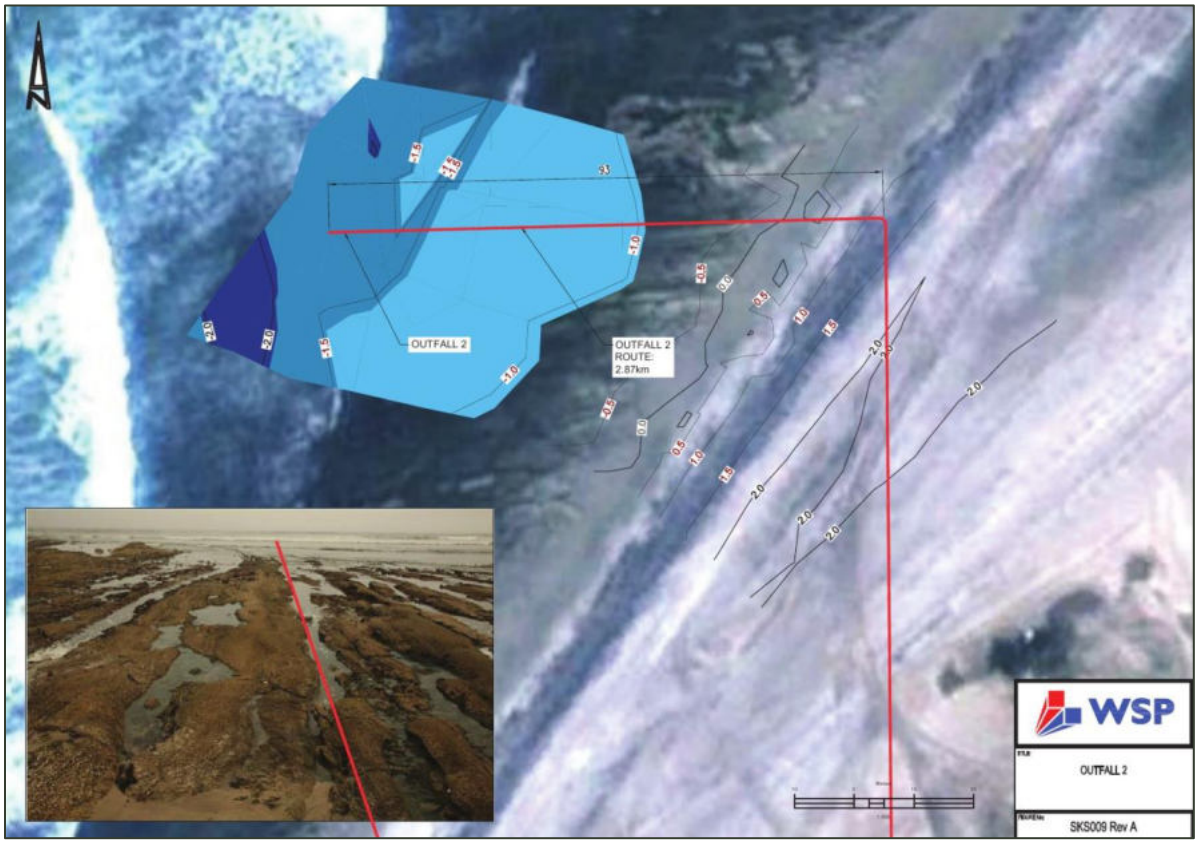
Financially, this location is relatively expensive due to the longer land-side and marine pipelines. However, the construction of the land-side pipeline will be easier, as it is not located on the salt work's berms and service roads. The life cycle cost is therefore also higher when compared to the other sites. It should be noted though if the RO plant were to move further north from the Base Case layout, this option would become increasingly attractive.

Considering the operation and maintenance of Outfall 1, the partly sheltered location provides opportunity. Being less exposed to wave attack, maintenance of the brine diffuser is expected to be easier and will provide a greater frequency and duration of weather widows in which to undertake the work.

4.2.2 Outfall 2

Outfall 2 is situated 170m along the beach, north of the existing Salt Work's seawater intake. It is located at a gently sloping relatively even natural rock shelf. The rock shelf has no prominent features which can be utilised as protection of the outfall structure, as depicted in Figure 19.

Figure 19: Brine Outfall 2 Concept Layout



Technically, Outfall 2 is similar to Outfall 1. Waves tend to approach the location at an oblique angle due to its position behind the headland. Wave breaking expected at the termination point of the pipeline. The oblique approach and breaking along the headland creates a strong longshore current, which is favourable for the brine dispersion. Rip currents are not expected at this location. The strong longshore currents are evident by the bare rock shelf without any sand. The seaward end (diffuser) of the pipeline stands very little risk of being buried by sand.

Constructability of the marine works at Outfall 2 is expected relatively uncomplicated due to the good accessibility onto the flat rock shelf and relatively calm conditions. The laying of the pipeline over land may encounter some difficulty when having to trench through the berms and service roads between the salt pans. Option 2 has both the longest section of marine pipeline, as well as the longest section of land pipeline (using the RO plant Base Case location), and therefore the construction period is expected to be the longest and most expensive of the outfall options.

Due to the featureless rock shelf at Outfall 2, the visual impact of the outfall structure will be the higher as when compared to outfalls 3 and 5. Due to its high visual prominence and location on the rocky shore, it is expected that it will have a lower acceptance by the community.

The outfall will introduce a new solid structure perpendicular to the coastline. It is therefore expected to have a significant effect on shoreline dynamics. Because of the obstruction, sediment, normally transported north along the coast by the fast flowing longshore current, is expected to accumulate along the concrete encased pipeline structure. This may lead to sand accretion over the presently rocky shelf, altering the natural marine and shoreline habitat structures.

4.2.3 Outfall 3

Outfall 3 is located in a small bay area 920m south of the existing Salt Works seawater intake, on the outer edge of a natural headland. A large rock ridge extends into the surf zone at the south of the small bay. For this option it was envisaged to place the outfall pipeline just north of the rock ridge inside the small bay. This ridge will serve to conceal and protect the outfall pipeline, as well as to provide access for construction or maintenance, as depicted in Figure 20.

Figure 20: Brine Outfall 3 Concept Layout

Due to the location of Outfall 3 on the headland it has an excellent exposure to waves and related currents. Rip currents could form at the location due to the shore parallel approaching waves. Longshore currents are also expected to increase in speed around the headland. This location, however, has the potential of becoming buried by sand as it is positioned at the end of a sandy coastal stretch and in a sandy bay, which could cover the outfall.

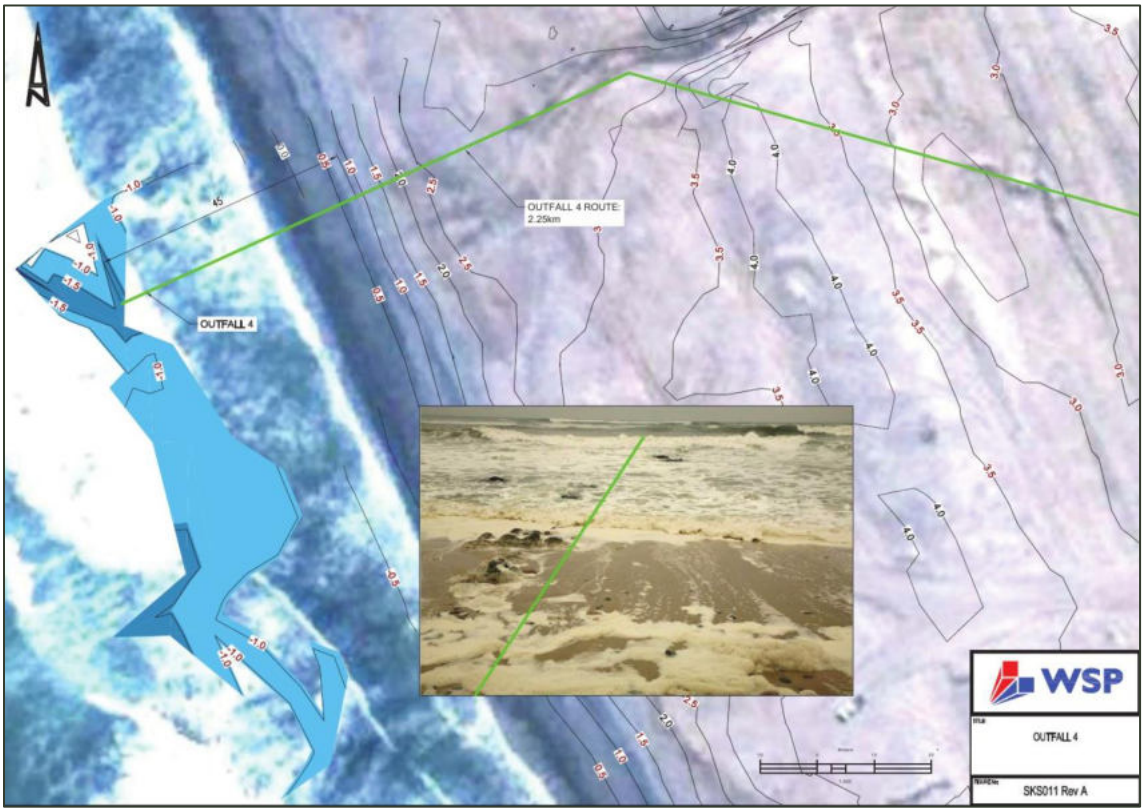
Constructability of the civil works (landward of the high water mark) has similar difficulty to that of Outfall 2, where the pipeline must be trenched on the berms and service roads between the evaporation ponds. Constructability of the marine works is made easier by the access via the rock ridge, but the exposure to waves and currents at the site increases the difficulty thereof. Due to this the construction time and impact on the implementation program is expected to be comparatively more significant than for outfall locations 1 and 2. Financially, this outfall option is a median as when compared with the other outfall options.

The exposure to waves and currents makes this a difficult option to maintain both in terms of the skills required and available good weather days to perform the work. The rocky ridge at the outfall location will be used as a secure foundation for the outfall structure and offer operational protection. The visual impact will be low as the structure can be incorporated as part of the ridge and hidden from view. The outfall structure will not protrude seaward of the rock ridge, thus having a minimal impact on any sediment transport past the headland. Some accretion and erosion of sediment on the beach during a storm might be experienced due to a protruding pipeline section on the upper rock beach.

4.2.4 Outfall 4

Outfall 4 is located at the present Salt Works bitterns discharge site. At this location the beach is predominantly sandy with a pebble/cobble berm between the low-water and high-water mark. Irregular rock outcrops are present in the surf zone, as depicted in Figure 21 .

Figure 21: Brine Outfall 4 Concept Layout



Waves approach the shore parallel to the coastline. Waves tend to initially break on offshore reefs creating irregular patterns and currents. An inner breaker zone close to shore is characterised by powerful waves breaking close to the shoreline. This can be seen in the steep beach slope at the location as well as the presence of coarser sediments and the cobble berm along the shore. Due to the powerful shore parallel breaks, strong rip currents are expected around this section of the site. High turbulence associated with these currents will create an environment desirable for the dilution and dispersion of brine.

The beach at this location is sandy. Blockage and potential burial of the diffuser could therefore readily occur. The outfall structure would cause some disruption of the coastal dynamics, but this would be localised and of limited magnitude.

Constructability is rated as most involved in comparison to the other alternatives, considering the powerful wave breaking close to shore, the steep beach slope, the dynamic sand base at the location and the lack of plant access for marine construction. Other locations all have some form of rock shelf or ridge from which plant or people can operate during placement. This is expected to lengthen the construction time and has a comparatively larger impact on the implementation program. An extended wet works programme is also not favoured from a construction phase environmental impact perspective.

Financially, this outfall is rated relatively high considering its short land-side pipeline and the second shortest marine construction works of the options considered. The short pipeline length reduces operating costs since it utilises less energy for pumping. The land section of the pipeline will cross the salt work's berms and service roads, which is not ideal.

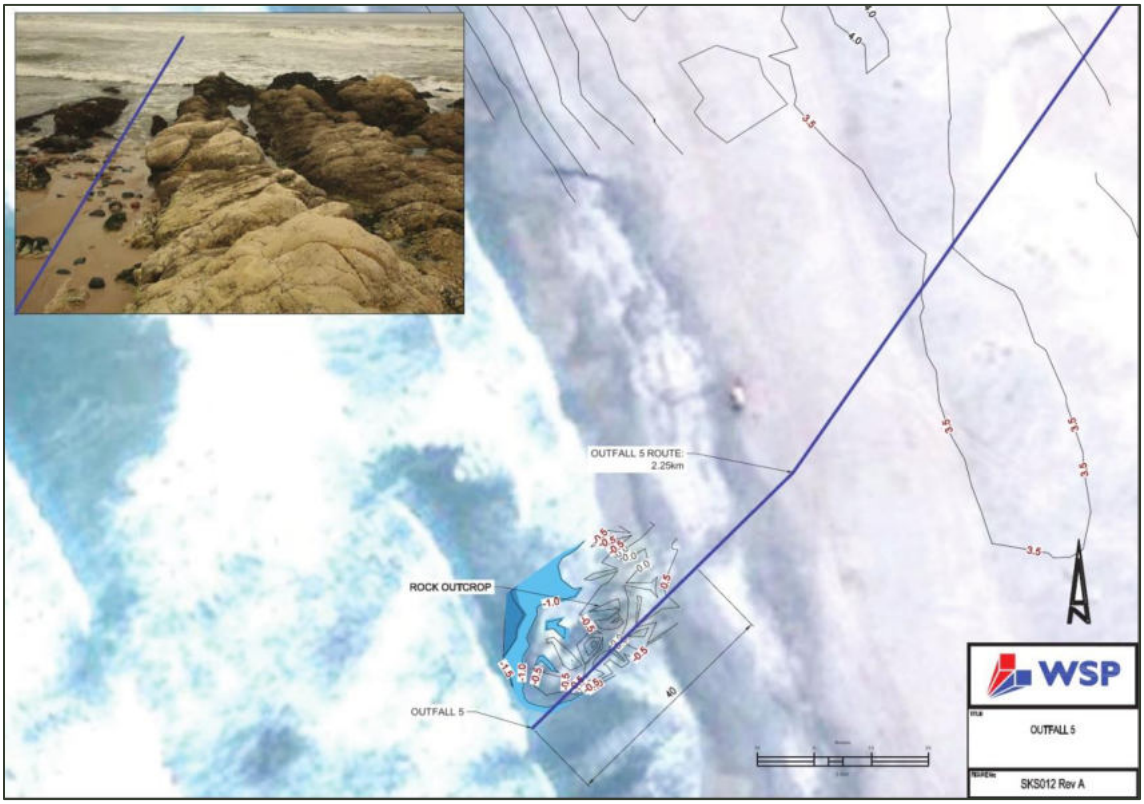
Skills needed for maintenance of the brine diffuser is higher as a result of the wave exposure at the location. Similarly, less "good weather days" will exist to facilitate maintenance works. As marine maintenance is however expected to be low, this is not considered a significant limitation.

This outfall, similar to Outfall 2, will not be hidden by a natural rock structure and will therefore have a more prominent visual impact compared to other locations. This location rates lower from a health and safety perspective due to the high exposure to waves which will make construction and maintenance more hazardous. The pipeline route tracks away from the main bird assemblage areas in the salt pans and therefore construction related disturbances of salt pan birdlife are expected to be lower than those for outfall options 1, 2, and 3. However the pipeline will need to traverse the Damara Tern breeding site, which is considered environmentally sensitive and disturbance would be unfavourable (Although construction maybe scheduled outside of the October – April breeding period).

4.2.5 Outfall 5

Outfall 5 is situated 230m to the south of the present Salt Works bitterns discharge site and located at a rock outcrop within the shallow surf zone. The outfall structure is envisaged to follow a route just to the south of the rock outcrop along a shallow sand filled channel. The structure would be buried in this channel thus be flanked by rock on both sides. The beach slope is steep at this location and local conditions created a sufficiently deep area close to shore, just seaward of the rock outcrop. The outfall would terminate at this point. Outfall 5 is depicted in Figure 22.

Figure 22: Brine Outfall 5 Concept Layout



Wave exposure at the location is similar to that at Outfall 4. Similar current conditions will also prevail. Land based pipeline lengths to Outfalls 4 and 5 are similar and follow similar routes (over the salt work's berms and service roads, which is not ideal). Outfall 5, however, has a shorter marine pipeline section due to the steep beach and a deep area just seaward of the rock outcrop. The rock outcrop will facilitate construction in terms of protection as well as acting as natural shuttering for the placement of concrete encasement. The construction of this outfall is therefore considered more feasible than that of Outfall 4 despite otherwise similar conditions.

The Cost of constructing this outfall will be less than that of Outfall 4 since the marine works would be reduced and there is an availability of better founding conditions. Life cycle and operational costs would be comparable to that of Outfall 4 due to the similar pipeline lengths and absorbed power required for the pumping operation. As Outfall 5 is the least expensive alternative, a higher return on equity is expected and therefore a higher rating is given.

The operation and maintenance of Outfall 5 is expected to be similar to Outfall 4. As with the other locations an experienced diver would be required to perform maintenance operations on the brine diffuser if and when required.

Similar to Outfall 3, the visual impact of this outfall will be minimised by the incorporation of the outfall structure within the natural rock outcrop at the location. Visually, this location may offer a more acceptable solution to the community. The same attribute of the location also reduces its potential impact on shoreline dynamics. Similar to Outfall option 4, the pipeline route tracks away from the main salt pan bird assemblage areas and therefore construction related disturbances of birdlife are expected to be reduced over those for outfall options 1, 2, and 3. However the pipeline will need to traverse the Damara Tern breeding site, which is considered environmentally sensitive and disturbance would be unfavourable (Although construction maybe scheduled outside of the October – April breeding period).

4.2.6 Recommendation

Trade off study assessment results:

- All attributes of Outfall 1 taken into consideration, it is rated at 71/100, as the second best brine outfall location.
- All attributes of Outfall 2 taken into consideration it is rated at 56/100, as the least favorable brine outfall location. Its biggest drawbacks are the length and visual related impacts, as well as the potential to cause localised accretion of sand along the currently rocky shore. The brine pipeline route also tracks near to the main bird assemblage areas and guano platforms (as when compared to options 1, 4 and 5), which my increase disruption of local birdlife during the construction period.
- All attributes of Outfall 3 taken into consideration it is rated at 64/100 and is a good median option for a brine outfall location.
- All attributes of Outfall 4 taken into consideration it is rated at 63/100 and is the second least preferred location.
- All attributes of Outfall 5 taken into consideration it is rated at 72/100 as the most suitable of the identified brine outfall locations.

With the location of the RO Plant at Site 1, Outfall 5, located just south of present Swakopmund Salt work's bitterns outfall, is recommended as the preferred brine outfall location and is included in as part of the Base Case project layout. Outfall 5 is recommended due to its exposure to waves and currents which are favourable for brine dispersion. Comparatively, Outfall 5 also has the shortest pipeline route and lower related pumping energy requirements. The main drawback of Outfall 5 is that the land pipeline needs to cross the Salt Works earth berms and pan service roads which may cause issues during construction. The pipeline would also traverse the core Damara Tern Breeding site which is considered environmentally sensitive and disturbance would be unfavourable.

Outfall 1 also has comparable energy available for dispersion and could therefor also be recommended as feasible alternative brine outfall location. For Outfall 1, the land pipeline is longer (for RO plant sites 1 and 3), but the pipeline does not need to cross the salt work's berms and service roads or the identified core Damara Term breeding area. The bulk of the marine pipeline can be tied onto the existing concrete berm of the old Salt Works seawater intake which makes this a brown fields development form the environmental perspective. Outfall 1 has been retained as a feasible

alternative for assessment in the SEIA phase because not only is it a suitable location from varying perspectives, but if the RO plant were to move further north than the location described in the Base Case then the pipeline length shortens and Outfall 1 becomes more attractive.

4.3 TRADE OFF STUDY 3 ~ BRINE DISCHARGE METHOD

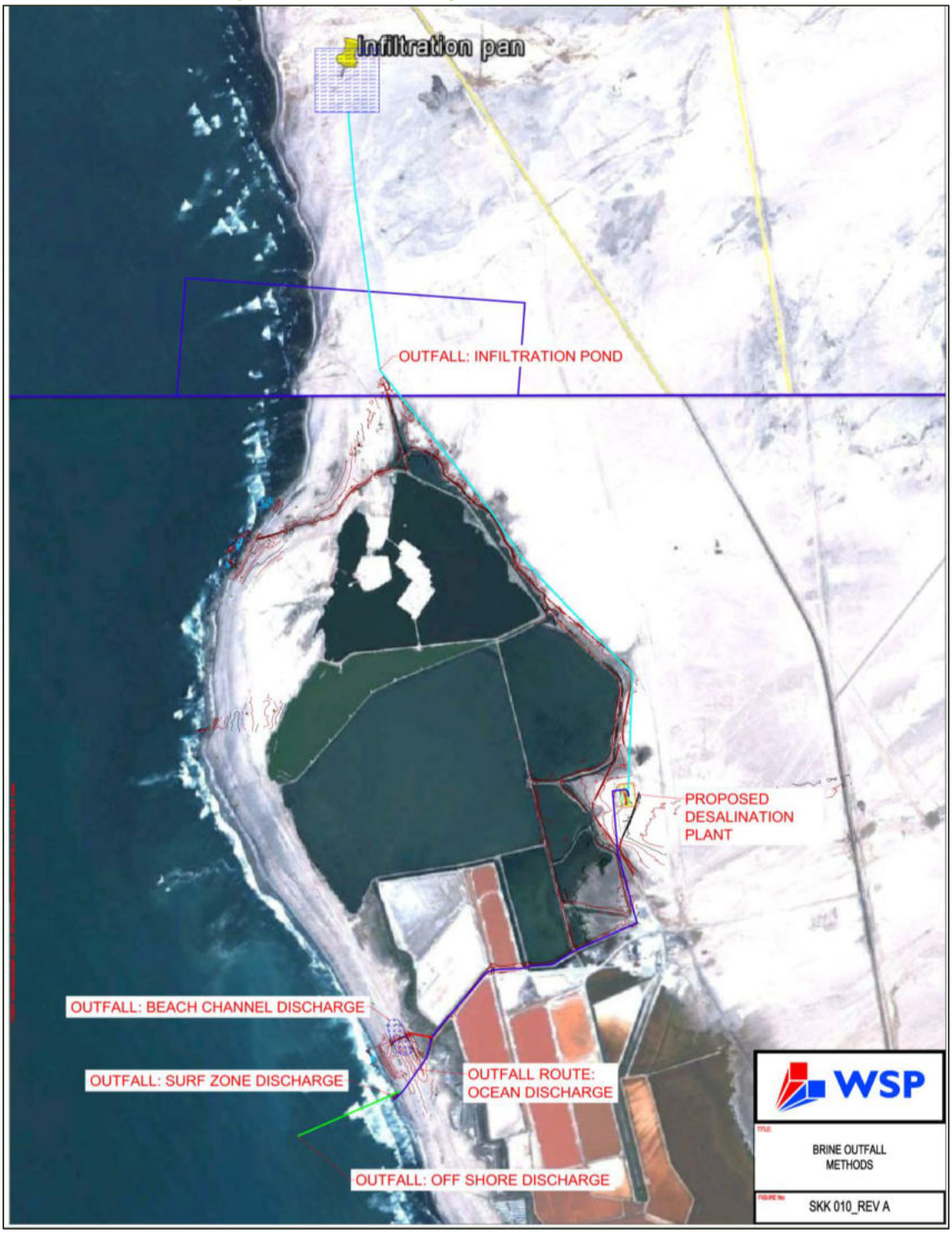
Four brine discharge methods were identified and assessed (preferred in bold text):

- Discharge method 1: Surf zone discharge;
- Discharge method 2: Offshore discharge;
- Discharge method 3: Infiltration Pond; and
- Discharge method 4: Beach channel.

The hyper saline waste stream is not a toxic waste stream (as would be the case for raw municipal waste water), but rather a concentrated component of the extracted sea water. It is important to note that a build-up of hyper saline brine within an area, where no dispersion of the brine can take place, can alter the ambient salinity if allowed to accumulate (not mix / diffuse). This accumulation could be toxic to seafloor communities where the effluent brine collects. As a result, careful analysis of the disposal method of the brine stream along with the receiving ambient environment need to be undertaken in order to assess the impact of the effluent stream on the ambient environment.

Various disposal methods for waste water disposal exist. This trade-off study identified and assessed four methods for brine disposal as already mentioned and briefly described in the subsection to follow. Figure 23 shows the brine discharge methodologies expressed in spatial concept.

Figure 23: Brine discharge methods in spatial concept



4.3.1 Discharge method 1 ~ Surf zone discharge

The surf zone discharge consists of a discharge pipe extending into the surf zone terminating with a diffuser that aids in diffusing the brine effluent at the discharge point. The diffuser will typically be located in approximately -1.6m to mean sea level water depth (0.6m below the Lowest Astronomical Tide (LAT) waterline). For this study, the pipe will extend approximately between 50m and 80m into the surf zone from the high water mark.

From the technical perspective the surf zone discharge consists of only a short section of pipe in surf zone. This section can be easily constructed at low water tidal levels and would consist of a concrete encased pipe extending to approximately -1.6m of water to mean sea level (submerged during low tide conditions). The outfall pipe will terminate in an engineered diffuser. The natural shape of the nearshore rocks/gully can be used to lay the pipe instead of a deep excavation through this zone as

with the deep discharge method. For this type of installation, a low level of marine contracting experience would be necessary.

Financially, the surfzone discharge has a relatively low construction cost due to a low level of marine contractor experience and non-specialised plant necessary to install the structure. Nearshore bathymetry measurements indicate that adequate and accessible locations for the surf zone discharge exist quite close to the shore, thus pipe lengths are limited.

From an operations and maintenance perspective, the surf zone discharge consists of a buried pipeline up to the surf zone from which point the pipe is encased in concrete as it surfaces. The surf zone outfall pipe and diffuser will be designed for minimal maintenance. Maintenance and assessment of the diffuser is carried out in shallow water depths at low tide and is thus easily accessible, however, this is still dependent on the prevailing sea conditions. The materials are robust and designed to operate in the surf zone.

Security of supply is a function of the design of the pipe and its materials; i.e. the chance of equipment failure is deemed very low. During maintenance, the surf zone outfall pipeline can easily be cleaned via pigging.

From a health, safety, environmental and community perspective the assumed location and relatively low flows make a strong case for surf zone discharge due to the fact that the energetic coast line at the site (wave breaking and longshore currents) aids in the advection/diffusion process. Typically for surf zone brine discharges at energetic coastlines, the mix-zone boundary (i.e. area where salinity is increased more than 2PSU above ambient ocean salinity) is in the order of 20 to 50m from the source. Therefore this option would be able to comply with the required environmental standards even though this option is not necessarily considered to be environmental best practise for brine discharge. Much larger desalination plants across the world (e.g. Israel and Spain) discharge their brine into the surf zone, however, it is normally co-discharged (already diluted) with other effluent streams.

Also taken into account is the relatively high discharge velocity (between 4m/s and 6m/s) of the brine jet situated within “shallow” water. Although the effluent is non-toxic to humans, the jet produced by the discharge might affect activities in its immediate proximity. The jet velocity, however, reduces significantly within a small distance and then minimal effect will be noted.

4.3.2 Discharge method 2 ~ Offshore discharge

The offshore discharge consists of a discharge pipe extending beyond the surf zone into deeper water, terminating with a diffuser structure that aids in diffusing the brine effluent at the discharge point. The diffuser will typically be located in water depths of approximately -5m to mean sea level to -10m to mean sea level. For this study, the pipe will extend approximately 500m to 700m offshore as measured from the high water mark.

From the technical perspective the offshore discharge is difficult to construct and places a heavy demand on labour, specialised construction plant and resources. In addition, substantial temporary works (e.g. jetty extending through the surf zone) will be necessary to excavate a trench through the surfzone for the outfall pipeline. This will involve blasting and piling.

An offshore pipeline will have a significant influence on the project implementation programme, as construction is of a much larger scale than the other alternatives and in addition will be significantly more weather dependent. Construction could typically be between 10 to 14 months.

However, the offshore discharge is a fit for purpose solution and conforms to best international practise standards. Required dilutions are typically met within 10 to 15m from the discharge point.

Financially, the construction of the offshore discharge pipeline requires specialist marine labour and plant along with a large amount of temporary works (e.g. jetty). This type of construction is capital intensive in terms of labour and temporary works rather than material costs.

From an operations and maintenance perspective, specialist marine expertise would be necessary for inspection and maintenance of the offshore pipeline and diffuser. Specialist equipment and expertise would include specialist divers and equipment that will be able to assist in underwater maintenance at water depths up to 10m.

Security of supply is a function of the design of the pipe and its materials; i.e. the chance of equipment failure is deemed very low. However, repairing or cleaning the outfall line will require specialist skills.

From a health and safety, environmental and community impacts and compliance perspective, the offshore outfall complies with best international practise as this method is implemented around the world for waste water discharges into the ocean. It is important to note that there is merit to discharging toxic waste (e.g. municipal effluent) into deeper offshore waters where it cannot be a health risk to humans. However, desalination brine effluent is not toxic to humans and thus does not have inherent health risks when discharged closer to shore.

On the other hand, the construction effort, albeit temporary, would impact on the marine and coastal habitats. Blasting of hard rock through the surf zone, the impact of a large precast/assembly construction yard onshore, piling of a temporary jetty, etc. during the construction period (10 to 14 months) would result in significant environmental impacts during the construction phase and the pipeline running across the seafloor could serve as an migratory obstacle to the benthic communities in the immediate area.

4.3.3 Discharge method 3 ~ Infiltration Pond

Infiltration ponds are large unlined dam structures what rely on the underlying terrestrial hydraulic conductivity properties that will allow water to percolate away through its bottom and side walls over time and eventually re-enter the ocean. The effectiveness of infiltration facilities depend heavily on the performance of the near surface soil characteristics, sub-surface geology and pond geometry.

From a technical perspective, an infiltration pond will most likely be located to the north of the site. An infiltration pond is easy to construct and requires only a limited amount of construction plant (e.g. a bulldozer or excavator) and construction personnel. The pond is easily accessible and can be constructed, maintained and/or extended.

However, the design of an infiltration pond is problematic because of the large uncertainties associated with the predictions of the long and short infiltration rates. Thus, detailed geological investigations are needed in order assess the potential infiltration rates at the site. It is possible that across the whole site, an infiltration pond might not meet the infiltration rates required as per the brine effluent flows. As such, this option might have an inherent fatal flaw.

From a financial perspective the infiltration pond is relatively easy to construct and can be done with regular construction plant that is normally readily available. However, the pond would probably need to be very large in order to be effective as an infiltration pond. An estimated size for the pond (based on Kuiseb River soil properties data) is approximately 9ha with an average depth of 2m (depending on the soil properties this could increase to more than the estimated 9ha). As such, the bulk of the costs are contained in the amount of earth moving that needs to be done. In addition, the pond would most probably be extended or moved during the life of mine.

From an operations and maintenance perspective the monitoring of the infiltration pond is very important as flooding can occur if the infiltration rate decreases (due to fouling, siltation, etc.).

Access and maintenance of the pond is simple and can be easily done by site personnel and readily available construction equipment. It is important to note that the pond can, from the onset be very large in footprint size. In addition, it has the ability to grow in size depending on the hydraulic performance of the pond over the life of the mine. Thus, the scope of the maintenance has the potential to increase.

From a health and safety, environmental and community impacts and compliance perspective, the assumed location of the infiltration pond may render this option environmentally acceptable as there is no chance of contamination of any aquifers. In addition, saline ponds are already in existence and could, eventually, augment Salt Works ponds. On the other hand, the large plan size of the proposed pond (approx. 9ha) will increase the project footprint within the sensitive coastal environment and might impact on the nesting areas of some birds (i.e. Damara Tern) and other terrestrial species. The visual impact will also increase, although an evaporation pond would be consistent with the existing salt pans in the areas. This option may also expose wading, filter-feeding birdlife to water treatment chemicals contained in the brine, the long term health effects of which are difficult to predict and, on a precautionary basis, is therefore not recommended.

4.3.4 Discharge method 4 ~ Beach channel

The beach channel is an alternative that consists of a natural excavated beach channel (not formalised in terms of a permanent structure) longitudinally along the beach near the high water mark. The brine is retained in the channel for a short while. Some of the brine will seep into the loose beach sand while the remainder will overflow the channel and flow down the beach slope towards the water line and surf zone. During high tide, waves from the surfzone will mix with the brine and to a certain extent dilute the brine in the channel and “flush” the channel with sea water.

From a technical perspective, a beach channel is easy and quick to construct and requires only a limited amount of construction plant (e.g. a bulldozer or excavator) and construction personnel. The channel is easily accessible and can be constructed, maintained, and/or extended with ease. However, this option is not a fit for purpose solution and does not comply with international best practise or standards.

From a financial perspective the beach channel is easy to construct and has easy access; however, due to the location and nature of the channel, constant adjustments, expansions, etc. are needed to maintain the working mechanism of the channel. The beach channel has a small capital cost in shaping and constructing the channel but would require the same capital amount to be spent multiple times a year due to the constant attention and maintenance required.

From an operations and maintenance perspective, the beach channel has easy access and can be easily maintained. There is no permanently installed infrastructure (ignoring the open outfall pipe) that needs to be maintained apart from shaping the beach channel. Conditional assessments can be easily performed and remedy made with a fast turnaround time. As discussed above, this will however be required regularly.

From a health and safety, environmental and community impacts and compliance perspective, this option would most probably have the largest environmental impact as brine would seep into the beach at the high water mark, as well as overflow the channel sides and form a constant discharge down the beach slope to the surf. The method will thus impede on recreational use of the sandy beach area at the discharge location. Overflow from the channel will affect the sandy shoreline dynamics of the site. There would be very little control over the dilution of the brine and ocean conditions may arise where brine accumulates in the high biodiversity nearshore zone. This option is also the ‘least engineered’ option and thus very little control can be exercised over the environmental potential impact this option can have and is this not supported.

4.3.5 Recommendation

Trade off study assessment results and overview:

- Discharge method 1 ~ Surf zone discharge is rated as 76/100
  - Best brine disposal solution for the life of mine and magnitude of flow.
  - Acceptable brine discharge dilutions can be achieved through engineering design in conjunction with the wave energy assisting in the further dilution and advection of the already dispersed brine.
  - Lowest installation capital cost.
  - Accessible and relatively easy maintenance.

- Discharge method 2 ~ Beach channel is rated as 66/100
  - Easy to construct and maintain.
  - Least expensive solution.
  - Not environmentally and socially acceptable.
  - Will need constant maintenance and monitoring.

- Discharge method 3 ~ Infiltration Pond is rated as 63/100
  - Relatively cheap option to construct although not the least expensive. However, the location of the pond has an effect on cost but dependent on the in-situ geological properties.
  - Relatively easy construction and maintenance.
  - Depends heavily on geology and drainage potential of the soil – could be a fatal flaw.
  - Could be a very large pond (approximately 9ha) depending on hydraulic properties of the geology.
  - Large footprint, affecting potential nesting areas of birds.
  - Not common industry practice for disposal of brine.
  - May expose waders and filter-feeding birdlife to chemical co-discharges.

- Discharge method 4 ~ Offshore discharge is rated as 42/100
  - Most expensive solution. In fact, the high cost could render the project unfeasible.
  - Best international practice solution.
  - Significant short term environmental impacts during construction (estimated to be in excess of 10 months).
  - Acceptable dilution of effluent brine can be achieved through engineering design.

As a result, discharge method 1, namely the **surf zone discharge** is recommended as the most suitable and cost effective method to dispose of the brine effluent. It was also further decided that onshore discharge options carried to great an environmental risk and the offshore discharge would render the project unfeasible and so none of the other options was carried forward and assessed as part of the SEIA.

4.4 TRADE OFF STUDIES 4, 7 AND 9 ~ SEAWATER DELIVERY SYSTEMS[17]

- For trade off study 4, three seawater conveyance options were identified and assessed, as follows (preferred in bold text):
  - **Supply Option 1 ~ Salt Works Channel;**
  - Supply Option 2 ~ Pipeline and Channel; and
  - Supply Option 3 ~ Dedicated Pipeline.

- For trade off study 7, four seawater storage options were identified and assed, as follows (preferred in bold text):
  - Storage Option A ~ No storage;
  - Storage Option B ~ Oyster pond;
  - **Storage Option C ~ Own pond; and**
  - Storage Option D ~ On-site tank.

- For trade off study 9, twelve option combinations taken from trade off studies 4 and 7 were assessed, as follows (preferred in bold text):
  - Option 1A ~ Salt Works channel / No storage;
  - Option 1B ~ Salt Works channel / Oyster pond;
  - **Option 1C ~ Salt Works channel / Own pond;**
  - Option 1D ~ Salt Works channel / On-site tank;
  - Option 2A ~ Pipeline and Channel / No storage;
  - Option 2B ~ Pipeline and Channel / Oyster pond;
  - Option 2C ~ Pipeline and Channel / Own pond;
  - Option 2D ~ Pipeline and Channel / On-site tank;
  - Option 3A ~ Dedicated Pipeline / No storage;
  - Option 3B ~ Dedicated Pipeline / Oyster pond;
  - Option 3C ~ Dedicated Pipeline / Own Storage; and
  - Option 3D ~ Dedicated Pipeline / On-site tank.

There are two main alternatives to convey seawater from the intake system to the plant. The first is by gravity flow, using the existing Salt Works seawater channel, and the second is by pumping the seawater in a new, dedicated pipeline. Linked to this issue, is whether or not to store seawater (to provide a supply buffer), how much to store, and whether to make use of the existing Salt Works ponds, create a new dedicated pond or install seawater storage capacity (concrete holding tank) at the RO plant. The issues were originally assigned as the subject of 3 different Trade off studies, namely:

- Trade off study 4 ~ Seawater Channel vs Pipeline;
- Trade off study 7 ~ Optimum Seawater Storage Capacity; and
- Trade off study 9 ~ Seawater Direct to Plant vs Seawater Pond.

However, these options are interdependent, where one affects the other, and could not be dealt with in isolation. Therefore, these trade-off studies have been married into a single trade-off study looking at the seawater delivery system holistically. This study evaluated the conveyance options and storage options, and then as combined seawater delivery solutions and comparatively assessed

[17] *Modified from (Trade-Off Study Report 4,7 & 9: Seawater Pipeline vs Seawater Channel, 2014)*

these. The evaluation takes into account the key components that are employed to convey and store seawater (and feedwater) up to the plant inlet. The components taken into account are as follows:

- Seawater intake pumps;
- Seawater channel upgrade;
- Seawater pipeline;
- Feed water storage tank at plant;
- Feed water storage ponds (earthworks and erosion protection);
- Feed water storage ponds inlets and culverts;
- Feed water pumps and sumps; and
- Feed water pipeline to plant.

4.4.1 Trade off study 4 ~ Seawater Channel vs Pipeline

The alternatives identified to deliver seawater from the sea intake to the plant are:

4.4.1.1 Supply Option 1 ~ Salt Works Channel

This option would involve abstracting seawater from the Yellow Shelf intake location and then:

- Piping it to the start of the existing Salt Works seawater channel and allow the seawater to gravitate 3.1km, around the salt pans to the RO Plant site (as is currently done for the Salt Works pans, refer to Figure 24); and
- Pump the seawater from the channel and into RO plant pre-treatment systems.

Figure 24: Salt Works Seawater Intake Channel

Seawater is pumped from the sea intake to the start of the existing seawater channel. The channel falls at a minimal slope to feed into the Salt Works pond system. As a conveyance option, the existing seawater channel can transfer the required volumes required by the RO Plant.

The advantages and disadvantages of this option area summarised as follows:

Table 7: Salt Works channel advantages and disadvantages

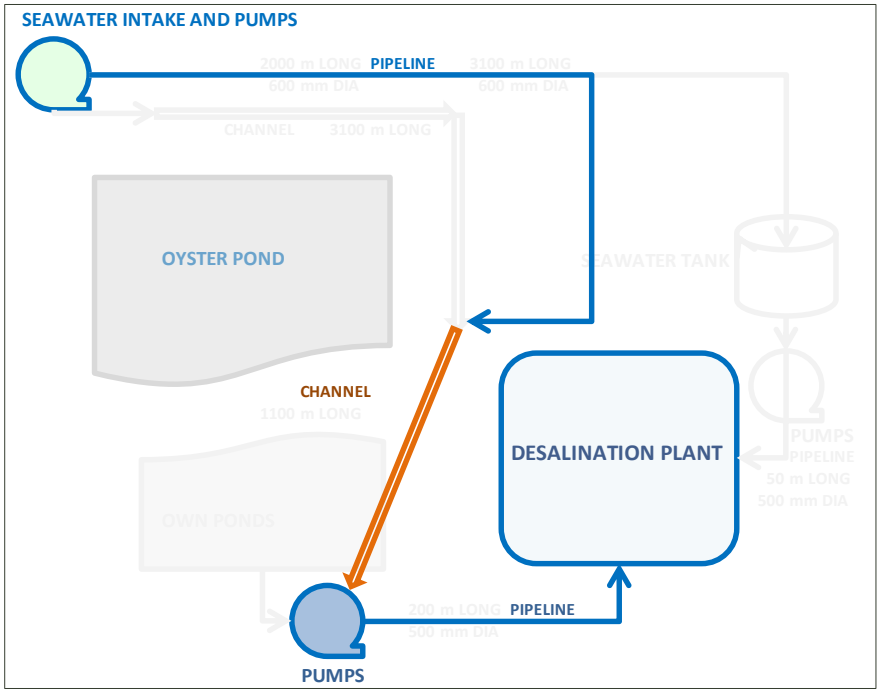
Advantages:	Disadvantages:
• Existing and proven method; • Water quality benefit (e.g. buffer to harmful algal blooms/red tides, temperature etc.); • Sufficient capacity with cleaning out and minor upgrading; • Low impact during construction; • Low capex cost; • No need to use biocides to control biological growth; and • Reduced project footprint.	• Flow control and measurement inputs required; • Shared facility with Salt Works; • Evaporation and infiltration losses decrease electrical efficiency; • Probable pollution (birds, animals, waste spills from Salt Works or Oyster activities); • Difficult operation to clean out channel for initial capacity (possibly manual work); and • Channel maintenance (removal of sediment).

4.4.1.2 Supply Option 2 ~ Pipeline and Channel

This option would involve abstracting seawater from the Yellow Shelf intake location and then following:

- Pump into a new pipeline 2.0km to existing channel downstream of Oyster Pond inlet;
- Gravitate in the existing seawater channel 1.1km; and
- Pump from channel to plant.

Figure 25: Schematic layout of the combined pipeline and channel option



This is a combination option that makes use of a new pipeline and the existing seawater channel. Seawater is pumped in a new pipeline from the sea intake to a point past the Oyster pond inlet on the seawater channel. The channel then conveys the water onwards to the plant.

The advantages and disadvantages of this option area summarised as follows:

Table 8: Pipeline and channel advantages and disadvantages

Advantages:	Disadvantages:
• Bypasses the section of seawater channel that is in constant use by the Salt Works; • Reduces flow control and measurement inputs; • Medium impact during construction; and • Medium capex cost.	• Partially shared facility with Salt Works; • Some evaporation and infiltration losses; • Possible pollution of intake water (birds, animals, waste spills from Salt Works or Oyster activities); and • Biocides would be required in the pipeline to control biological growth.

4.4.1.3 Supply Option 3 ~ Dedicated Pipeline

This option would involve abstracting seawater from the Yellow Shelf intake location and then following:

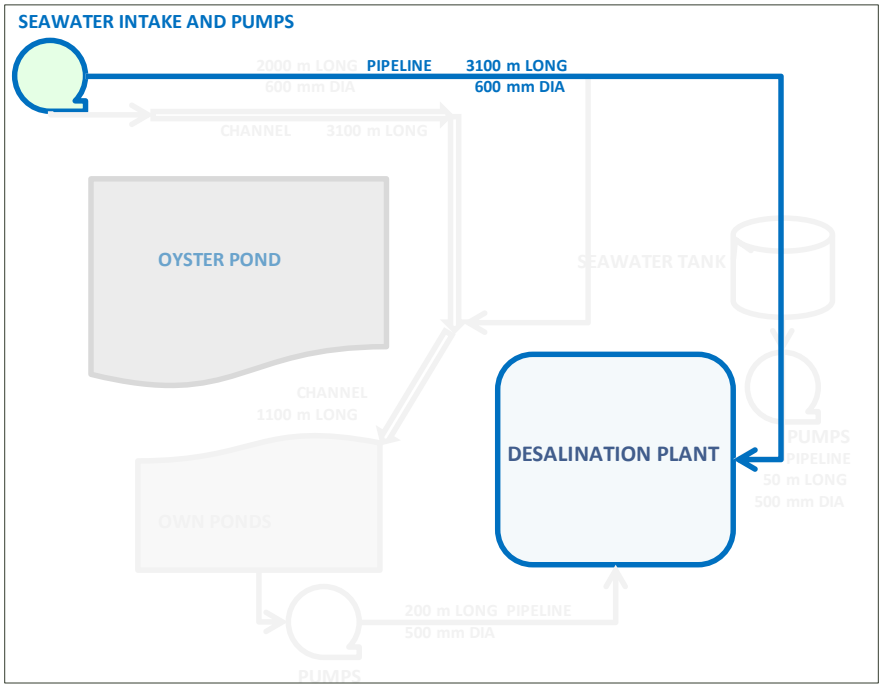
- Pump seawater into a new, dedicated pipeline 3.1km long, directly to the plant (or storage at/near the plant).

The advantages and disadvantages of this option area summarised as follows:

Table 9: Dedicated pipeline advantages and disadvantages

Advantages:	Disadvantages:
• Full control over flow and management of raw water; • Independence from Salt Works operations; • Minimise losses to evaporation and infiltration; • Minimise pollution; and • Only one pumping installation (when combined with the no storage option).	• No water quality buffer effect; • High impact during construction; • High capex cost; and • Biocides (i.e. Chlorine) would be needed to minimise biological growth in the pipeline.

Figure 26: Option 3 - schematic of pipeline only



4.4.2 Trade-off study 7 ~ Storage options

The option to store seawater in a storage tank or pond system presents the same set of storage options to each of the above delivery/conveyance systems.

The options for providing storage and ponds have been identified, and are listed below, together with their respective advantages and disadvantages. Note that the advantages and disadvantages listed here, only apply to the provision of storage, not to the whole delivery system (i.e. conveyance methods).

The pond options have a moderating ("buffer") effect on the highly variable quality and temperature of the incoming seawater, which can be affected by variations in ocean and climatic conditions. The no storage option achieves no (or much less) moderating effect, and will not protect water quality when there are high sediment loads, cold currents, or algal blooms etc.

Other direct water quality benefits of the ponds are sedimentation and exposure to UV at shallow depths which serves to curb biological growth, reducing the need for biocide chemicals. Data collection is ongoing and these trends in improving water quality from sea, to channel, to pond will be closely monitored, and considered in the final design decisions.

4.4.2.1 Storage Option A ~ No storage

This option would involve the following:

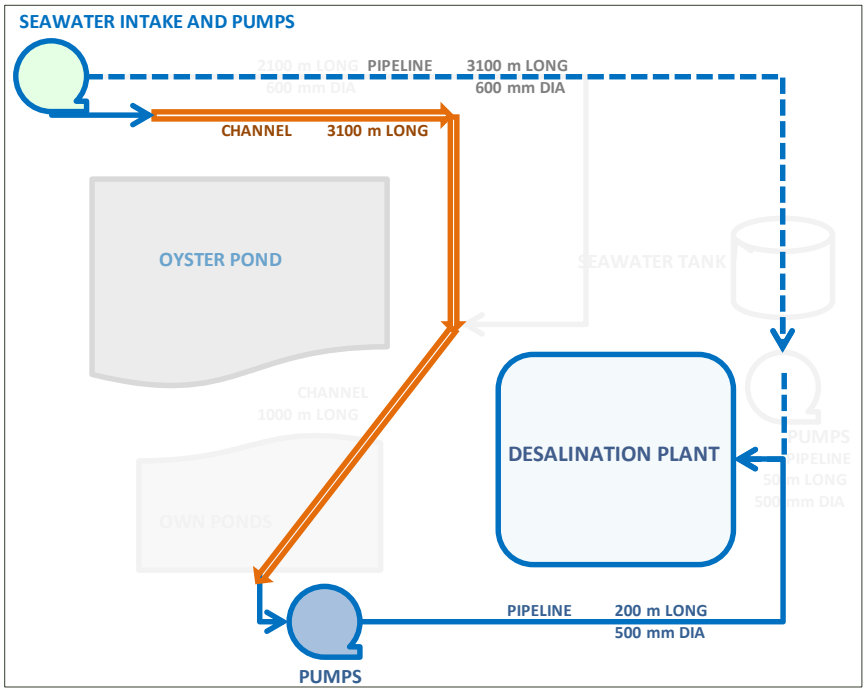
- No storage provision; and
- Deliver seawater directly to pre-treatment plant inlet.

The advantages and disadvantages of this option area summarised as follows:

Table 10: No storage advantages and disadvantages

Advantages:	Disadvantages:
• No cost for storage; and • No construction impact.	• No security of supply; • No water quality benefits; • No water quality buffer effect; • High capex cost required for compulsory intake option; and • Possible higher capex cost of pre-treatment.

Figure 27: Storage Option A schematic - no storage



4.4.2.2 Storage Option B ~ Oyster pond

This option would involve the following:

- Use the existing Salt Works Oyster pond as the buffer pond for the desalination plant abstraction.

The advantages and disadvantages of this option area summarised as follows:

Table 11: Oyster pond storage advantages and disadvantages

Advantages:	**Disadvantages:**
• Low cost; • Low construction impact; • Water quality benefits; and • Storage for security of supply.	• Dependence on Salt Works and Oyster breeding operations; and • Minimum flexibility.

Figure 28: Existing oyster pond

4.4.2.3 Storage Option C ~ Own pond

This option would involve the following:

- Construct a new dedicated pond at a suitable location near to the RO Plant providing up to 42 hours retention time. The pond may be constructed on dry land, or may cordon off a portion of an existing pan currently used by the Salt Works, if acceptable.

The advantages and disadvantages of this option area summarised as follows:

Table 12: Own pond advantages and disadvantages

Advantages:	Disadvantages:
• Water quality benefits; • Storage for security of supply; • Independence and flexibility of operation; • Low to medium cost; and • Medium construction impact.	• Dependence on Salt Works agreement on pond space; and • More cost than using the oyster pond.

4.4.2.4 Storage Option D ~ On-site tank

This option would involve the following:

- Constructing a large seawater storage tank within the RO plant complex.

The advantages and disadvantages of this option area summarised as follows:

Table 13: On site tank advantages and disadvantages

Advantages:	Disadvantages:
• Independence and flexibility of operation; • Some storage for continuity of supply; and • Low construction impact (all within plant site).	• Limited storage for security of supply; • High capex cost; • Medium visual impact; and • Cleaning and maintenance (difficult access).

Figure 29: Example of a storage tank

4.6 TRADE-OFF STUDY 9 ~ SEAWATER DIRECT TO PLANT VS SEAWATER POND (COMBINED OPTIONS)

In practice, the storage and conveyance components of the seawater delivery system must be combined and optimised to provide the best overall solution for delivering seawater to the plant. Thus, Trade-off study 9 results in combinations of options coming out of trade-off studies 4 and 7, discussed above. Each of the conveyance options have been evaluated with each of the storage options, and preliminary concept design and cost estimate was carried out to allow for a competitive assessment. Table 14 reveals the 12 conveyance and storage option combinations that were considered and assessed in the trade off study. The combination code (i.e. 1A) is used to refer to these combinations through the remaining trade-off study.

Table 14: Combined Seawater delivery systems

		Storage Options			
		Option A ~ No Storage	Option B ~ Oyster Pond	Option C ~ Own Pond	Option D On-Site Tank
Conveyance Options	Option 1 ~ Seawater channel	1A	1B	1C	1D
	Option 2 ~ Seawater pipeline and channel	2A	2B	2C	2D
	Option 3 ~ Seawater pipeline	3A	3B	3C	3D

Certain combined options have low cost, but also have some technical and other difficulties, for example Option 1B, the channel conveyance and oyster pond storage combination, which is the lowest cost option has significant technical issues and should be avoided.

Due to the cost associated with new pipelines, and reservoirs or tanks, as when compared to using the existing channels and ponds, the combinations using conveyance option 3 (Pipeline) or storage option D (on-site tank), are naturally going to be more costly than other combinations. Logically then, the highest cost combination is Option 3D, which combines these two costly options.

From a financial perspective it follows then, that the optimum solution probably lies between conveyance option 1 (channel) and storage options A, B and C. However, for storage Option A (no storage), an additional factor is required in that, without any storage, there must be a constant supply of seawater to the plant. This limits the intake alternatives to the Outer Shelf intake (See Section 0), which then adds a cost premium for storage Option A.

For each combination of options, a similar concept design process was carried out and presented, together with the costing and schematic layout. The pros and cons of the different conveyance options, and the different storage options, were discussed and assessed using a number of technical and financial criteria. This has not been repeated here but the results of the assessment are provided under the recommendation heading to follow. Should the any person be interested in reviewing this detailed assessment they may request such from Rössing Uranium.

4.6.1 Recommendation

A decision matrix was compiled for conveyance options and for storage options and then the two sets of scores were combined as shown in the table below to obtain the best combined option.

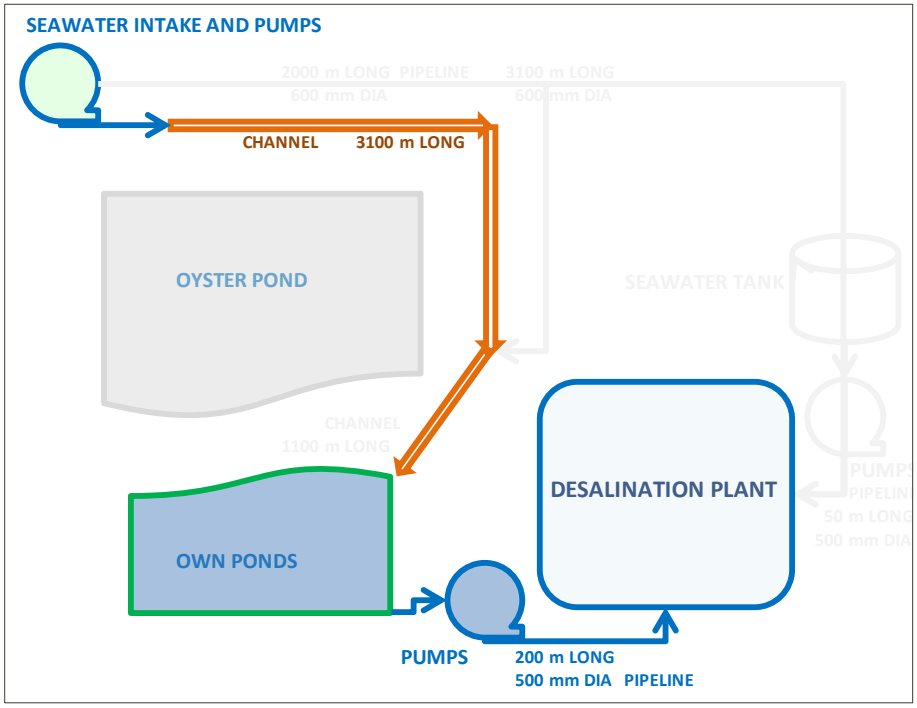
Table 15: Seawater conveyance and storage option combination assessement results

STORAGE OPTIONS / CONVEYANCE OPTIONS		SCORES	Option A No storage	Option B Oyster Pond	Option C Own Pond	Option D On-site Tank
			14.10	20.00	21.60	16.60
OPTION 1	CHANNEL	20.60	34.70	40.60	42.20	37.20
OPTION 2	PIPELINE and CHANNEL	20.20	34.30	40.20	41.80	36.80
OPTION 3	PIPELINE	19.80	33.90	39.80	41.40	36.40

The combinations that make use of the seawater channel and the ponds were the options that scored higher overall and are revealed by the greener shading in Table 15. The highest scoring was attributed to the Seawater channel (Option1) in combination with the Own pond (Option C) and should be taken forward as the preferred seawater delivery system.

The preferred Option 1C combines the technical advantages of a large storage pond that can be operated independently from the Salt Works and oyster breeding activities, with the relatively low cost of using the existing seawater channel to convey water from the sea intake to the plant. A schematic of the preferred Option 1C is provided here.

Figure 30: Option 1C schematic – seawater channel with own pond



4.7 TRADE OFF STUDY 5 ~ PLANT LOCATION[18]

Three plant locations were identified and assessed in this trade off study, as follows (preferred in bold text):

- RO Plant site 1 ~ Central site.
- RO Plant site 2 ~ Northern site; and

[18] *Modified from (Trade-Off Study Report 5: Optimum Plant Location, 2014)*

- RO Plant site 3 ~ Eastern Site;

The Swakopmund Salt Works is the designated location of the proposed desalination plant with the objective to supply water to the Rössing Uranium Mine. There are a number of potential locations for the proposed desalination plant within the boundaries of the Salt Works area (indicated in Figure 31 below). The purpose of this trade-off study is to determine the optimum location of the plant within the Salt Works based on the multi-criteria considering technical, financial, operation and maintenance, legal and regulatory and HSEC criteria.

Figure 31: RO Plant site Options

The locations are briefly described and assessed below.

4.7.1 RO Plant site 1 ~ Central site

Option 1 is located in close proximity to the existing Salt Works ponds proposed to be converted to raw water storage reservoirs and centrally located in terms of proposed raw water intake, brine disposal, and product water supply positions, with good access from existing roads with the Salt Works. Elevation of site varies between approximately 3m to 6m above mean sea level.

It is anticipated that the option 1 location will not impact or interfere with the everyday operation of the Salt Works. The financial aspects associated with the construction and operation of the RO Plant at this locality was assessed as being of lower cost for all financial aspects than site options 2 and 3.

On the environmental side, the central to southern part of the Option 1 area has been identified as a core Damara Tern breeding area, which should be avoided by development, and therefore the

northern / north-eastern end of this area (site 1b) has emerged as a preferred location for the plant within site option 1 area. The identified Damara Tern breeding areas have been indicated in Figure 31.

4.7.2 RO Plant site 2 ~ Northern site

The Option 2 plant location is located to the north of Option 1 next to the existing raw water supply canal expected to be utilized. The location is at a similar elevation to that of Option 1 and also next to an existing access road, which is expected to require upgrading. This site is located closer to the proposed seawater intake, but further away from the brine disposal discharge (in fact Site option 2 would make the northern discharge option increasingly preferable).

In terms of environmental impact, Option 2 is in relative close proximity to the existing Bird Island which could cause some disturbance to the existing bird population and Guano production.

It is anticipated that option 2 location will not impact or interfere with the everyday operation of the Salt Works. Site 2 has the highest construction of the three options but has a similar operations and maintenance cost (Lifecycle cost) as compared to Site option 3. All costs associated with Site 2 are higher than site 1.

4.7.3 RO Plant site 3 ~ Eastern Site

The Option 3 plant location is located to the east of Option 1 next to the main access road entering the Salt Works. The location is at a similar elevation to that of Option 1 and also next to an existing access road. This site is located further from the proposed seawater intake, but closer to the brine disposal discharge.

In terms of environmental impact the Option 3 location could pose a higher visual impact and is in close vicinity to bird nesting areas.

It is anticipated that site option 3 will not impact or interfere with the everyday operation of the Salt Works as long as the access to the plant is upgraded and controlled. The construction cost is the lower than site 2 and the operations and maintenance costs (lifecycle costs) are similar. All costs associated with Site 3 were found to be higher than those at site 1.

4.7.4 Recommendation

Following a detailed evaluation of identified solutions in terms of plant locations the following comparative results were concluded that based on the above assessment it is recommended that the proposed Rössing Uranium desalination plant be located at the Option 1 location, but shifted to site 1b, which lies outside of the identified core Damara Tern breeding area, with the exact location within the Option 1 area to be confirmed through the SEIA process and agreement from the Swakopmund Salt Works owners.

Table 16: Site option assessement results

EVALUATION SCORING (weighting)	OPTION 1	OPTION 2	OPTION 3
Technical (30%)	16	15	17
Financial (35%)	15	10	11
Operation and maintenance (0%)	0	0	0
Legal and Regulatory (0%)	0	0	0
health, safety, environment and community (35%)	15	16	15
WEIGHTED TOTALS	15.30	13.60	14.20

Site Option 1 is therefore recommended as the preferred location for the Rössing Uranium desalination plant and forms the basis of the Base Case layout. However due to the presence of Damara Tern breeding areas, potential noise sensitive and visual sensitive receptors, each site has its environmental benefits and limitations and, as a result of this, it was deemed prudent that all three site options be retained as alternatives and carried into the SEIA and undergo full assessment. The assessment findings provide further information or clarity on which of these options is most suitable as the go forward option (refer to Section 7 of this report).

4.8 TRADE OFF STUDY 6 ~ PLANT SIZE VS ENERGY[19]

Four plant size options were identified and assessed from the perspective of energy cost and efficiency, as follows (the preferred option in bold text):

- Plant size option A ~ 9,000m^3/d RO Plant;
- Plant size option B ~ 10,000m^3/d RO Plant;
- Plant size option C ~ 11,000m^3/d RO Plant; and
- Plant size option D ~ 12,000m^3/d RO Plant.

The energy consumption of a SWRO desalination plant has a significant impact on its life cycle cost and is therefore critical to optimize this aspect. The purpose of this trade-off study is to ensure that the new desalination plant is correctly sized to optimise the life cycle cost of the plant, particularly in terms of energy costs.

The re-evaluation starts with a Base Case plant size of 9,000m^3/d (Option A) and increases in 1,000m^3/d intervals. Option B corresponds to the recommended option from Trade off study 8 which finds a size of 10,000m^3/d to be suitable, and which reviewed the plant size in terms of projected demand and overall product water storage in order to achieve an optimum balance between water demand, storage, and security of supply.

Based on actual water usage over a period of the past 4 years it was established the annual water demand at the Rössing Uranium mine is, on average, 3.0 Mm^3 which equates to an average daily demand of 8,200m^3/d. The size of the smallest plant (base option A) is therefore assumed to be 9,000m^3/d to allow for redundancies and/or peaks.

A 9,000m^3/d plant with a five percent allowance for downtime (95% availability) operating at full capacity can produce 3,112Mm^3/a. (The concept design in the pre-feasibility study was based on approximately 90% plant availability, and this will be further refined in the final design). All of the options are programmed to produce an equal volume water, 3,112Mm^3/a, which forms the basis of

[19] *Modified from (Trade-Off Study Report 6: Optimum Plant Size - Energy Efficiency, 2014)*

this energy cost comparison, that is to say if a larger capacity plant were used it can be run less of the time to achieve the demand, thus allowing it to avoid peak electrical tariff periods or only run when conditions are optimal (in theory).

The Erongo RED Time-of-Use (TOU) energy tariffs are used to minimise the cost of plant energy usage. Effectively the hours of peak energy tariff used to produce the set volume of water is minimised.

The following Key Assumptions were made in this Addendum:

- All the options were programmed to produce 3,112Mm^3/a.
- Weekly production cycles are used instead of daily cycles as the peak energy tariff periods are only implemented during weekdays. The weekly energy usage is therefore optimised per season and then summed per annum.
- A maximum of two RO system starts (equipment startups consume more electricity than normal operation and should be avoided when considering electrical efficiency) per day with an estimated five hours shutdown period per day are used.
- The energy tariffs will increase 18% per year for the first five years and 10% thereafter.
- The product water reservoir (buffering storage) on site is sufficient to balance out the pumping rates required by any variations in plant size (practical limit of extra storage is 2,000m^3/day i.e. 12,000m^3/d in total).
- The rate of discount for monetary values to the base year is six percent per year.

The hours used to produce the assumed 3,112Mm^3/a of product water together with the energy required are listed the table below.

Table 17: Plant size vs energy options

Plant size and energy use of options	Option A	Option B	Option C	Option D
Size (m^3/day)	9,000	10,000	11,000	12,000
Peak Energy Tariff hours per week	40	15.65	2.6	0
Standard Energy Tariff hours per week	47	47	47	38.7
Off-peak Energy Tariff hours per week	81	81	81	81
Total hours per week	168	143.65	130.6	119.7
Total annual energy cost (N$/annum)	14,576,496	13,744,897	13,171,802	12,881,209

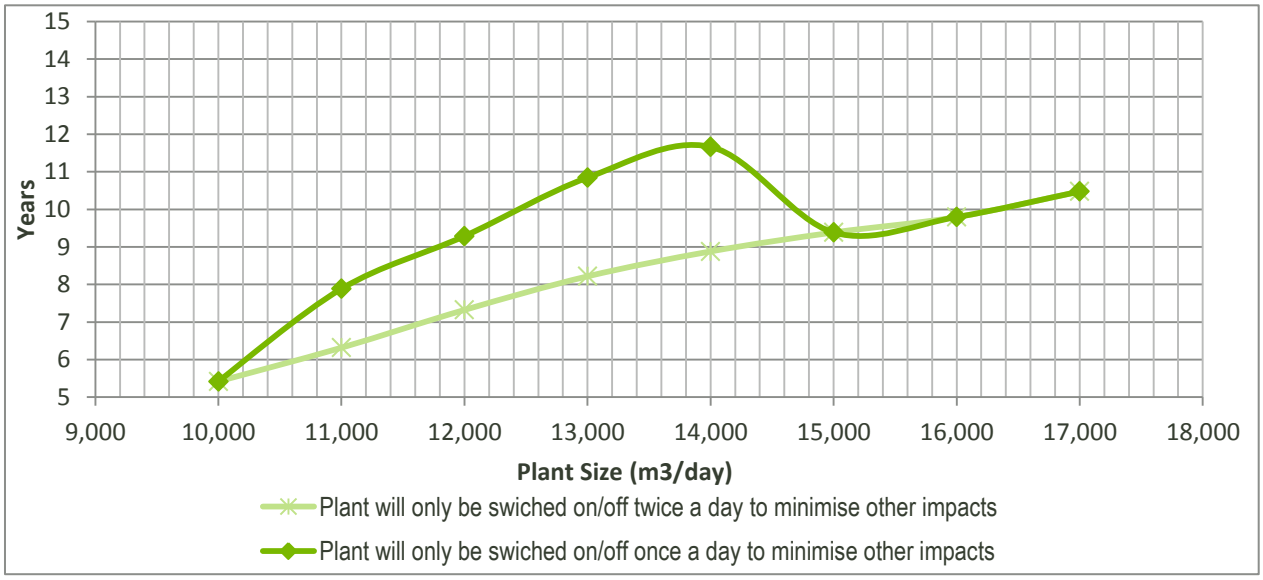
The return on investment period is derived where the net present value of the energy saving per year and the additional CAPEX cost is zero. The return on investment period for the options reported ranges from five to seven years, indicating a small financial gain by increasing the plant size.

Table 18: The return on investment periods

	Option A	Option B	Option C	Option D
Proposed plant size (m^3/day)	9 000	10,000	11,000	12,000
Return of Investment Period (years)	Base option	5.42	6.32	7.32

The return on investment periods for the full list of options evaluated are illustrated in the figure below.

Figure 32: Plant size vs return of investment



The evaluation in terms of the weighted multi-criteria decision framework yielded the following results.

Table 19: Plant size vs energy assessment results

EVALUATION SCORING (weighting)	OPTION A	OPTION B	OPTION C	OPTION D
Technical (15%)	13	13	13	12
Financial (60%)	20	20	17	16
Operation and maintenance (15%)	3	6	6	6
Legal and Regulatory (0%)	0	0	0	0
HSEC (10%)	5	6	6	6
WEIGHTED TOTALS	14.9	15.5	13.7	12.9

Based on the assessment it is recommended that Option B (10,000m^3/d) be implemented as the proposed Rössing Uranium desalination plant size. This recommendation is made despite the fact that Option B is not the most cost effective energy use option overall. The additional CAPEX requirement of Option D is not warranted, taking into account that the Option B plant size is the recommended capacity determined by the water demands and optimum water storage aspects.

4.9 TRADE OFF STUDY 8 ~ PLANT SIZE VS PRODUCT WATER STORAGE[20]

Three plant size options were investigated, starting with a plant capacity of 8,500m^3/d, which is only slightly above the average capacity required to meet the annual demand, but with limited availability for maintenance during peak demand periods. The other two options have increasing capacity and therefore increasing ability to meet the peak demands and increased downtime allowable for maintenance. The comparison of the options is based on providing plant production capacity and reservoir capacity to achieve no failures in supplying the demand while meeting the required minimum supply level at the mine reservoirs. The options are as follows:

[20] *Source: (Trade-off Study 8: Plant size vs Product Water Storage, 2014)*

- Option 1 ~ Plant size 8,500m^3/d with a 28,800m^3;
- Option 2 ~ Plant size 9,100m^3/d with a 6,000m^3; and
- Option 3 ~ Plant size 10,000m^3/d with zero storage.

All three of these options have been developed in a way that would satisfy Rössing Uranium's supply objects on an engineering calculations basis. The approach to determine the plant sizing, starts with the stated demand of 3.0Mm^3/a, which converts to an average flow of 8,200m^3/d. Based on process and operation and maintenance considerations, the process peak flow (i.e. the plant sizing) is estimated at 9,100m^3/d. The final plant sizing then takes into account further issues of process unit module sizes, feedwater security and storage, and product system storage and the peak month and peak week demands.

Rössing Uranium's current water supply system gets water from the Swakopmund Base Station, the water is pumped in a 700mm steel pipeline to the terminal reservoirs that serve the town of Arandis and the Mine. The existing pumping system of 4 pump stations from Swakopmund Base Station to the terminal reservoirs has capacity to pump up to 1500m^3/h compared to a maximum flow of less than 500m^3/h from the RO plant (and so no capacity issues are foreseen).

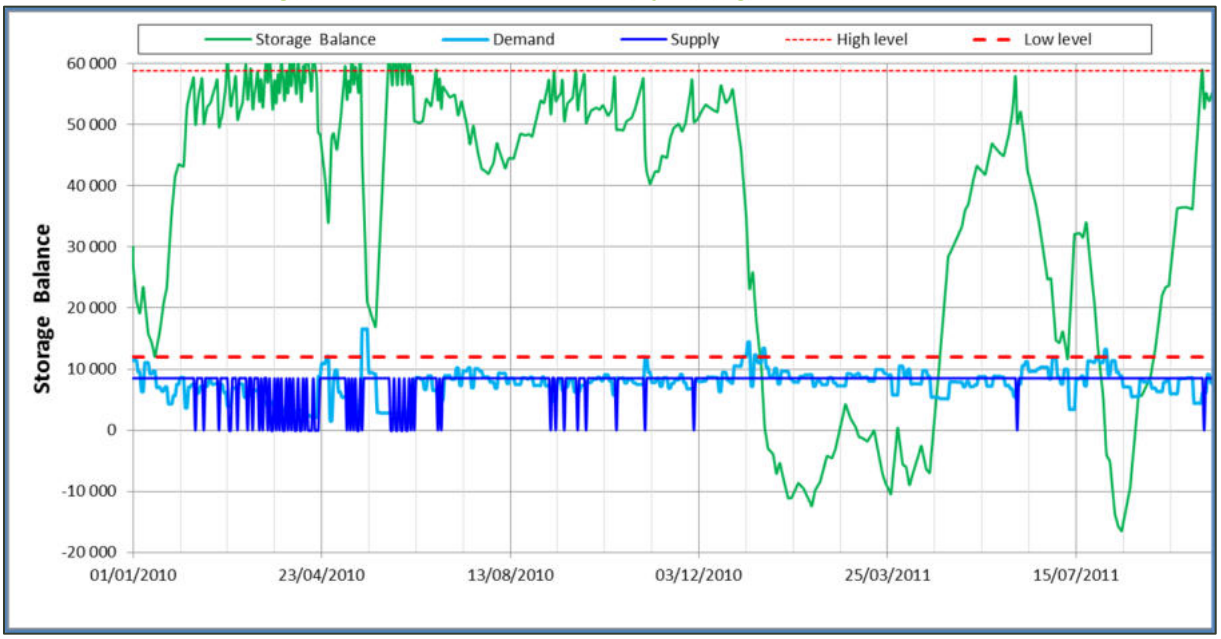
The terminal reservoir capacity is 60,000m^3 (comprised of three 20,000m^3 reservoirs), and the Mine has access to 48,000m^3 or 80% of this stored capacity, while maintaining a low level limit in at least one of the 20,000m^3 reservoirs so as to provide pressure to Arandis town. The low level limit is set at 30% of full level, which translates to 6,000m^3 of unusable storage in one reservoir. By adding 2 days of working storage and 2 days of emergency storage for Arandis a further 6,000m^3 of storage is rendered unavailable. This adds to make a total of 12,000m^3 reserved for Arandis, and the remaining 48,000m^3 for the mine.

A simulation was run for each plant size option, to meet the mine's water demand while maintaining the required plant availability for maintenance downtime, as well as meeting the minimum storage criteria. The simulation provided the required storage volume required for each corresponding plant size.

4.9.1 Option 1 ~ 8,500m^3/d plant

- Plant capacity 8,500m^3/d (plant availability would be limited for maintenance during the peak months, and would likely suffer numerous failures to supply).
- Reservoir – to protect against failure to supply an additional product water storage capacity = 28,800m^3 would be required to avoid failures.

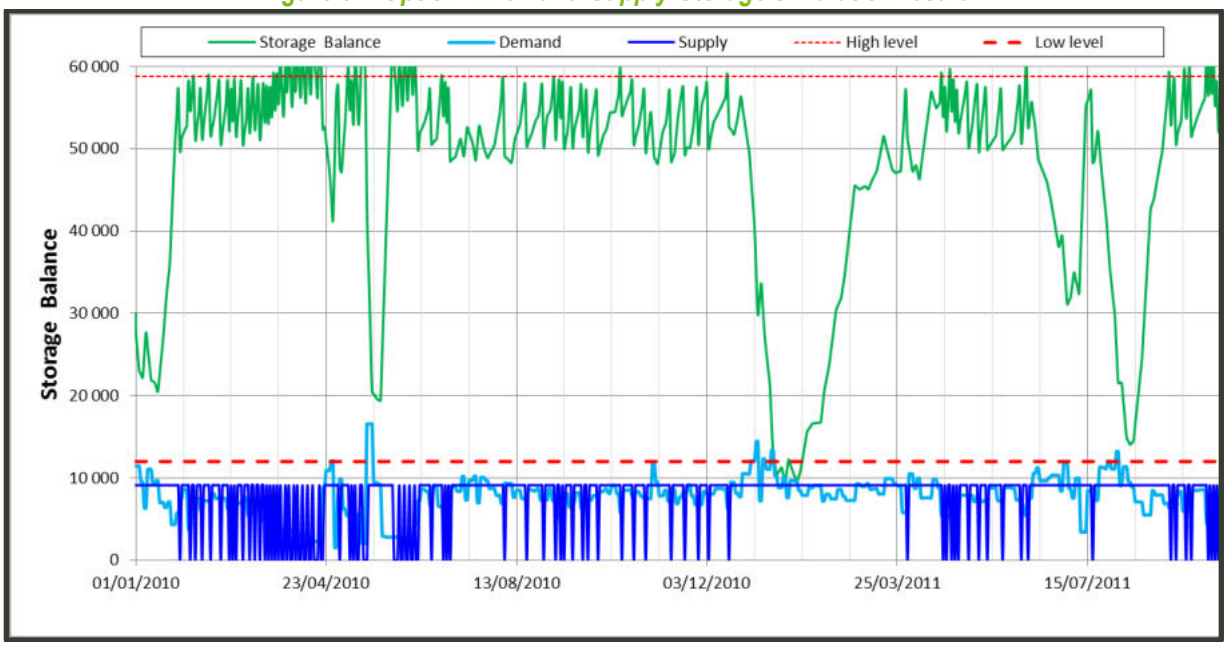
Figure 33: Option 1 Demand-Supply-Storage simulation result



4.9.2 Option 2 ~ 9,100m^3/d plant

- Plant capacity 9,100m^3/d (plant availability would be limited for maintenance during the peak months, and would likely suffer numerous failures to supply).
- Reservoir – to protect against failure to supply an additional product water storage capacity = 6,000m^3 would be required to avoid failures.

Figure 34: Option 2 Demand-Supply-Storage simulation result

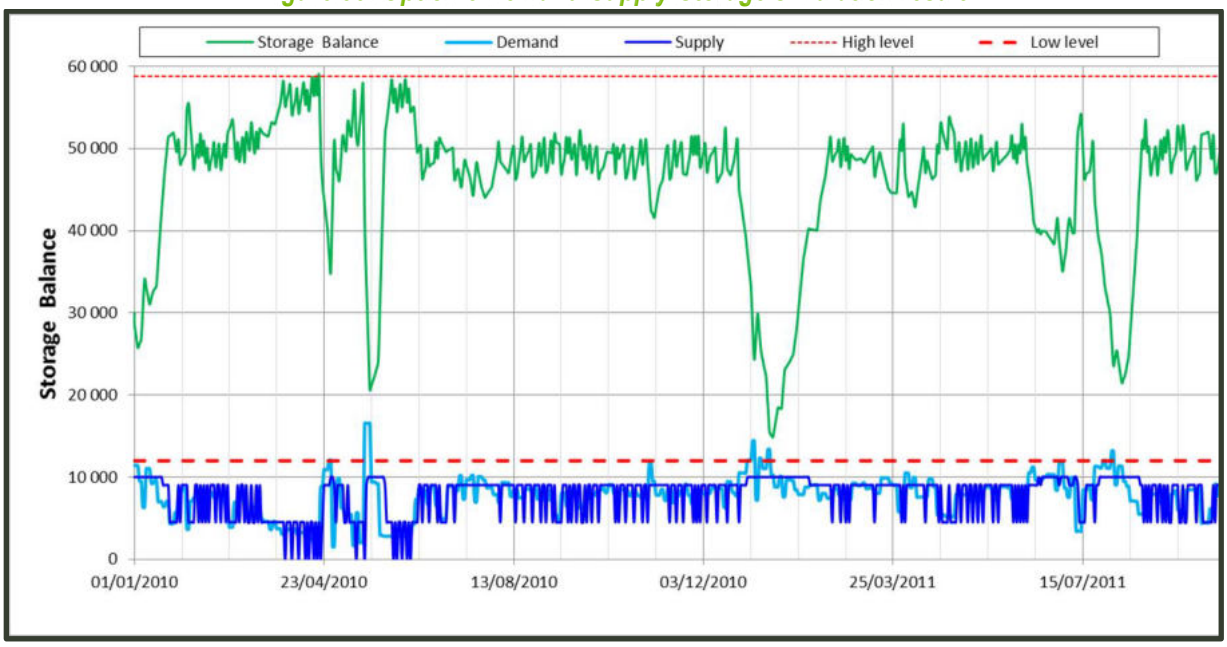


On options 1 and 2, there are numerous failures to meet the supply criteria within the storage limits, which is shown by the storage balance (green line) exceeding the high and low level limits (red lines).

4.9.3 Option 3 ~ 10,000m^3/d plant

- Plant capacity 10,000m^3/d (good plant availability for maintenance in peak months, with no supply failures).
- Reservoir – no additional product water storage capacity is required.

Figure 35: Option 3 Demand-Supply-Storage simulation result



4.9.4 Recommendation

Adding the financial data shows that the capital cost of increasing the RO Plant capacity, compared to the capital cost of providing additional reservoir storage capacity is relatively well balanced (combined capex difference of N$17.9m for option 2 and N$15m for option 3) when the plant size exceeds the average demand by 10% or more.

In addition, the high failure rate of option 1 on staying within the required storage limits means that there is increased risk of falling behind in water production, and not being able to catch up, should there be operational, power supply or other factors affecting production.

Assessing these options through the criteria of Technical (30% weighting), Financial (30% weighting), operation and maintenance (10% weighting), legal and regulatory requirements (10% weighting), and health, safety, environment and community consideration (10% weighting), the following result emerges:

- Option 1 ~ 17.50 (70%);
- Option 2 ~ 22.10 (88.4%); and
- Option 3 ~ 25.00 (100%).

It follows then that option 3 (namely the 10,000m^3/d plant with zero storage) has been recommended as the go forward option for the project and from the SEIA perspective is deemed to form part of the Base Case and all alternatives being assessed. Options 1 and 2 are considered unfeasible and will not be assessed in the SEIA.

4.10 TRADE OFF STUDY 10 ~ PROGREEN VS TRADITIONAL

Two main proposals from Sea Water Reverse Osmosis (SWRO) technology providers were received and evaluated (preferred option in bold text):

- Option 1 ~ Combined Veolia/IDE proposal including all of the systems required for the project (traditional)
- Option 2 ~ IDE proposal for main RO system with an integrated pre-treatment aspect (Pro-Green^{TM})

4.10.1 Recommendations

The IDE proposal emerged as the preferred proposal, and this was confirmed after a number of technical issues were clarified by IDE.

The proprietary bioflocculation pretreatment step provides additional means for the plant to cope with poor quality feed water. The bioflocculation process forms part of the integrated system (PROGREEN^{TM}) at no additional cost, and is integrated with the RO system design and control.

This bioflocculation process is based on the use of naturally occurring biological matter in the incoming seawater, and does not need imported species. There is a “start-up” period required for the process, and this must be implemented as a long-lead item in the programme.

The modular RO systems are to be manufactured on skids, delivered in containers, and installed on concrete plinths in an industrial type building.

4.11 TRADE OFF STUDY 11 ~ SEAWATER INTAKE POWER SUPPLY

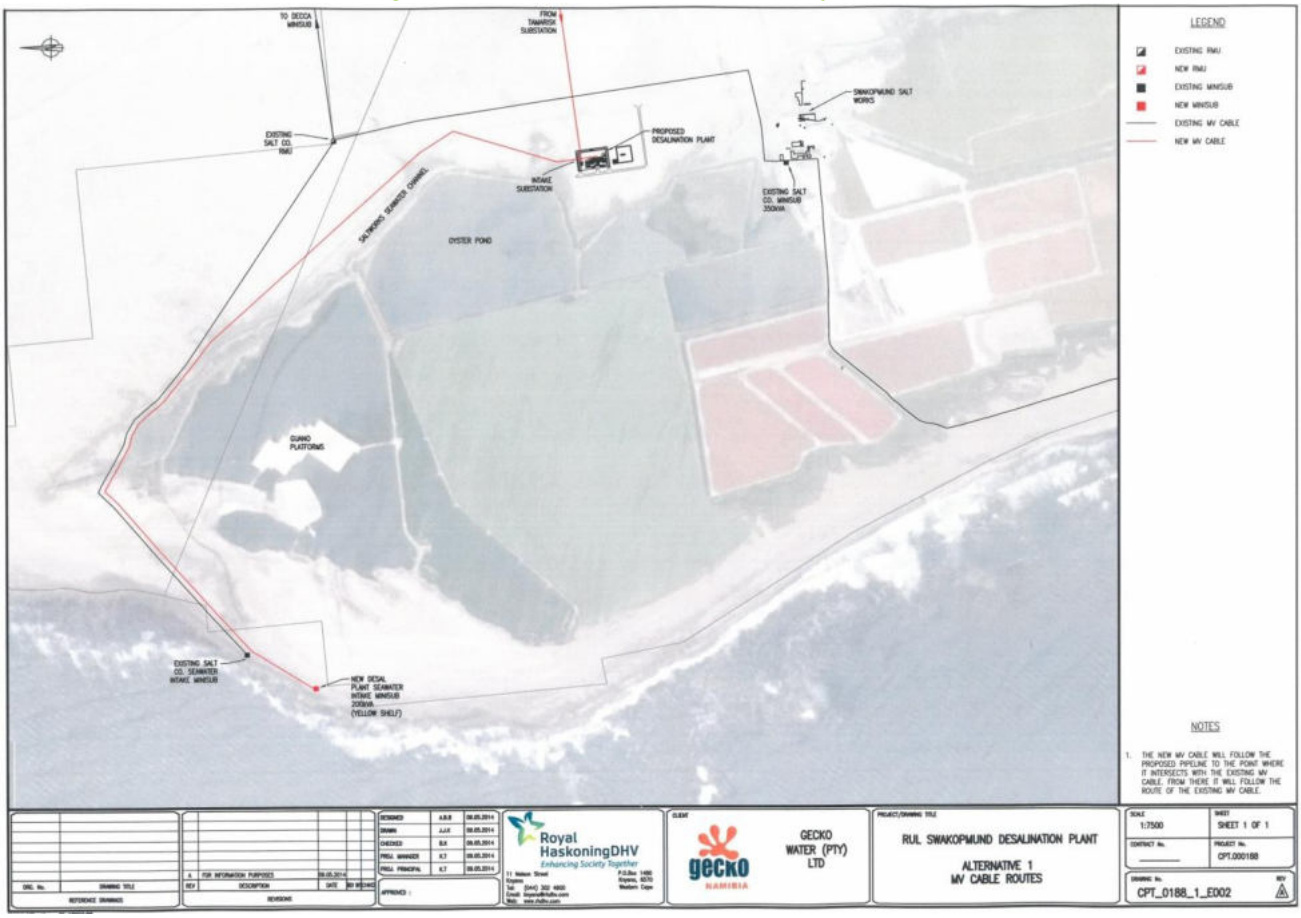
Two power supply options were identified and assessed for the seawater intake as follows (Preferred option in bold text):

- Option 1 ~ Install a new dedicated power supply to the seawater intake.
- Option 2 ~ Share the existing power supply cable to the Salt Work seawater intake.

4.11.1 Option 1: New cable

A new medium voltage intake substation for the desalination plant with a dedicated feeder circuit breaker to the seawater intake will be installed as part of the desalination plant. For this alternative a dedicated 25mm², 3 core, 6.35/11kV Paper Insulated Lead Covered cable will be installed from the intake substation to the new seawater intake miniature substation. A 25mm² bare earth conductor will be installed along the new medium voltage power cable for earth continuity. The power and earthing cables will be installed around the oyster ponds as per Figure 36 within a dedicated trench of 600mm (w) x 1000mm (d). The desktop measurement of the cable route is approximately 3km. Cable markers to indicate the position of the new medium voltage cable will be installed at every turning point. This alternative will allow dedicated metering at the medium voltage intake substation and no further metering of the low voltage supplies is envisaged. Option 1 is represented in Figure 36 to follow.

Figure 36: Seawater intake power supply option 1



4.11.2 Option 2: Re-use of existing cable

For this option, a new section of 25mm², 3 core, 6.35/11kV Paper Insulated Lead Covered cable would be installed from the intake substation to the new Salt Company T-off ring main unit. A new 25mm² Bare Earth Conductor will be installed on the new medium voltage power cable for earthing continuity. The power and earthing cables will be installed, as per Figure 37 to follow, in a dedicated trench of 600mm (w) x 1000mm (d). The desktop measurement of this cable route is approximately 930m. Cable markers to indicate the position of the new medium voltage cable will be installed at every turning point.

The existing 3-way ring main unit at the Salt Works Company T-off position will be disconnected and removed. A new 4-way ring main unit will be installed into the existing building to accept a connection from the intake substation. The existing feeders to the Salt Pan miniature substation, the Decca miniature substation and the Salt Works sea intake miniature substation will be re-connected to the new 4-way ring main unit. This allows the sharing of the existing 25mm², 3 three core, 6.35/11kV cable between the Salt Works Company seawater intake and the new Salt Company T-off. The risk in this alternative lies in the section of shared cable. If for any reason (electrical cable fault, unforeseen damage or routine maintenance on the Salt Company miniature substation) there is a loss of power in this section of the cable then the desalination plant will also lose their water intake pumping system. Due to this being a shared power cable it will have to be discussed with Erongo Red to take over the ownership of this section of the cable.

A further section of 25mm², three core medium voltage cable will be installed from the existing Salt Works. Technically this alternative is less desired as it has several more connection points in series which are points of potential failure. The integrity of the desalination plant seawater intake pumping system is dependent on the correct functioning of various other pieces of equipment in the network. This increases the mean time to failure. Another consideration is the mean time to repair of the

major equipment, especially the Salt Works Company T-off ring main unit. The failure of this ring main unit will have severe consequences to the desalination plant process as this type of switchgear is not readily available. This mean time to repair can be reduced by installing a fully modular type ring main unit. This will allow the replacement of the single failed isolator rather than the entire ring main unit.

This alternative has a further operational complication as it will require new metering to be installed into the low voltage compartments of the seawater intake miniature substations. This is required to measure the power consumption of the desalination plant and Salt Works Company independently.

Figure 37: Seawater intake power supply option 2

4.11.3 Recommendations

This section aims to summarise the findings and recommendations for the trade-off study for the electrical supply options of the new seawater intake pumping system.

The findings that flow from this trade-off study are as follows:

- Alternative 1 is technically more suitable;
- Alternative 1 is more appropriate to operational and maintenance procedures;
- Alternative 2 is financially more attractive;
- Both alternatives have no regulatory impacts; and
- Alternative 2 is more attractive in terms of health, safety, environment and community.

The recommendation is based on the analysis of the multi-criteria decision framework and it is recommended that Alternative 1 be implemented due to the various technical and operational advantages and the nominal impact of the increased capital expense in the greater scheme of the project.

In terms of the SEIA, option 1 will be incorporated into the project and option 2 has been deemed unfeasible and excluded from further assessment.

4.12 PROJECT ALTERNATIVES ASSESSED IN THE SEIA

Taking all the trade off studies into considertation, Table 20 below provides a summary of the feasible project alternatives considered and assessed as part of the SEIA process (i.e. the specialist assessments and section 7 of this SEIA report). These alternatives are comprised of certain option combinations that can work together to best meet the project parameters. Refer to Figure 38 below for a layout of the various feasible project alternatives considered in the SEIA.

The first column in the table below is the Base Case project, as was presented in section 3 above. Each of the alternatives (other columns in the table below) explains difference in relation to the Base Case project.

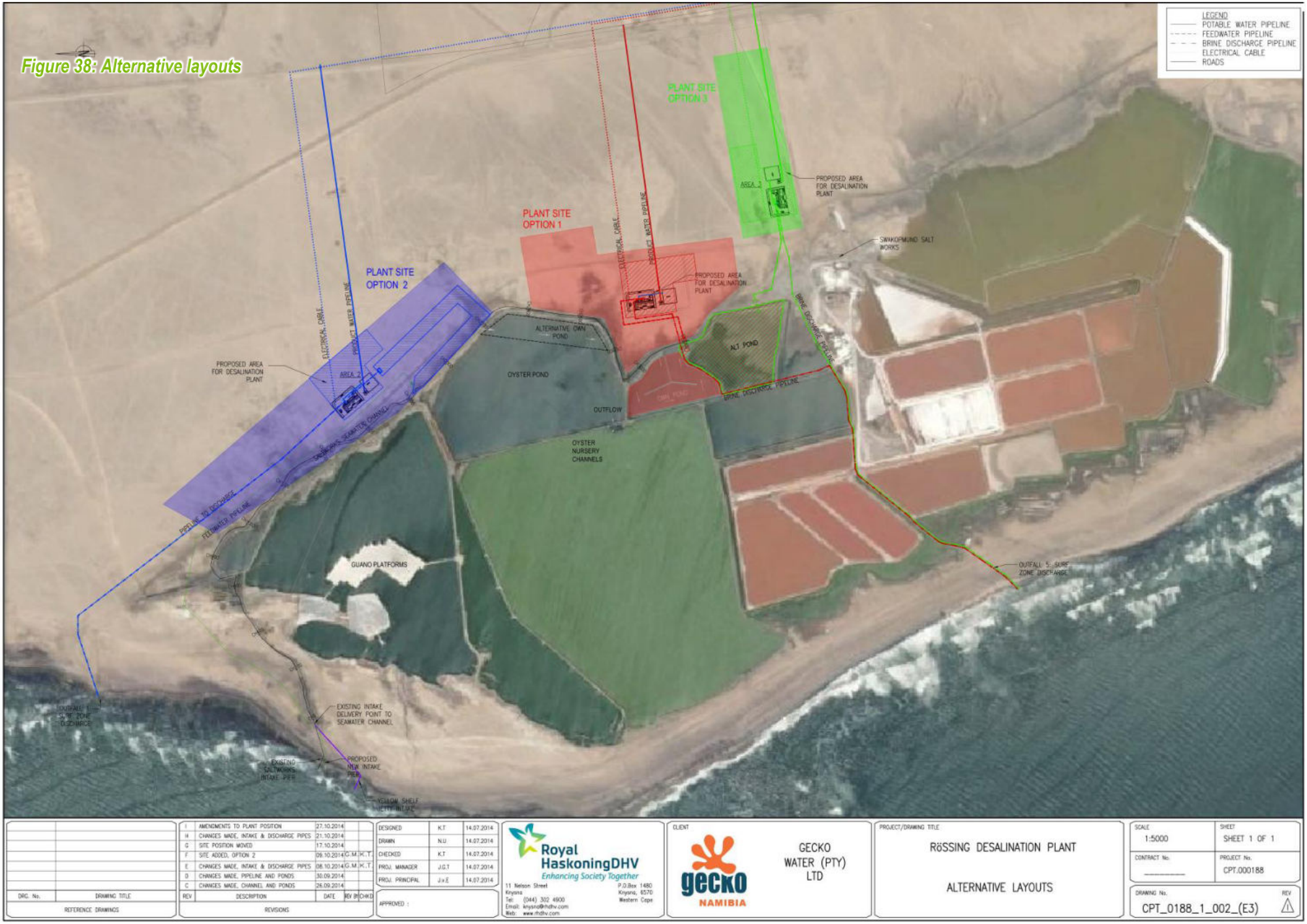
In addition to the Base Case and the identified feasible alternatives, the No-Go alternative was also assessed. The No-Go alternative serves as a basis for comparison and can serve to validate the need and desirability for the project.

Table 20: Summary of project alternatives assessed in the SEIA process

Base Case (pre-mitigation) (site 1)	Base Case (post-mitigation) (site 1)	Alternative 1 – Site 2	Alternative 2 – Site 3	Alternative 3 –with overhead power	Alternative 4 -No Go Alternative
RO Plant ~ 10,000m³/d seawater reverse osmosis (RO) plant and associated facilities situated in the centre of site locality 1. The RO plant will house the pre-treatment systems and the various pumps for the product water system. The plant will also house various ancillary facilities (chemical stores, offices, ablutions, roads, parking bays, maintenance areas, spares stores, etc.). The RO plant and associated facilities will be mostly housed within a single warehouse type structure, to protect them from the corrosive coastal air.	Same as Base Case alternative except that the Plant would be situated in the north / north-eastern area of location 1.	Same as Base Case alternative except that the Plant would be situated on site locality 2.	Same as Base Case alternative except that the plant would be situated in site locality 3.	Same as Base Case	No implementation means no direct environmental impacts. There will however be potentially significant socio-economic opportunity impacts.
Seawater intake system ~ A new seawater intake jetty and associated pumps and pipes will be erected just south of the existing Salt Works intake jetty. Seawater will enter the existing (possibly upgraded) Salt Works seawater intake channel and gravitate around the Salt Works and enter into a new seawater buffer pond located near the RO plant. A new electrical cable will be run from the RO plant around the eastern and northern shores of the salt pans, and provide power to the intake pumps on the new jetty.	Same as Base Case except that the new seawater intake pond would be situated closer to the RO plant on Site locality 2.	Same as Base Case except that the new seawater intake pond would be situated closer to the RO plant on Site locality 2.	Same as Base Case	Same as Base Case	
Pre-treatment system ~ Sea water abstracted from the buffer pond will be filtered and conditioned ahead of the desalination process. This may involve the use of pre-treatment chemicals or biological processes in combination with physical screens and filters to ensure that the water is free of particulates that could foul the RO membranes, and that the pH is optimum to allow for efficient RO process.	Same as Base Case	Same as Base Case	Same as Base Case	Same as Base Case	
Product water system ~ clear water from the RO process will then be re-mineralised to meet potable water standards and pumped via an 850m long pipeline, running due east from the plant, into the existing NamWater pipeline running along the eastern side of the Henties Bay Road (C34).	Same as Base Case	Same as Base Case	Same as Base Case	Same as Base Case	
Brine disposal system ~ Brine (together with filter backwash from the pre-treatment system and chemical cleaning processes) will be pumped from the plant via a new pipeline to ocean discharge (surf discharge) location situated south of the Salt Works bitterns outlet (southern discharge site).	Same as Base Case alternative except that due to RO Plant site on site 2, the northern discharge (Outfall 1) site becomes preferred due to the shorter pipe length.	Same as Base Case alternative except that due to RO Plant site on site 2, the northern discharge (Outfall 1) site becomes preferred due to the shorter pipe length.	Same as Base Case	Same as Base Case	
Electrical supply system ~ A buried cable would run from the existing Tamarisk substation in the northern parts of Swakopmund, along the C34 toward Henties Bay and then turn due west on a vector to connect with the new mini-substation to be constructed adjacent the RO plant. The cable between the C34 and the plant should follow the same route as the	Same as Base Case. However the exact location where the buried cable would turn west from the Henties Bay Road is	Same as Base Case. However the exact location where the buried cable would turn west from the Henties Bay Road is	Same as Base Case. However the exact location where the buried cable would turn	Same as Base Case alternative except that the distribution line from the Tamarisk substation along the	

Base Case (pre-mitigation) (site 1)	Base Case (post-mitigation) (site 1)	Alternative 1 – Site 2	Alternative 2 – Site 3	Alternative 3 –with overhead power	Alternative 4 -No Go Alternative
product water pipeline connecting with the NamWater pipeline. Note also that a buried cable will run from the RO plant to the new seawater intake jetty.	located further north.	located further north.	west from the Henties Bay Road is located further south.	C34 to Henties Bay will be above ground as opposed to a buried cable. From the C34 to the plant will remain a buried cable.	

Figure 38: Alternative layouts



5 DESCRIPTION OF THE AFFECTED ENVIRONMENT

This section provides an overview of the social and environmental characteristics of the study area at present, which forms the basis for the assessment of the potential impacts.

5.1 SOCIO-ECONOMIC ENVIRONMENT[21]

5.1.1 The Erongo Region

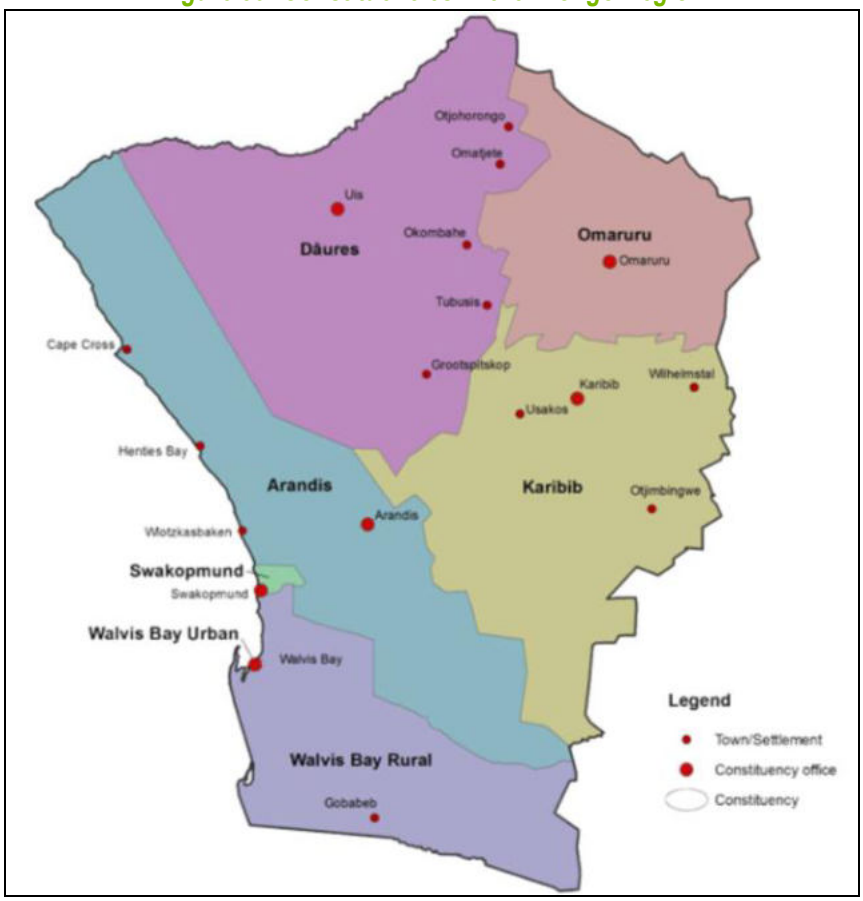
The 2011 Population and Housing Census found that the population of the Erongo Region was 150,809 which is a considerable increase of 43,146 from 107,663 in 2001. This represents an overall annual growth rate of 3.4% but the towns of Swakopmund and Walvis Bay have experienced growth rates of 5.3% and 5% respectively. More than three quarters of the region's population live in the coastal towns of Walvis Bay, Swakopmund, and Henties Bay and in Arandis which is slightly inland.

Walvis Bay sources its water from the Kuiseb aquifer while the other three towns and three big mines source their water from the Swakopmund and Omdel aquifers and more recently the Areva desalination plant. Of relevance to this project is therefore the socio-economic description of the activities reliant on the Omdel aquifer; for this reason Walvis Bay's activities are not detailed.

The region has seven constituencies and the planned project is within the northern boundary of Swakopmund, adjacent to the very elongated Arandis constituency Figure 39.

[21] *The socio-economic section was authored by Auriol Ashby of Ashby Associates CC (and Dr Jonathan Barnes of Design & Development Services CC).*

Figure 39: Constituencies in the Erongo Region



The main employment sectors in the Erongo Region are manufacturing (11.5%), mining (11.7%), fishing and agriculture (11.5%), construction (9%), repair of motor vehicles (9%) and administrative / support services (8%). The region's growth has been largely due to the mining sector, the harbour and fishing industry based in Walvis Bay, and the tourism sector which is focused around Swakopmund. All these industries are dependent on a reliable supply of fresh and potable water and the mining industry will be the biggest water consumer followed by the municipalities once Husab mine is operational.

As a measure of living standards, the Erongo Region has the second highest per capita consumption of all Namibia's regions, estimated at N$22,700 per person per year in 2009/10 and this has grown by 54% in 5 years from N$14,700/person/year. When this is compared to six of the northern regions where rates are below N$9,000/person, it partly explains why the region experiences high in-migration. Oshiwambo languages are the most common, used by 39% of households. Other main language groups are Afrikaans (20%) and Nama/Damara (19%) with English (5%) and German (3%) making up a small minority.

5.1.2 Swakopmund

The Swakopmund Constituency has a total population of 44,700 in 2011, made up of slightly more males than females (23,700 to 21,000), largely due to the inward migration of men seeking work in the mines and supporting industries. The constituency is entirely urban and Swakopmund is the fourth largest town in Namibia (after Windhoek, Rundu and Walvis Bay). The town grew by 18,000 people from 2001 – 2011; however, it is much less densely populated with 228 people/km^2 than Walvis Bay which has a population of 62,096 and a density of almost 1,900 people/ km^2.

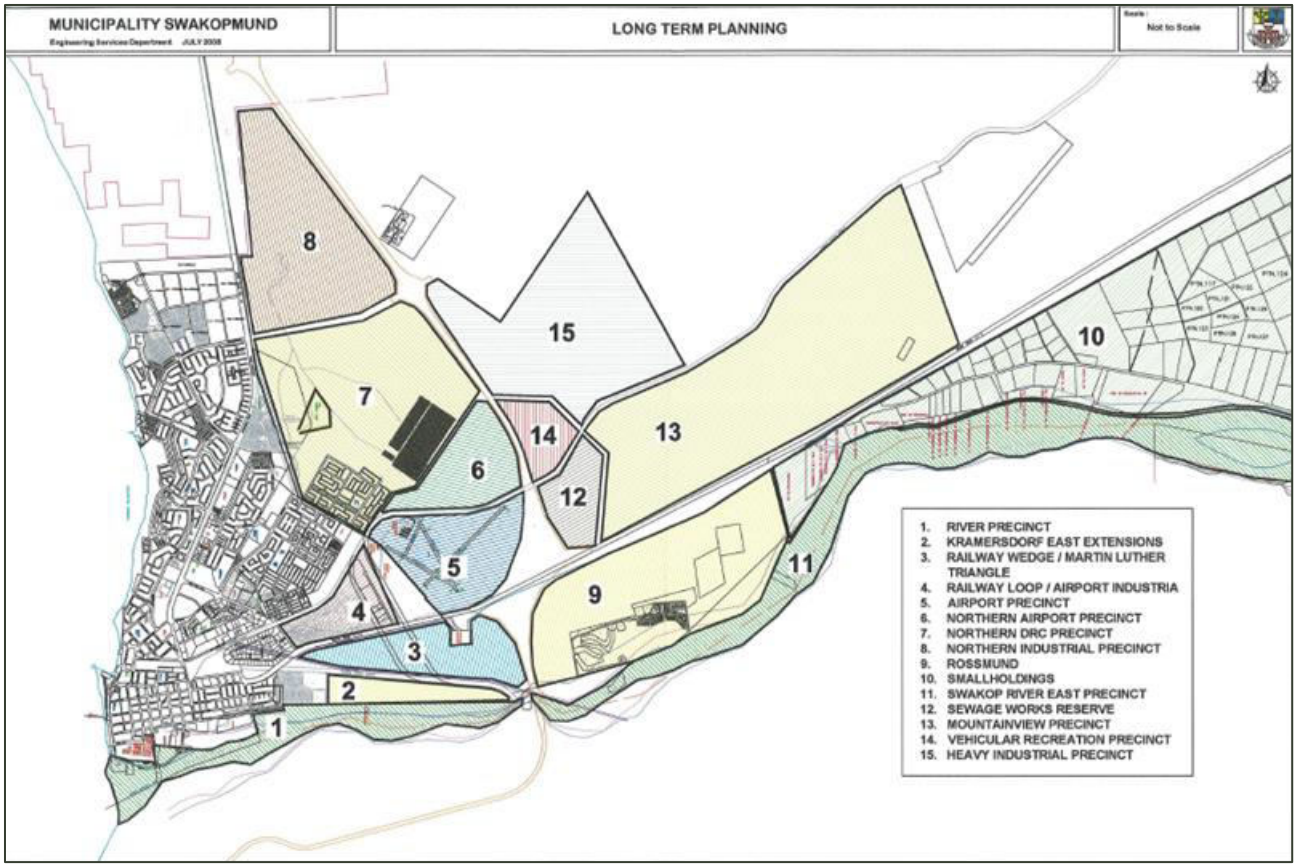
Swakopmund's spatial development is constrained by the Swakop River to the south which is the border with Walvis Bay constituency, the Atlantic to the west and the desert to the north and east. The town's growth northwards along the coast has developed the middle to upper income residential

suburbs of Vineta, Hage Heights and Mile 4, with the Swakopmund Salt Works and site for the proposed project, being the only large scale industrial site.

The lower income suburbs of Mondesa and the DRC have smaller erven (plots) and are to the east of the town centre. Industrial precincts are north and eastwards of the DRC, with good road access to the B2 main road which links Swakopmund to Walvis Bay and the Trans-Caprivi and Trans Kalahari Highways. Further up-market residential developments are spreading eastwards where there are views of the Swakop River valley and dunes beyond.

The long term town plan of 2008 has not yet been updated (Figure 40). Note that the proposed site is off the map, to the north.

Figure 40: Long term town plan for Swakopmund



Households in Swakopmund are the smallest in the region with 3.1 persons, compared to a regional average of 3.3 people per household. Forty four percent of households own their own home (with or without mortgage/ bond) compared to those who rent (42%). The large majority of households use electricity as their main fuel source for cooking (81%) and lighting (84%). Almost all households (99.7%) have access to safe drinking water.

Almost 80% of Swakopmund's population over the age of 15 is economically active – i.e. they are part of the potential labour force. Of those, three quarters (over 19,000 people) are employed while over 6,600 people are unemployed. About 5,000 people are economically inactive, being pensioners, students or homemakers. As a result of this high employment, 77% of households rely on wages and salaries as their main source of income and a further 10% rely on income from business.

5.1.3 Arandis and Henties Bay

Arandis is located about 60 km east of Swakopmund, off the main B2 road to Windhoek, and the national railway to Walvis Bay. The 2011 Population Census found that Arandis had a population of 5,170 people in 2011 while Henties Bay, a small town 67km north of Swakopmund had a population of 4,720. Both towns are dependent on water from the Omdel aquifer.

Arandis was established in 1970 to house employees of the Rössing mine and it has always been very economically dependent on RUL with most residents either working at the Rössing mine or for contractors of RUL. The higher income employees tend to prefer to live in Swakopmund, thereby causing the local buying power in Arandis to be insufficient for some basic commodities such as fuel, until recently. During the depressed uranium prices of the 1990s, the mine was threatened with closure and the town barely survived. Since then, the Town Council, RUL, and the Rössing Foundation have made great strides in trying to diversify the town's economy.

New life has been breathed into the town with RUL's mine extension, the development of Areva's Trekkopje mine, the Husab mine, and the forthcoming Arandis Power Heavy Fuel Oil Plant. These have spurred the town to plan for expansion and the constituency has showed a population annual growth rate of 2.9% since 2001.

Henties Bay, at the Omaruru River mouth, is primarily a holiday town with the ocean and miles of beaches as its main attractions. It is a thriving angling community and it is one of the few places from where 4x4 driving and quad biking is still permitted in designated areas within the Dorob National Park. The University of Namibia has established the Sam Nujoma Marine and Coastal Resources Research Centre at Henties Bay which focuses on mushroom development, coastal agriculture and plant biodiversity, renewable energy sources, water resources, as well as the coastal environment.

Nearly three quarters of the constituency's labour force is employed (72%) compared to the national average of 63%. Seventy two percent (72%) of households depend on wages and salaries. Unemployment Is 28% compared to the national average of 37%.

5.1.4 The mining economy

The contribution of the mining economy to the Erongo Region and to Namibia's Gross Domestic Product (GDP) as a whole is significant. Non-diamond mining contributes about 50% of its annual total profits to government in the form of direct and indirect taxes. The mining sector in the coastal region is dominated by uranium mining and exploration. Since the March 2011 tsunami and subsequent severe damage to the Fukushima reactors in Japan, the uranium industry has suffered from low global uranium prices. Although some countries have cut back their nuclear energy programme, there are still 1,100 nuclear reactors worldwide with a further 72 under construction, 173 planned and 309 proposed. Morgan Stanley Research predicts that supply cutbacks (from Paladin and Cameco) are likely to cause a gradual increase in uranium price. It also expects nine nuclear plants to restart by year end 2014 and another seven in 2015 (Japan) (Chamber of Mines, 2014).

Although the current spot price is about US$35/lb for uranium oxide, most uranium transactions and mines depend on longer term contracts rather than the spot price, hence the continued development of the Husab mine and the survival of LHU and RUL. Rössing's sales portfolio has a mix of long-term and short-term price exposures including a number of sales contracts running beyond 2017. In April 2014, RUL reported to stakeholders that it has embarked on severe cost-cutting measures, including the retrenchment. In June 2014, it further announced that to survive the low spot price and market over-supply, RUL will only produce sufficient quantities to supply into existing long term contracts

where official prices are US$45/lb. This will make RUL insensitive to further spot price reductions but will still keep options open in the event that spot prices increase significantly.

In 2013, RUL employed about 1,140 employees of whom 98% were Namibian and after the 2014 retrenchments, it now has 901 employees and approximately 500 – 600 contractors. The Rössing mine will require approximately 3 million cubic metres of water per annum (Mm^3/ a) for the next 10 years when the life of mine is expected to end.

The Husab mine is in the construction phase; mining operations have begun to remove the overburden and the processing plant is to be commissioned into operation by the fourth quarter 2015. At full production, it expects to produce 15Mlb of uranium oxide per annum, which will require 8 - 10 Mm^3/ annum of water. It is 90% Chinese-owned and 10% owned by the Namibian State-owned mining company Epangelo Mining Company. The Husab mine expects to provide 1,600 permanent employees (Chinese and Namibian) and a further 8,000 indirect jobs in Namibia through the multiplier effect estimated at seven additional jobs to every mining job. The life of mine for zones 1 and 2 is 20 years. During operations, employees are expected to find housing in the nearby towns of Swakopmund, Arandis and Walvis Bay. It anticipates contributing N$1.1 - 1.7 billion per year in corporate tax including N$220-million per year in royalty payments and pay employee PAYE, duties, withholding and other taxes.

Langer Heinrich Uranium (LHU) has completed two expansions and is now producing uranium oxide at a rate of 5.7Mlb per annum. In January 2014, Paladin entered into an agreement to sell a 25% stake in the Langer Heinrich Mine to a wholly owned subsidiary of China National Nuclear Corporation (CNNC). The offtake component of the agreement allows CNNC to purchase its pro-rata share of product at the prevailing market spot price. There is also opportunity for Paladin to secure additional long-term offtake agreements with CNNC. It is expected that the agreement will enhance the long-term growth and development of the Langer Heinrich operation. A Stage 4 expansion could increase production up to 8.7Mlb uranium oxide per annum, when higher uranium prices occur to justify expansion. Including Stage 4, the life of mine is 17 years.

In 2013, LHU provided jobs for over 1,100 permanent staff and contractors. Its water use in 2012/13 was approximately 2 Mm^3 per annum, supplied from NamWater (1.69 Mm^3/a), a bore field, runoff water collected in the mine pits, and supernatant recovery from the tailings storage facilities. The licence limit for abstraction from the groundwater is 0.5Mm^3 per year although the total abstraction during 2012/13 was 0.28Mm^3 which is 57% of the limit. LHU's water demand would increase to approximately 7 Mm^3 per annum once the Stage 4 expansion is operational.

The Strategic Environmental Assessment for the central Namib Uranium Rush of 2010 constructed various scenarios of mining and associated industrial development up to 2020.

- Scenario 1: the 2010 situation with two operating mines (RUL and Langer Heinrich Uranium and two other mines under construction (Trekkopje and Valencia).
- Scenario 2 included these four mines (and their expansions) plus two others e.g. Bannerman's Etango Project and the Husab mine. It predicted that these projects are likely to be accompanied by the construction of NamWater's desalination plant, an emergency diesel power plant, a 400 mw coal-or gas-fired power station and two chemical plants to supply the mines with reagents.
- Scenario 3 built on Scenario 2 with further expansion of those mines and the addition of at least two more mines, such as Reptile Uranium's Omahola Project and West Australian Metals' Marenica Project.
- Scenario 4 assumed that most or all of the mines will close down at a similar time on an unplanned basis, leaving an un-rehabilitated legacy of mine infrastructure, mass unemployment and excess capacity in all public and private infrastructure (including water supply).

Even with depressed uranium prices, Langer Heinrich and RUL continue to operate and Husab is fast coming on track. These mines require a reliable water supply at a market related price.

5.1.5 Guano Production

There is a commercial guano platform covering 31,000m^2 in one of the northern pans which remains productive. Guano production rates have fallen and this is associated, in part, to the reduction in pelagic shoaling fish species along the coastline, which served as a primary food source for marine birds.

The most common seabird species occupying the guano platforms is the Cape Cormorant. Its ability to move to different breeding localities enables it to take immediate advantage of good feeding conditions that may arise. It produces three eggs per clutch and so it has the potential to increase rapidly in good feeding years while they also decrease rapidly in periods of reduced availability of prey.

5.1.6 Water Supply and Demand

5.1.6.1 Current Supply Options

Current water supply sources in Erongo's coastal region are the Omdel and Kuiseb Aquifers and the desalination plant built and owned by Areva.

The Omdel dam and aquifer recharge scheme was completed in 1994 but its sustainable yield is not fully understood. Based on figures in 2000, NamWater calculated that it has a sustainable yield of 9.8M m^3/a. Water Scarcity Solutions estimated the extractable recharge of Omdel to be about 7.1Mm^3/a. It concluded that by doubling the natural recharge, the scheme enabled the delay in a desalination plant being built which "*permitted the use of newer and more cost-effective desalination technology than would have been possible in 1990*". On 31 October 2013, the Ministry of Agriculture, Water and Forestry (MAWF) formally reduced the permissible Omdel aquifer abstraction from 9Mm^3 to 4.5Mm^3. NamWater in agreement with the MAWF, applied to abstract 5.5 Mm^3/a from Omdel for a period of two years. A permit to that amount has not yet been granted. NamWater has begun to conduct new hydrogeological modelling of the Omdel Dam aquifer which, together with the hydrological modelling already completed, will give them a better figure for its sustainable yield; results are due in April 2015. Current indications are that the 5.5 Mm^3/a figure may have to be revised downwards.

The Department of Water Affairs estimates that the sustainable yield for the active Kuiseb between Swartbank and the Delta is in the order of 7 Mm^3/a" (DWA 2008. p15). As this is the main source for Walvis Bay and its future developments, it is noteworthy only because the DWA cite it as a possible source for LHU: "*The current available natural water resources of the Kuiseb & Omdel scheme, excluding the recent upgrades at Omdel to accommodate Langer Heinrich, are 12.9 Mm^3/a. This can be increased to a max of 15.9 Mm^3/a by developing other natural resources within both catchments*" (DWA 2008 p12).

To conclude, the sustainable yield of aquifer water available for all coastal users ranges from 10.9Mm^3/a (Water Scarcity Solutions) to 12.5Mm^3/a.

The Areva desalination plant was financed by the French government to serve the Trekkopje mine. It was built to serve a capacity of 20 million m^3 per annum and the water inlet pipe and power supply were built to allow for more than double that capacity, at the request of NamWater, with the view of NamWater building a second plant to prepare for the predicted boom years of uranium mining. The construction of the marine intake and discharge structures is a significant component of the capital

cost of a desalination plant. This additional infrastructure could bring the total water production at Wlotzkabaken to 40Mm^3/a. Areva planned that if the Trekkopje mine reached full production, there would still be a surplus of 8Mm^3/a of water available for other users. In the present global climate, the plant is essentially over specified and unlikely to be ever commercially viable.

Since then, NamWater has planned to develop a desalination plant nearer to the mining areas, at Mile 6 with the aim of supplying 15 Mm^3/year to be increased to 25 Mm^3/year as the demand increased. It would have a minimum lifespan of 20 years. If NamWater decided to build that plant, Government would have to raise billions of dollars; the predicted capital cost in 2009 was approximately N$1.8 billion. By April 2014, the project was in an advanced planning stage with three shortlisted bid teams with base offers ranging from US$2.06/m^3 to US$2.31/m^3. However, the Tender Board of Namibia cancelled the tender reportedly saying that "the bidders did not meet tender conditions".

In January 2014, *GWI Desalination* reported that Areva SA has reportedly offered to sell its N$2.9 billion (US$276.3) **plant** to the GRN and Areva wished to retain a 10 to 20 percent stake in the facility. The Government's cancellation of the Mile 6 tender and its apparent silence on Areva's offer to purchase their plant suggests that government does not have the funds to proceed: "*It's not a lack of political will that the project is yet to get off the ground, but a question of the availability of resources as the construction of a desalination plant is not a cheap undertaking*." MWAF Minister John Mutorwa said.

The over-specified Areva plant and therefore its financing, coupled with the current small off-take of 6Mm^3/a, makes the fixed charges and related finance charges very costly to run. Negotiations between Areva and NamWater are not made public but Areva seems to be insisting that NamWater and therefore end users must pay for this over capitalisation. NamWater and the mines have no alternative available water supply so they are forced to accept the unfair and uneconomic prices.

5.1.6.2 Balancing Water Demand and Supply

In 2009, the Erongo Region consumed about 12 Mm^3 of water annually, with the main users being Walvis Bay, 4.3 Mm^3, the RUL mine used 3.3 Mm^3 and Swakopmund used 3 Mm^3.

Currently, demand is very close to the supply capacity. No-one can predict when demand will outstrip supply as over the medium term it depends to a large extent on how much water can be obtained and conveyed from the Areva plant and on how the mining demand will develop. Predictions of mining demand change frequently as the mines adjust their operational plans to adapt to their customers and the sales price.

NamWater is working on the predictions shown in Table 21. It shows that the domestic demand in the coastal region is estimated to be 12.4 Mm^3/a in 2014 and could rise to 14.7Mm^3/a by 2018. The demand in the mining and industrial sectors is predicted to be 5.4Mm^3/a in 2014 and could rise to 13,7Mm^3/a by 2018 with just the certain users, including RUL. When these demand predictions are balanced with the supply, including being supplied 10Mm^3/a from Areva, there could be a shortfall of about 5Mm^3/a in 2016 which would rise to 8Mm^3/a from 2017.

This scenario depends on a number of assumptions about what mining developments will actually take place. If the uranium price were to recover significantly (such as over US$80/lb), development of a number of new mines including Trekkopje, Etango, Omahola and Marenica could significantly increase demand resulting in a further shortfall. If Areva started mining at full production at Trekkopje, it would need 12 Mm^3/a for its own use and therefore only a maximum of 8 Mm^3/a of water would be available for others, increasing the shortfall further.

Table 21. Predicted water demand, sources and surplus for the Erongo Coast

Consumer		Predicted Water Demand (m³)				
		2014*	2015	2016	2017	2018
Domestic Demand	Municipality of Walvis Bay	5,888,343	6,056,760	6,238,463	6,425,617	6,618,385
	NamPort	266,387	271,715	277,149	282,692	288,346
	Smaller consumers fed from Kuiseb	274,074	279,555	285,147	290,849	296,666
	Municipality of Swakopmund	4,298,566	4,803,390	5,151,366	5,305,907	5,465,084
	Municipality of Henties Bay	549,604	577,084	605,938	636,235	668,047
	Arandis Town Council	432,000	480,000	500,000	550,000	605,000
	Smaller consumers fed from Omdel	99,520	101,510	103,541	105,612	107,724
	Plus 5% Losses	590,425	628,501	658,080	679,846	702,463
	Total Domestic/Municipal	**12,398,919**	**13,198,516**	**13,819,684**	**14,276,758**	**14,751,715**
Mining & Industrial Demand	Rössing	2,715,634	2,715,634	2,715,634	2,715,634	2,715,634
	Langer Heinrich	1,677,290	1,438,964	1,426,815	1,441,294	1,441,294
	Husab	775,025	1,661,000	6,201,000	8,419,000	8,600,000
	Zhonghe					
	Sandpiper Phosphate					
	Etango					
	Valencia					
	Omahola					
	Namib Lead & Zinc		50,000	200,000	250,000	250,000
	Plus 5% Losses	258,397	293,280	527,172	641,296	650,346
	Total Mines & Industry	**5,426,346**	**6,158,878**	**11,070,621**	**13,467,224**	**13,657,274**
	Total Domestic & Mines	**17,825,265**	**19,357,393**	**24,890,305**	**27,743,982**	**28,408,990**
Sources	Omdel	5,500,000	5,500,000	2,700,000	2,700,000	2,700,000
	Kuiseb	7,000,000	7,000,000	7,000,000	7,000,000	7,000,000
	Swartbank J-line					
	New Source - Areva	5,426,000	5,426,000	10,000,000	10,000,000	10,000,000
	Total Sources	**17,926,000**	**17,926,000**	**19,700,000**	**19,700,000**	**19,700,000**
	Total Surplus	**100,735**	**-1,431,393**	**-5,190,305**	**-8,043,982**	**-8,708,990**

Note: * calendar year starting in January.

5.1.6.3 Water Tariffs

NamWater supplies the Swakopmund, Arandis, and Henties Bay municipalities with Omdel aquifer water, and currently only the mines receive the very expensive desalinated water. NamWater and Municipalities have significantly increased their charges above inflation in recent years. Water Scarcity Solutions estimated the cost of Omdel water is N$2.5/m^3 (WSS 2013). Swakopmund water tariffs for domestic and business users are similar, with the lowest cost being about N$7/m^3. Domestic tariffs increased from May 2014 to the following (pers. comm. Swakopmund Municipality):

0-9 m^3	N$61.75
9m³-30 m³	N$11.65/m^3
30m³-60 m³	N$16.30/m^3
60 m³ and above	N$24.10/ m^3

In 2011, NamWater added a 15% mark-up to its conveyancing cost to the mines only. NamWater did not reply to our request for information but it is possible that this mark-up not only contributes to coastal water infrastructure but it could also subsidise other users in the region or elsewhere in the country.

The three mines (RUL, LHU and Husab) in operation / development currently require approximately 6Mm^3/a, and the demand will grow to approximately 12.5Mm^3/pa over the next three years. The smaller off-take than the Areva plant was built for makes the repayment of investment costs - the fixed charges and related finance charges very costly. As RUL uses approximately half of the current

off-take, it effectively carries half the cost of this plant. Rössing is currently paying N$45 to N$50/m^3 for desalinated water. However, these contracts are on a take or pay basis and therefore during periods of low usage, the actual water cost exceeded N$90/$m^3$.

In 2012 (the last full year on aquifer water), RUL's water cost was N$39 million. In 2014 (the first full year on desalinated water), the cost for water is expected to be N$129 million. For RUL, this is a commercially unsustainable situation and hence it proposes a smaller, more efficient desalination plant. RUL's preliminary indications are that it can produce water at below US$2.50/$m^3$ (~N$29/$m^3$), before conveyancing costs. (The accepted benchmark for desalinated water is between US$2.00/$m^3$ and US$2.50/$m^3$). This is substantially less than the existing water price, which has been well above US$4/$m^3$ (~N$40/$m^3$), before conveyancing costs. (As the cost of conveyancing will exist whether it is Areva's water or RUL-produced water, RUL assumes conveyancing costs to be cost neutral). By constructing its own desalination plant, RUL is anticipating a saving in water costs of approximately N$30m to N$50m per year against the current water cost.

The key issues revolve around inadequate supply of desalinated water, as well as the cost at which it is or can be produced and sold to users.

5.2 PHYSICAL ENVIRONMENT

5.2.1 Surrounding landuses

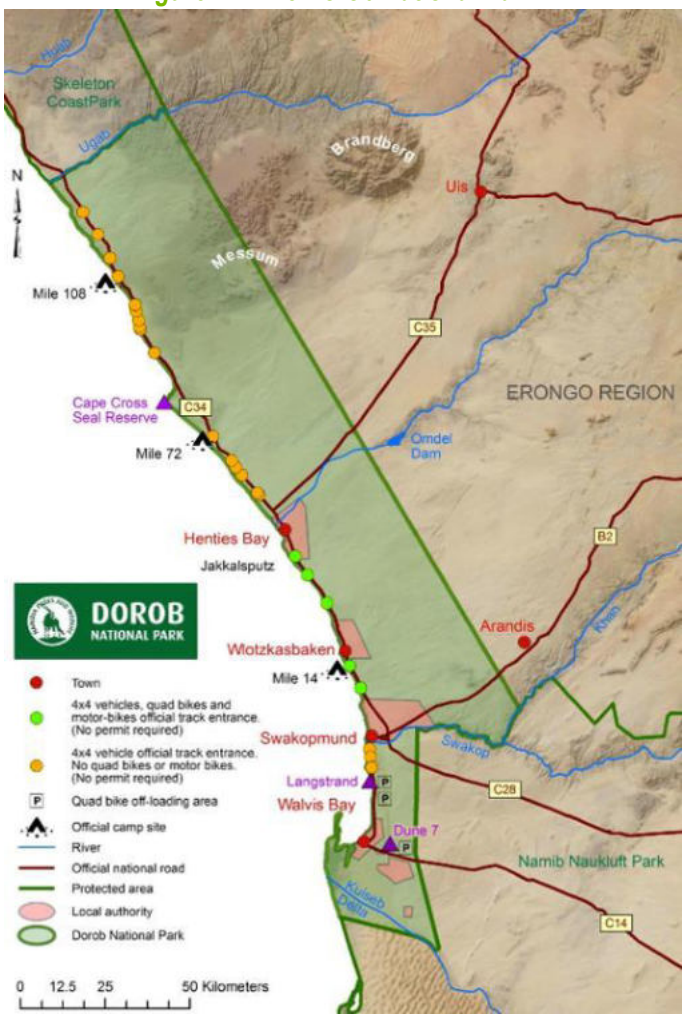
The proposed project is situated within the Swakopmund Salt Works. The primary landuse associated with the salt pans is the production of salt, guano, and oysters. The site is also a private nature reserve and is identified as an important bird area, and is frequented by a variety of marine bird species. The gravel plains surrounding the salt pans are used as nesting sites by the Damara Tern, which is a breeding endemic seabird, globally Near Threatened and also Near Threatened in Namibia.

East of the site is the C34, a secondary route providing a scenic drive to Henties Bay along the coastline. The road is a popular tourist route and provides access to the Dorob National Park and its natural attractions, associated recreation areas and tourism facilities.

Dorob National Park (Dorob meaning "dry land") is a 1,600km long strip of land, encompassing a spectacular coastal dune belt, vast gravel plains, rich botanical diversity (including extensive lichen fields), major ephemeral river systems and their river mouths and Namibia's richest coastal area for birds. Some 75 species of birds flock to this coast, with nearly 1.6 million birds recorded here at times[22]. Apart from several Ramsar listed wetlands, the Dorob has been included under the category of "Important Bird Areas" by BirdLife International. The Damara Tern is considered a flagship species of the coastal area. It is found in the park, although non-breeding individuals will migrate to the north in winter. Figure 41 provides a map of the Dorob National Park and the major natural features and tourist attractions of the region.

[22] Source: http://travelnewsnamibia.com/news/2012-2013-rules-regulations-dorob-national-park/#.UYdhYb26ZLM

Figure 41: The Dorob National Park[23]



The town of Swakopmund is expanding, and is generally moving northward along the coastline, toward the Swakopmund Salt Works. The Swakop River and dune systems to the south of Swakopmund act as a natural barrier to town expansion. The town of Swakopmund has a rich heritage and is characterised by a Germanic and European influenced architecture, adding to its tourism appeal. Traditionally a coastal resort town, Swakopmund has seen significant growth due to its proximity to the uranium mining areas of the Erongo Region. Uranium mining in the area grew rapidly as a result of favourable global uranium market prices, although this growth has subsided as a result of changing market conditions. Numerous migrant workers seeking jobs with the mines, or commercial fishing and associated industries, have taken up residence in the towns of Swakopmund and Walvis Bay, which has spurred the rapid growth of both towns. A number of mining support enterprises have also established themselves in Swakopmund and use it as a base from where to serve the major mining operations in the area.

The Benguela upwelling supports a significant commercial fishing industry. Fishing trawlers and associated industry are mostly based in Walvis Bay due to the port facilities. Natural fish stocks are however declining and the fishing industry are likely to diminish, with a few fish processing facilities already having closed operations. In the face of declining fishing stocks, mariculture has been

[23] *Source: http://stories.namibiatourism.com.na/blog/bid/352325/The-National-Parks-of-Namibia-Nkasa-Lupala-and-Dorob*

identified as a good diversification strategy for the industry and investigations into this avenue continue and are likely to witness a growing impetus.

5.2.2 Climate

Swakopmund's climate is strongly moderated by its proximity to the Atlantic Ocean and the associated cold Benguela current which brings cold water up from the Polar Regions and flows along the Namibian coastline. Swakopmund has a cool, hyper arid desert climate with very little rainfall throughout the year (average annual rainfall is a mere 11mm). Most rainfall occurs in March and August is the driest month. The average annual temperature is 15.3°C. The warmest month is February with an average temperature of 18.3°C compared to August, which is the coldest month, with an average temperature of 12.9°C (Climate-Data.org, 2014). The highest temperatures recorded (up to 40°C) typically only occur during the winter months and are associated with bergwind conditions which blow hot and dry air from the inland areas. The average diurnal meteorological parameters for the area are included in Table 22.

A thick coastal fog is a frequent occurrence along the Namibian coast and provides sufficient moisture for a number of highly adapted fauna and flora species to survive in the arid environment. The fog extends inland as far as 50km (World Wildlife Fund, 2014). Fog occurs more frequently along the Central Namib Desert coast than elsewhere, probably due to the upwelling off that part of the coast. An average of 146 days of fog per year has been recorded at Walvis Bay (Mendelsohn *et al*. 2002). Of relevance to this project is that the heavy fog combined with ocean salt spray, results in a highly corrosive environment near the coast and all equipment, structures, and facilities must be designed to contend with this environment.

24 hour average wind speed and wind direction data for Swakopmund (2001 to 2006) was also supplied for use in the study. A distinction between the wind field during the day and night can however not be made from 24 hour average data. Hourly data recorded at Wlotzkasbaken were applied in calculations. The diurnal wind field at Wlotzkasbaken, the nearest representative meteorological station is presented in Figure 42.

Table 22: Average diurnal meteorological parameters

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

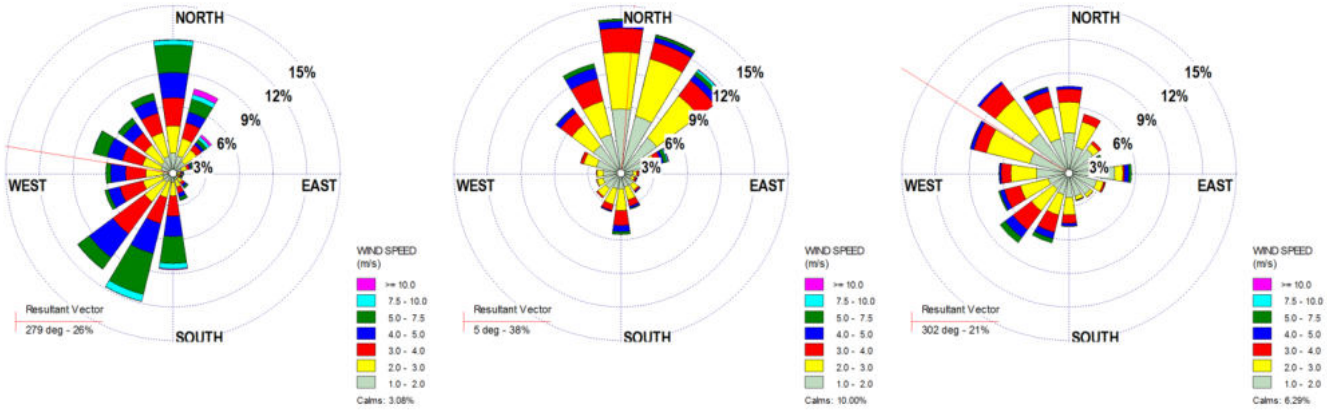
Notes:

(a) Since NSR are all located to the south of the proposed desalination plant, a wind direction of 0° will be considered in the assessment.

(b) Air pressure at 0 m above sea level.

(c) Relative humidity should not be higher than 100%. Values in brackets are what was reported in Wlotzkasbaken data. The maximum of 100% was applied in calculations.

Figure 42: Wind roses



(a) Wlotzkasbaken day-time wind rose (07:00 to 22:00) **(b) Wlotzkasbaken night-time wind rose (22:00 to 07:00)** **(c) Swakopmund period average wind rose from 24-hour average data**

5.2.3 Geology and geomorphology

The geology of the Swakopmund area is characterised by schists and dolomites of the Swakop Group, falling within the Damara Supergroup and Gariep Complex, with Damara Granites and Kalahari and Namib Sands. Extensive gypsum and calcrete deposits have developed in low lying areas. Gypsum plains are found within 60km of the coast and generally coincide with the regular fog zone (CSIR, 2009). The dominant landscape is mainly Central-western Plains. Broad geomorphological characteristics include a shore of mixed sand and rock, with gravelly coastal plains in the study area, with the Arandis Mountain (just over 600m high) further to the east and a narrow dune belt further to the south. Natural surface water is limited to drainage lines and coastal pans. To the south lies the Swakop River Valley, deeply incised by an ephemeral river. Man-made aquatic habitats in the vicinity of the study area include the Swakopmund Salt Works and Municipal sewage works.

5.2.4 Topography

The Swakopmund Salt Works is situated in the Central-Western Plains, on a gently sloping, low relief coastal plain. The Swakopmund Salt Works is characterised by an absence of topographical features and takes advantage of a natural depression in local topography which facilitates its use for salt evaporation ponds. The evaporation pans cover approximately 4km^2 representing an area of naturally low elevation bounded on the western, or seaward, side by a wide bar of sandy gravel. This latter feature appears to have been augmented by artificial embankment construction, but remains a largely natural remnant of a late Pleistocene sea level high stand. The area occupied by the evaporation pans may represent a palaeo-lagoon feature associated with a series of sea level high stands, which is associated with evidence of a 2.5m sea level rise at several points on the Namib coast. The low relief character and particularly the vertical proximity to the ocean is advantageous for the purposes of a desalination plant, as seawater does not have to be pumped to a significant height, which adds to the electrical efficiency of the facility.

Figure 43 provides a view of the proposed desalination plant site with the Salt Works evaporation ponds in the background and reveals the near featureless landscape that characterises the area.

Figure 43: General view of the Base Case desalination plant site

5.2.5 Soils

The soils surrounding the Swakopmund Salt Works can be described as Petric Gypsisols, and Petric Calcysols (Mendelsohn *et al.* 2002). Together with a challenging climate, these are regarded as having a low agricultural potential (Ministry of Environment and Tourism, 2002). The coastline is characterised by deep, sandy, poor, and fragile soils that are prone to degradation. Soil conservation is of critical importance in these areas, where vegetation is sparse, leaving the soil exposed to the elements and erosive forces. Lichens play an important role in paedogenesis and soil stabilisation through their contribution to the formation of biological soil crusts in the Namib Desert areas. The lichens are however prone to disturbance by man and are very slow to recover from disturbances.

The coastline of central Namibia is dominated by sandy beaches, with rocky habitats being represented only by occasional rocky outcrops. The beaches surrounding the project area are also littered with gravel and cobble stones and the sea sand is described as damp, light yellowish brown, very loose, medium to fine sand dispersed with darker mineral sands, as shown in Figure 44.

Figure 44: View of the beach areas of the Swakopmund Salt Works area

5.2.6 Hydrology

There are a number of poorly defined ephemeral drainage lines in the area which drain the stormwater toward the salt pans and ocean. As a result of the low annual precipitation, the region is characterised by a lack of surface water features. The nearest river of significance is the Swakop River which is a non-perennial river situated south of Swakopmund, approximately 10km to the south of the proposed project. The project is unlikely to impact on surface freshwater features and standard engineering protocols will be applied with regard to stormwater controls.

Groundwater reserves in the vicinity of the study area are limited to the Kuiseb, Swakop, and Omaruru alluvial bed aquifers of the Erongo groundwater basin, which supply Henties Bay, Swakopmund and Walvis Bay as well as Arandis, and historically Rössing Uranium and Langer Heinrich Mines (CSIR, 2009). A groundwater study undertaken for the Wlotzkasbaken desalination plant, 30km north of Swakopmund, detected no freshwater table at the beach, and seawater penetrated inland to at least 500m from the high water mark at a depth of 1.5m. The salt water intrusion is expected to be greater in the areas surrounding the Swakopmund Salt Works as a result of the salt evaporation ponds and an associated infiltration of seawater, and in some instances concentrated seawater, into the soils.

5.2.7 Oceanography[24]

5.2.7.1 Seabed Topography, Bathymetry and Sediments

The coastal strip around Swakopmund is covered by a 2m to 3m thick layer of very loose, medium to fine grained sea sand, which stretches approximately 200m inland. Only in the vicinity of Henties Bay is the shore backed by low sandy cliffs.

As part of the pre-feasibility phase for the NamWater Desalination Plant Project, the CSIR (CSIR, 2008) conducted a geophysical and hydrographical survey of the area directly north of the Salt Works using sub-bottom profiling and echo sounding. Although the Salt Works are located on a slight promontory, it is expected that the bathymetry offshore will be very similar to that recorded during the NamWater Study. This bathymetric data showed a gently sloping seabed reaching the -10m depth contour at around 1,700m offshore. No bathymetric data are available for depths inshore

[24] *Section written by Dr Andrea Pulfrich of Pisces Environmental and Christoph Soltau of WSP Coastal Engineers.*

of -3m to -4m contour, but existing information suggests a rock plate sloping very gently into the intertidal area. This rocky shelf is prominent between the old concrete intake structure and the current seawater intake for the Swakopmund Salt Works, and to the western-most point of the Salt Works (Figure 45a), becoming patchy further south (Figure 45b). Offshore blinders occur to the west and south of the old bitterns' disposal site. There is a prominent berm on the upper beach along much of the coastline (Figure 45c). From there, the beach slopes steeply to the low water mark.

Figure 45: The coastline west of the Salt Works[25]

a)

b)

c)

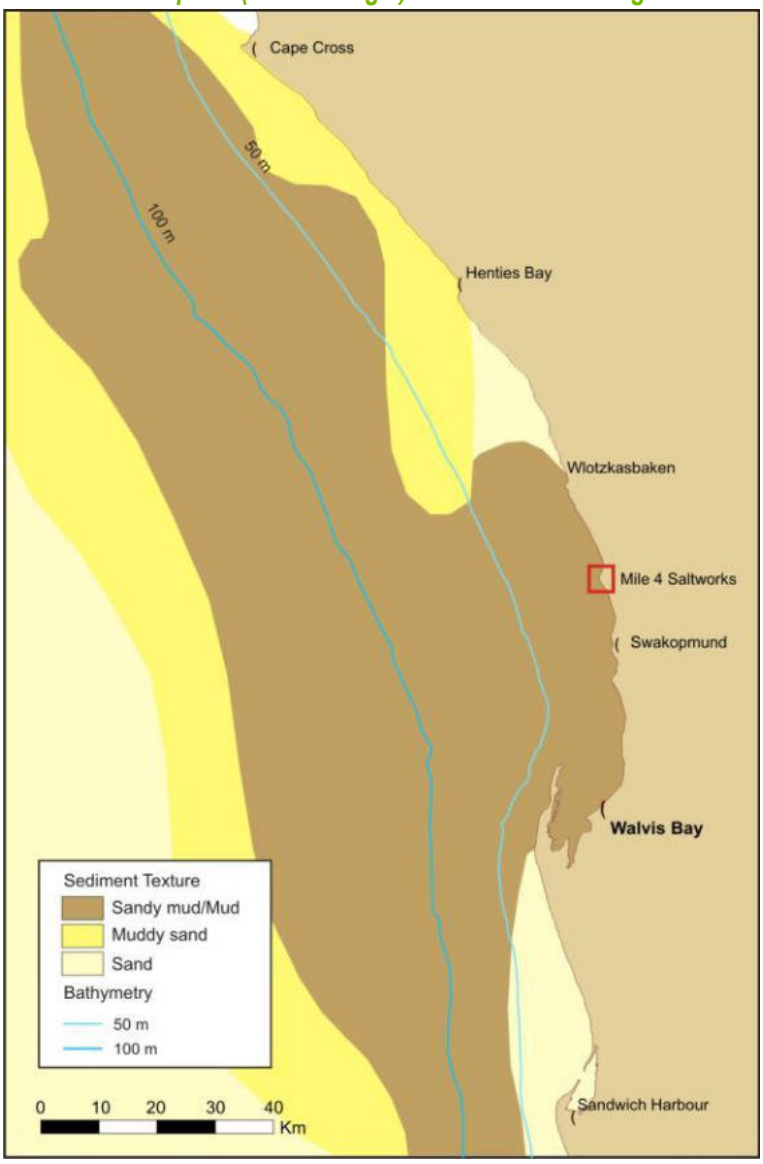
The surficial sediments in the intertidal and low-shore areas are generally dominated by moderately to well-sorted fine to medium sand with median particle sizes of 200µm to 400µm and heavy minerals present in the sediments. In the south of the study area, the sediments become coarser and can contain substantial proportions of gravel and pebbles, with occasional extensive pebble beds in the mid- and low-shore (Figure 45c).

[25] *Notes: The coastline is characterised by a rocky intertidal shelf in the north, and pebble beaches with a prominent berm further south (Photos: Christoph Soltau, WSP Coastal Engineers).*

Further offshore, the seafloor is dominated by undulated rock or hard sediment with occasional rock outcrops or reefs running either parallel or at an angle to the coastline. The rock surface appears rough with a micro relief of approximately 0.5m to1.0m. Sandy areas are sparse, and generally occur in small isolated patches scattered over the area. The sediment accumulations are thin with a maximum observed thickness of 1.8m.

Further offshore, beyond the -100m depth contour, the seabed is dominated by a tongue of sandy mud, which extends from south of Sandwich Harbour to the north past Henties Bay (Figure 46) These biogenic muds, which comprise organically rich diatomaceous oozes originating from planktonic detritus, are the main determinants of the formation of low-oxygen waters and sulphur eruptions off central Namibia.

Figure 46: The proposed desalination plant (red rectangle) in relation to the regional offshore seabed sediments



The central Namibian continental shelf is covered by layers of sediments primarily of biogenic (biological) origin as a result of the high productivity in the upwelled waters. A significant feature of the central Namibian middle shelf is an extensive mud belt.

5.2.7.2 Waves

The central Namibian coastline is influenced by major swells generated in the Roaring Forties, as well as significant sea waves generated locally by the persistent south-westerly winds. Apart from

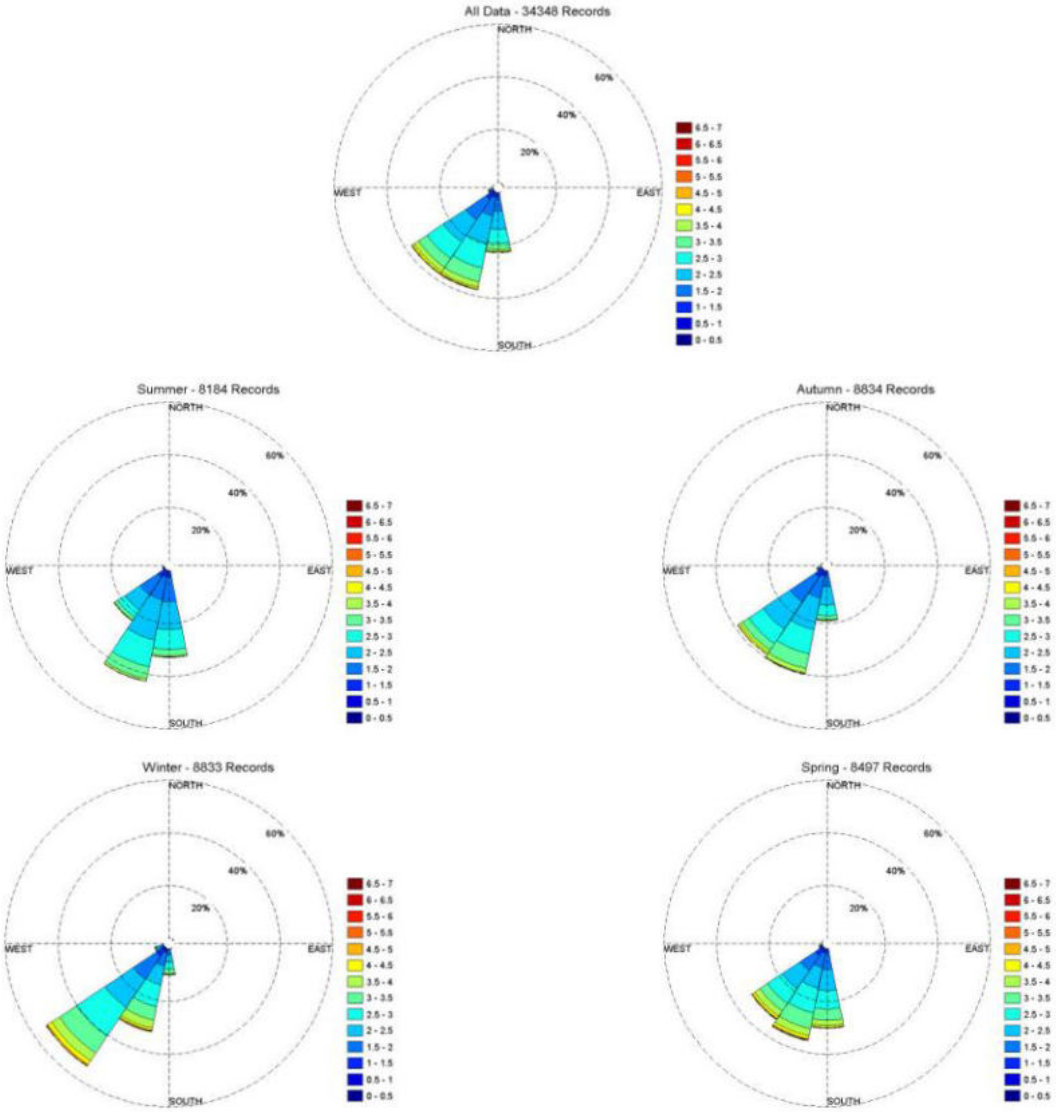
Walvis Bay and Swakopmund, wave shelter in the form of west to north-facing embayments, and coast lying in the lee of headlands are extremely limited.

No measured wave data are available for the Swakopmund to Henties Bay area. However, data collected by voluntary observing ships indicate that wave heights in the range of 1.5m to 2.5m occur most frequently, with a mean wave height of 2.14m and mean wave periods in the range of 8s to 13s (Figure 47). Longer period swells with mean periods of 11s to 15s generated by mid-latitude cyclones, occur about 30% of the time.

Wind-induced waves on the other hand have shorter wave periods (approximately 8s), and are generally steeper than swell-induced waves. Storms occur frequently with significant wave heights over 3m occurring 10% of the time. The largest waves recorded originate from the south to southwest sectors and may attain 4 to 6m.

The annual distribution indicates that 43% of the waves come from the south. There is no strong seasonal variation in the wave regime except for slight increases in swell from west-southwest to west direction in winter.

Figure 47: Seasonal offshore wave conditions[26]



5.2.7.3 Tides

In common with the rest of the southern African coast, tides in the study area are regular and semi-diurnal. The maximum tidal variation is approximately 2m, with a typical tidal variation of approximately 1m. Variations of the absolute water level as a result of meteorological conditions such as wind and waves can, however, occur adjacent to the shoreline and differences of up to 0.5m in level from the tidal predictions are not uncommon. Tidal currents are minimal with measurements of 0.1m/s reported at Walvis Bay. Table 23 lists mean tidal levels for Walvis Bay.

[26] *Notes: Data point located at 23° S, 13.75°E (CSIR, 2009).*

Table 23: Tide statistics for Walvis Bay[27]

DESCRIPTION	LEVEL IN M
Highest Astronomical Tide	+1.97
Mean High Water of Spring Tide	+1.69
Mean High Water of Neap Tide	+1.29
Mean Level	+0.98
Mean Sea Level	+0.97
Mean Low Water of Neap Tide	+0.67
Mean Low Water of Spring Tide	+0.27
Lowest Astronomical Tide	0.00

5.2.7.4 Coastal Currents

Current velocities in continental shelf areas of the Benguela region range generally between 10cm/s to 30cm/s (Boyd & Oberholster, 1994). The flows are predominantly wind-forced, barotropic and fluctuate between poleward and equatorward flow (Hutchings & Nelson, 1983) and (Shillington, et al., 1990). Fluctuation periods of these flows are 3 to10 days, although the long-term mean current residual is in an approximate northwestern (alongshore) direction. Currents in the nearshore environment along the coastline of the study area have not been well studied, but some surface-current measurements were done at Swakopmund between 1971 and 1972 (CSIR, 2005). Surface currents in the area appear to be quite variable, with flows primarily less than 30cm/s and an average velocity of 14cm/s. Current speeds in reverse flows observed between Walvis Bay and Henties Bay range between 2cm/s to 17cm/s. Near bottom shelf flow is mainly poleward (Nelson, 1989) with low velocities of typically 5cm/s.

5.2.7.5 Surf-zone Currents

Typically wave-driven flows dominate in the surf-zone (characteristically 150m to 250m wide), with the influence of waves on currents extending out to the base of the wave effect (approximately 40m) (Rogers, 1991). 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. Surf-zone currents have the ability to transport unconsolidated sediments along the coast in the northward littoral drift.

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 between 0.2m/s to 0.5m/s. Instantaneous measurements of cross-shore averaged longshore velocities are often much larger. Surf-zone-averaged longshore velocities in other exposed coastal regions commonly peak at

[27] *Note: All levels are referenced to Chart Datum. Source: (South African Navy, 2007)*

between 1.0m/s to 1.5m/s, with extremes exceeding 2m/s for high wave conditions (CSIR, 2002). The southerly longshore flows are considered to remain below 0.5m/s.

5.2.7.6 Upwelling

The major feature of the Benguela system is upwelling and the consequent high nutrient supply to surface waters leads to high biological production and large fish stocks. The prevailing longshore, equatorward winds move nearshore surface water northwards and offshore. To balance the displaced water, cold, deeper water wells up inshore. Although the rate and intensity of upwelling fluctuates with seasonal variations in wind patterns, the most intense upwelling tends to occur where the shelf is narrowest and the wind strongest. The largest and most intense upwelling cell is in the vicinity of Lüderitz, and upwelling can occur there throughout the year (Figure 48). Off northern and central Namibia, secondary upwelling cells occur. Upwelling in these cells is perennial, with a late winter maximum (Shannon L.V., 1985).

5.2.7.7 Water Masses and Temperature

South Atlantic Central Water comprises the bulk of the seawater in the study area, either in its pure form in the deeper regions, or mixed with previously upwelled water of the same origin on the continental shelf (Hutchings & Nelson, 1983). Salinities range between 34.5‰ and 35.5‰ (Shannon L.V., 1985). Data recorded over a ten year period at Swakopmund (1988 to 1998) show that seawater temperatures vary between 10°C and 23°C, averaging 14.9°C. They show a strong seasonality with lowest temperatures occurring during winter when upwelling is at a maximum (Figure 49).

During the non-upwelling season in summer, daily seawater temperature fluctuations of several degrees are common along the central Namibian nearshore coast. It appears that the thermal regime of the surf-zone is controlled by locally-forced offshore transport, which leads the associated temperature fluctuations by one day (Hagen & Bartholomae, 2007). This time-lag suggests the existence of a persistent recirculation cell in nearshore waters in this region.

Figure 48: The location in relation to the upwelling cells and the formation zones of low oxygen water

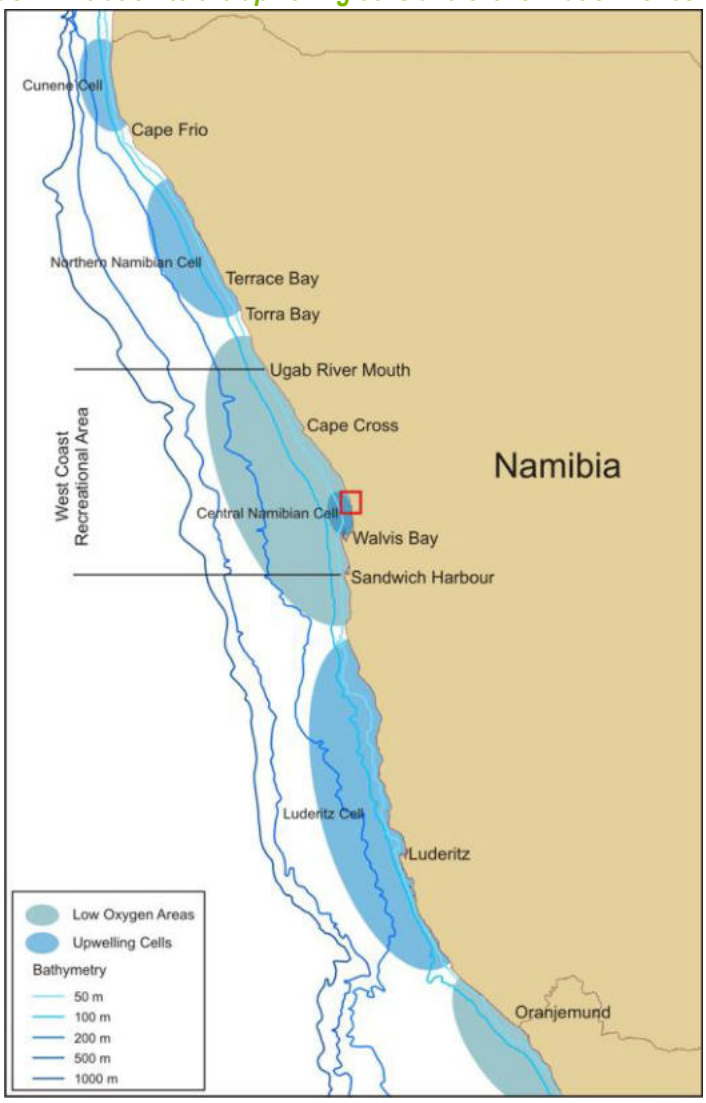
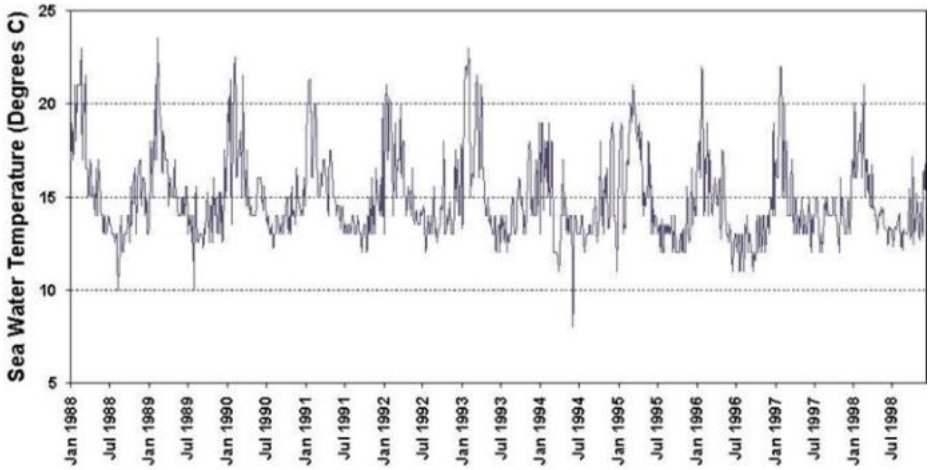


Figure 49: Seawater temperatures at Swakopmund recorded between 1988 and 1998



The continental shelf waters of the Benguela system are characterised by low oxygen concentrations, especially on the bottom. The South Atlantic Central Water itself has depressed oxygen concentrations (approximately 80% saturation value), but lower oxygen concentrations (of less than 40% saturation) frequently occur (Visser, 1969), (Bailey, Beyers, & Lipschitz, 1985) and (Chapman & Shannon, 1985).

Nutrient concentrations of upwelled water of the Benguela system attain 20µM nitrate-nitrogen, 1.5µM phosphate, and 15µM to 20µM silicate, indicating nutrient enrichment (Chapman & Shannon,

1985). This is mediated by nutrient regeneration from biogenic material in the sediments (Bailey, Beyers, & Lipschitz, 1985). Modification of these peak concentrations depends upon phytoplankton uptake which varies according to phytoplankton biomass and production rate. The range of nutrient concentrations can thus be large, but in general concentrations are high.

5.2.7.8 Turbidity

Turbidity is a measure of the degree to which the water transparency is lost due to the presence of suspended particulate matter. Total Suspended Particulate Matter is typically divided into Particulate Organic Matter and Particulate Inorganic Matter and the ratios between them varying considerably. The Particulate Organic Matter usually consists of detritus, bacteria, phytoplankton and zooplankton, and serves as a source of food for filter-feeders. Seasonal microphyte production associated with upwelling events will play an important role in determining the concentrations of Particulate Organic Matter in coastal waters. Particulate Inorganic Matter, on the other hand, is primarily of geological origin consisting of fine sands, silts, and clays. Particulate Inorganic Matter loading in nearshore waters is strongly related to natural inputs from rivers or from bergwind events, or through re-suspension of material on the seabed.

Concentrations of suspended particulate matter in shallow coastal waters can vary both spatially and temporally, typically ranging from a few mg/ℓ to several tens of mg/ℓ (Bricelj & Malouf, 1984), (Berg & Newell, 1986) and (Fegley, Macdonald, & Jacobsen, 1992). Field measurements of Total Suspended Particulate Matter and Particulate Inorganic Matter concentrations in the Benguela current system have indicated that outside of major flood events, background concentrations of coastal and continental shelf suspended sediments are generally less than 12mg/ℓ, showing significant long-shore variation (Zoutendyk, Turbid water in the Elizabeth Bay region: A review of the relevant literature, 1992) and (Zoutendyk, 1995). Considerably higher concentrations of Particulate Inorganic Matter have, however, been reported from southern African west coast waters under stronger wave conditions associated with high tides and storms, or under flood conditions.

The major source of turbidity in the swell-influenced nearshore areas off Namibia is the redistribution of fine inner shelf sediments by long-period Southern Ocean swells. The current velocities typical of the Benguela (10cm/s to 30cm/s) are capable of re-suspending and transporting considerable quantities of sediment equator wards. Under relatively calm wind conditions, however, much of the suspended fraction (silt and clay) that remains in suspension for longer periods becomes entrained in the slow poleward undercurrent (Shillington, et al., 1990) and (Bremmer & Rogers, 1991).

Superimposed on the suspended fine fraction, is the northward littoral drift of coarser bedload sediments, parallel to the coastline. This northward, nearshore transport is generated by the predominantly south-westerly swell and wind-induced waves. Longshore sediment transport, however, varies considerably in the shore-perpendicular dimension. Sediment transport in the surf-zone is much higher than at depth, due to high turbulence and convective flows associated with breaking waves, which suspend and mobilise sediment (Smith & Mocke, 2002).

On the inner and middle continental shelf, the ambient currents are insufficient to transport coarse sediments, and re-suspension and shoreward movement of these by wave-induced currents occur primarily under storm conditions (Drake *et al.* 1985 and Ward 1985).

The powerful easterly bergwinds occurring along the Namibian coastline in autumn and winter also play a significant role in sediment input into the coastal marine environment (Figure 50), potentially contributing the same order of magnitude of sediment input as the annual estimated input of sediment by the Orange River (Zoutendyk, 1992). For example, for a single bergwind event it was estimated that 50 million tons of dust were blown into the sea by extensive sandstorms along much

of the coast from Cape Frio (Namibia) in the north to Kleinzee, (South Africa) in the south (Shannon & O'Toole, 1982) with transport of the sediments up to 150km offshore.

Figure 50: Satellite image showing dust plumes being blown offshore from the Namibia coast[28]

5.2.7.9 Organic Inputs

The Benguela upwelling region is an area of particularly high natural productivity, with extremely high seasonal production of phytoplankton and zooplankton. These plankton blooms in turn serve as the basis for a rich food chain up through pelagic baitfish (anchovy, pilchard, round-herring and others), to predatory fish (snoek), mammals (primarily seals and dolphins) and seabirds (jackass penguins, cormorants, pelicans, terns and others). All of these species are subject to natural mortality, and a proportion of the annual production of all these trophic levels, particularly the plankton communities, die naturally and sink to the seabed.

Balanced multispecies ecosystem models have estimated that during the 1990s the Benguela region supported biomasses of 76.9t/km^2 of phytoplankton and 31.5t/km^2 of zooplankton alone (Shannon *et al*., 2003). Thirty six percent of the phytoplankton and 5% of the zooplankton are estimated to be lost to the seabed annually. This natural annual input of millions of tons of organic material onto the seabed off the southern African west coast has a substantial effect on the ecosystems of the Benguela region. It provides most of the food requirements of the particulate and filter-feeding benthic communities that inhabit the sandy-muds of this area, and results in the high organic content of the muds in the region. As most of the organic detritus is not directly consumed, it enters the seabed decomposition cycle, resulting in subsequent depletion of oxygen in deeper waters overlying these muds and the generation of hydrogen sulphide and sulphur eruptions along the coast.

An associated phenomenon ubiquitous to the Benguela system is red tides (dinoflagellate and/or ciliate blooms) (Shannon and Pillar, 1985 and Pitcher 1998). Also referred to as harmful algal blooms, these red tides can reach very large proportions, sometimes with spectacular effects. Toxic dinoflagellate species can cause extensive mortalities of fish and shellfish through direct poisoning, while degradation of organic-rich material derived from both toxic and non-toxic blooms results in oxygen depletion of subsurface water. Periodic low oxygen events associated with massive algal blooms in the nearshore can have catastrophic effects on the biota.

[28] Source: www.intute.ac.uk

5.2.7.10 Low Oxygen Events

The low oxygen concentrations are attributed to nutrient remineralisation in the bottom waters of the system (Chapman & Shannon, 1985). The absolute rate of this is dependent upon the net organic material build-up in the sediments, with the carbon rich mud deposits playing an important role. As the mud on the shelf is distributed in discrete patches, there are corresponding preferential areas for the formation of oxygen-poor water, the main one being off central Namibia (Chapman & Shannon, 1985). The distribution of oxygen-poor water is subject to short (daily) and medium term (seasonal) variability in the volumes of oxygen depleted water that develops (De Decker, 1970) and (Bailey and Chapman 1991). Subsequent upwelling processes can move this low-oxygen water up onto the inner shelf, and into nearshore waters, often with devastating effects on marine communities.

Oxygen deficient water can affect the marine biota at two levels. It can have sub-lethal effects, such as reduced growth and feeding, and an increased intermoult period specifically in the rock-lobster population (Beyers *et al.* 1994). The oxygen-depleted subsurface waters, characteristic of the southern and central Namibian shelf, are an important factor determining the distribution of rock lobster in the area. During the summer months of upwelling, lobsters show a seasonal inshore migration (Pollock and Shannon, 1987) and during periods of low oxygen become concentrated in shallower, better-oxygenated nearshore waters.

On a larger scale, periodic low oxygen events in the nearshore region can have catastrophic effects on the marine communities. Low-oxygen events associated with massive algal blooms can lead to large-scale stranding of rock lobsters, and mass mortalities of other marine biota and fish (Newman and Pollock, 1974; Matthews and Pitcher, 1996; Pitcher, 1998; Cockroft *et al.,* 2000). Very recently, in March 2008, a series of red tide or algal blooms dominated by the (non-toxic) dinoflagellate *Ceratium furca* occurred along the central Namibian coast (MFMR, 2008). These bloom formations ended in disaster for many coastal marine species and resulted in what was possibly the largest rock lobster walkout in recent memory (Figure 51). Other fish mortalities included those of rock suckers, rock fish, sole, eels, shy sharks, and other animals such as octopuses and red bait, which were trapped in the low oxygen area below the surf zone (Louw, 2008). The main cause for these mortalities and walkouts is oxygen starvation that results from the decomposition of huge amounts of organic matter. The blooms developed during a time where high temperatures combined with a lack of wind. These anoxic conditions were further exacerbated by the release of hydrogen sulphide - which is highly toxic to most marine organisms. Algal blooms usually occur during summer to autumn (February to April) but can also develop in winter during the bergwind periods, when similar warm windless conditions occur for extended periods.

Figure 51: 'Walk-outs' and mass mortalities of rock lobsters at the central Namibian coast[29]

5.2.7.11 Sulphur Eruptions

Closely associated with seafloor hypoxia, particularly off central Namibia between Cape Cross and Conception Bay, is the generation of toxic hydrogen sulphide and methane within the organically-rich, anoxic muds following decay of expansive algal blooms. Under conditions of severe oxygen depletion, hydrogen sulphide (H_2S) gas is formed by anaerobic bacteria in anoxic seabed muds (Brüchert *et al.* 2003). This is periodically released from the muds as sulphur eruptions, causing upwelling of anoxic water and formation of surface slicks of sulphur discoloured water (Emeis *et al,.* 2004), and even the temporary formation of floating mud islands (Waldron, 1901). Such eruptions are accompanied by a characteristic pungent smell along the coast and the sea takes on a lime green colour. These eruptions strip dissolved oxygen from the surrounding water column. Such complex chemical and biological processes are often associated with the occurrence of harmful algal blooms, causing large-scale mortalities to fish and crustaceans.

Sulphur eruptions have been known to occur off the Namibian coast for centuries (Waldron, 1901), and the biota in the area are likely to be naturally adapted to such pulsed events, and to subsequent hypoxia. However, satellite remote sensing has recently shown that eruptions occur more frequently, are more extensive and of longer duration than previously suspected, and that resultant hypoxic conditions last longer than thought (Weeks *et al.,* 2004).

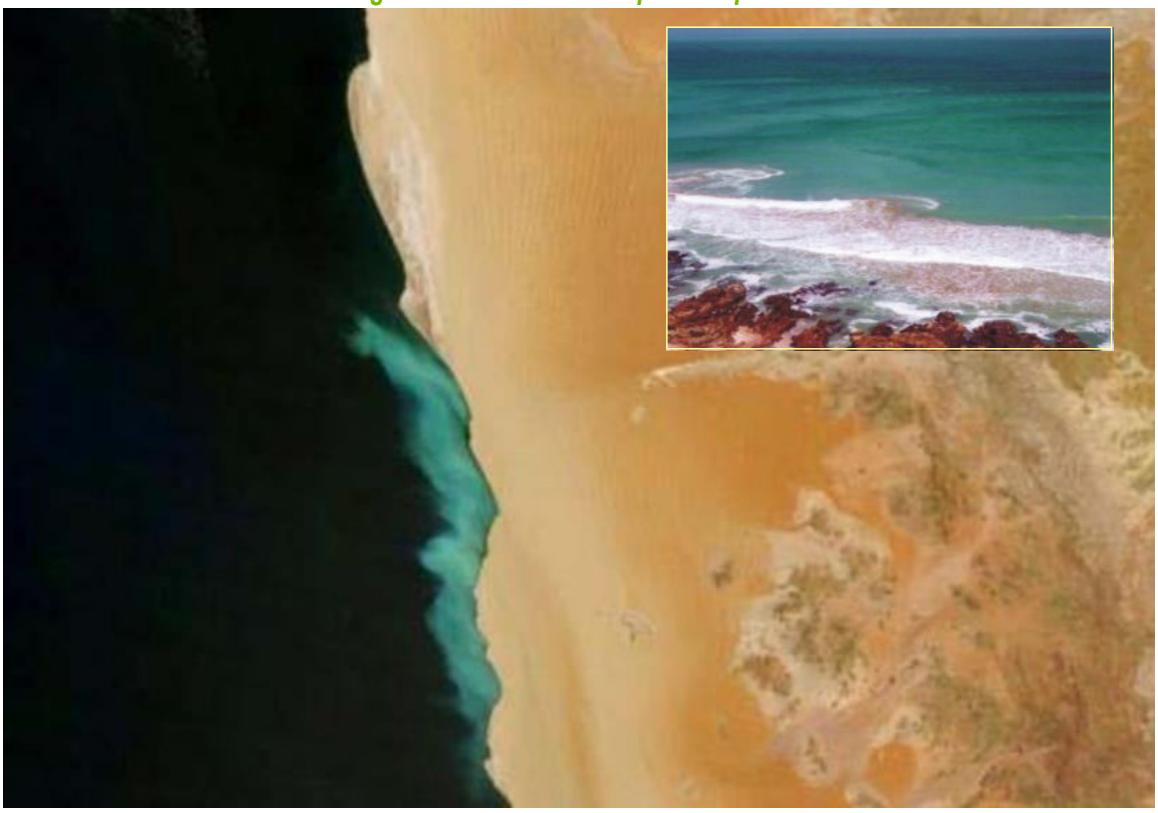
Recently, the role of micro-organisms in the detoxification of sulphidic water was investigated by a collaborative group of German and Namibian scientists[30]. During a research cruise in January 2004, the scientists hit upon a sulphidic water mass off the coast off Namibia covering 7,000km^2 of coastal seafloor. The surface waters, however, were well oxygenated. In the presence of oxygen, sulphide is oxidized and transformed into non-toxic forms of sulphur. Surprisingly though, there was an intermediate layer in the water column, which contained neither hydrogen sulphide nor oxygen. Further investigation indicated that sulphide diffusing upwards from the anoxic bottom water is consumed by autotrophic denitrifying bacteria below the oxic zone. The intermediate water layer is

[29] *Image source: Louw, 2008.*

[30] *Source: http://www.mpi-bremen.de/ Projekte_9.html and http://idw-online.de/pages/de/news 292832*

the habitat of detoxifying microorganisms, which by using nitrate transform sulphide into finely dispersed particles of sulphur that are non-toxic. Thus, the microorganisms create a buffer zone between the toxic deep water and the oxygenated surface waters. These results, however, also suggest that animals living on or near the seafloor in coastal waters may be affected by sulphur eruptions more often than previously thought. Up to now, sulphidic water masses were monitored with the help of satellites, taking pictures of the sea surface while orbiting the earth, as they show up as whitish/turquoise discolorations of surface water (Figure 52). However, many of these sulphidic events may go unnoticed by satellite because bacteria consume the hydrogen sulphide before it reaches the surface.

Figure 52: Near shore sulphur eruption[31]



5.2.8 Visual Character[32]

Landscape character is defined by the United Kingdom Institute of Environmental Management and Assessment as the "distinct and recognisable pattern of elements that occurs consistently in a particular type of landscape, and how this is perceived by people". It reflects particular combinations of geology, land form, soils, vegetation, land use, and human settlement'. It creates the specific sense of place or essential character and "spirit of the place". The following landmarks were identified as significant in defining the surrounding areas characteristic landscape:

- Swakopmund town;
- C34 National Road;
- Swakopmund Salt Works structures and works;

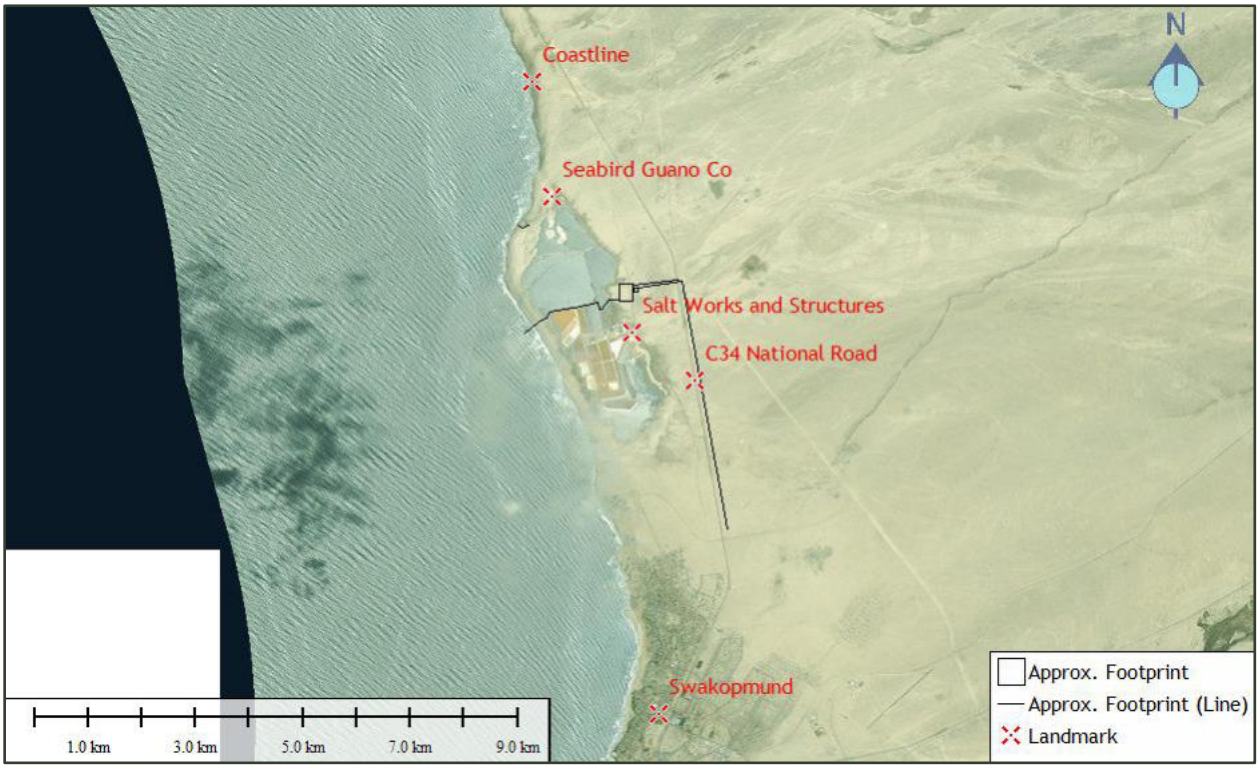
[31] *Notes: Satellite image showing discoloured water offshore the Namib Desert resulting from a near shore sulphur eruption (satellite image source: www.intute.ac.uk). Inset shows a photograph taken from shore at Sylvia Hill, north of Lüderitz, during such an event.*

[32] *Section written by Stephen Stead of VRMA.*

- Seabird Guano Company and other structures; and
- Atlantic Ocean coastline.

These landmarks are described in greater detail to follow:

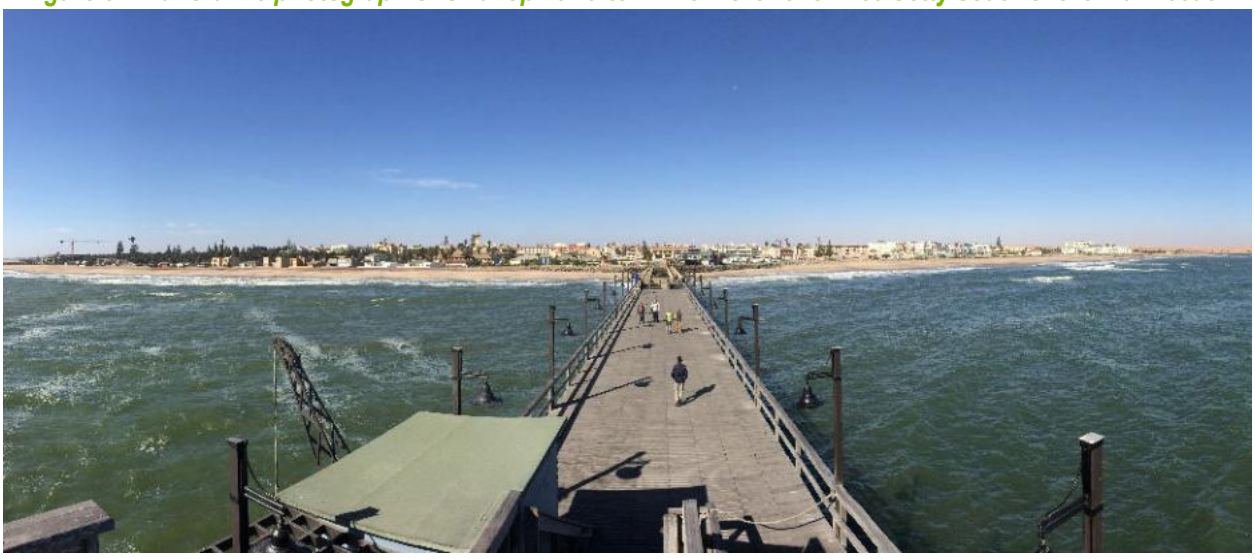
Figure 53: Landscape context photograph points overlay onto satellite image



5.2.8.1 Swakopmund town

Swakopmund lies on the B2 road and the Trans-Namib Railway from Windhoek to Walvis Bay. It is served by Swakopmund Airport and Swakopmund Railway Station. Visual significance of the town is increased due to the heritage of the town.

Figure 54: Panoramic photograph of Swakopmund town from the renowned Jetty south of the main beach



5.2.8.2 C34 National Road

The C34 is a salt road which links the town of Swakopmund with the small fishing and tourist town of Henties Bay. The road follows the coastline northwards and in certain areas the contrasting views of the Atlantic Ocean to the west and flat desert landscapes to the east create higher levels of scenic quality which add to the experience of the sense of place of the Namibian coastline. This route is utilised for tourism activities which radiate out from Swakopmund and as such it is likely that tourists utilising the road would have higher sensitivities to landscape change.

Figure 55: Photograph taken south of the C34 National Road with Swakopmund town in the background

5.2.8.3 Salt Works and structures

The Swakopmund Salt Works was established in 1936 and comprises a series of ad hoc structures, a small light house replica, salt stockpiles, and extensive evaporation pans. The older structures are painted a yellow colour which generates higher levels of colour contrast, but the more recent warehouse is a light grey-brown which significantly reduces the colour contrast. The area is an important birding destination due to birdlife being attracted to the large pans.

Figure 56: Photograph depicting the existing Salt Company (Pty) Ltd structures and salt stockpiles and warehouse

5.2.8.4 Seabird Guano Company and Other Structures

The Guano Company comprises one medium sized administrative building and a large warehouse. Colours are muted and grey which reduce colour contrast and visual intrusion. The green coloured governmental building generates strong colour contrast to the grey-browns of the characteristic landscape.

The Swakopmund Salt Work evaporation ponds are an important bird area and used for bird watching and photography activities. New structures in this viewshed may impact on these activities and the sense of place, and has been considered in the impact assessment (section 7 of this report).

Figure 57: The Guano Company structures and the green Correctional Services residence as seen from the C34 road

5.2.8.5 Atlantic Ocean Coastline

The coastline is an important tourist destination due to good coastal fishing with many camping sites located at defined “Miles” from the town of Swakopmund. Receptors driving along the coast would have low exposure to the proposed plant and substation, but would have high exposure views to any modifications proposed for the existing jetty. Although this is a tourist destination, due to the existing built precedent and lower levels of visual exposure (to the proposed plant) it is likely that receptors would have moderate sensitivity to landscape change. The intake structure, which comprised of a jetty, has the potential to create a significant, albeit local visual intrusion and will be considered during the SEIA phase.

Figure 58: Photograph taken north of the coastline from the existing Swakopmund Salt Work inlet structure

5.2.9 Noise Character[33]

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

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

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

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

Further, if the dimensions of a noise source are small compared with the distance to the listener, it is called a point source. All sources of noise (except traffic source) at the proposed desalination plant will be quantified as point sources. The sound energy from a point source spreads out spherically, so

[33] *Section authored by Nicolette von Reiche of Airshed Planning Professionals.*

that the sound pressure level is the same for all points at the same distance from the source, and decreases by 6dB per doubling of distance. This holds true until ground and air attenuation noticeably affect the level.

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

Impacts on the following individuals or communities will be considered:

- Employees of the Swakopmund Salt Works (industrial Noise Sensitive Receptors). The Swakopmund Salt Works plant area is situated within 1km south of the proposed site for the desalination plant.
- Residents of the northernmost suburbs of Swakopmund. The nearest residences of Swakopmund lie approximately 3.8km south-southeast of the proposed site for the desalination plant.
- Holiday makers at the Mile 4 Caravan Park (residential Noise Sensitive Receptors). The Mile 4 Caravan Park lies approximately 3.6km south of the proposed site for the desalination plant.
- Correctional services buildings/infrastructure approximately 1km to the north-northeast of the desalination plant. Six wardens currently reside there.

5.2.9.1 Atmospheric Absorption and Meteorology

The main meteorological parameters affecting the propagation of noise include wind speed, wind direction, and temperature. These, along with other parameters such as relative humidity, air pressure, solar radiation, and cloud cover affect the stability of the atmosphere and the ability of the atmosphere to absorb sound energy. Average day- and night-time wind speed, wind direction, temperature, relative humidity, pressure, and solar radiation that will eventually be used as input to the selected noise propagation model during the impact assessment phase of the project are provided in Table 22 (Section 5.2.2). Wlotzkasbaken data was obtained from a study completed by Airshed in 2011 (Liebenberg-Enslin & Krause, 2011). Wlotzkasbaken is located approximately 20km north of the proposed desalination plant.

It is well known that wind speed increases with altitude. This results in the "bending" of the path of sound to focus it on the downwind side and creating a "shadow" on the upwind side of the source. Depending on the wind speed, the downwind level may increase by a few decibels but the upwind level can drop by more than 20dB (Brüel & Kjær Sound & Vibration Measurement A/S, 2000). It should be noted that at wind speeds of more than 5m/s ambient noise levels are mostly dominated by wind generated noise. The diurnal wind field at Wlotzkasbaken, the nearest representative meteorological station is presented in section 5.2.2 above. Wind roses represent wind frequencies for the 16 cardinal wind directions. Frequencies are indicated by the length of the shaft when compared to the circles drawn to represent a frequency of occurrence. Wind speed classes are assigned to illustrate the frequencies with high and low winds occurring for each wind vector. The frequencies of calms, defined as periods for which wind speeds are below 1m/s, are also indicated.

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

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

5.2.9.2 Terrain, Ground Absorption and Reflection

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

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

5.2.9.3 Sampled Baseline Noise Levels

A summary of sampling locations, times, weather conditions, and observations made during sampling is provided in Table 24 and locations are shown on the map in Figure 59 and photographs of the baseline monitoring sites shown in Figure 60.

Table 24: Summary of sampling locations, times, weather conditions and general acoustic environment

Sampling Location	Coordinates	Sampling Date and Time	General Description of Environment from a Noise Perspective	Conditions During Sampling
1	14°31.672' E 22°35.792' S	Day-time 20-Aug-14 10:00	Audible noise sources included activities at the Swakopmund Salt Works, traffic towards the Swakopmund Salt Works and along the C34 as well as ocean surf.	Wind speed 1.9m/s (average) and 2.5m/s (maximum) Temperature 16°C Relative humidity 75% Thin clouds, 90% cloud cover
		Night-time 20-Aug-14 22:00	Audible noise sources included traffic along the C34 as well as ocean surf and some nocturnal birds.	Wind speed 1.8m/s (average) and 2m/s (maximum) Temperature 14°C Relative humidity 82% Clear skies
2	14°31.558' E 22°35.344' S	Day-time 20-Aug-14 10:24	Audible noise sources included birds, distant noise from the Swakopmund Salt Works, and traffic along the C34 as well as ocean surf.	Wind speed 1.9m/s (average) and 2.5m/s (maximum) Temperature 17°C Relative humidity 72% Thin clouds, 85% cloud cover
		Night-time 20-Aug-14 22:24	Audible noise sources included occasional traffic along the C34 and ocean surf.	Wind speed 2m/s (average) and 2.5m/s (maximum) Temperature 13°C Relative humidity 82% Clear skies
3	14°31.825' E 22°37.460' S	Day-time 20-Aug-14 10:58	Audible noise sources included construction noise to the south, occasional air traffic and road traffic along the C34.	Wind speed 3.8m/s (average) and 4.9m/s (maximum) Temperature 16°C Relative humidity 84% Thin clouds, 90% cloud cover
		Night-time 20-Aug-14 22:55	Audible noise sources included occasional traffic along the C34 and ocean surf.	Wind speed 0.8m/s (average) and1.9 m/s (maximum) Temperature 15°C Relative humidity 78% Clear skies

Figure 59: Environmental baseline noise sampling locations

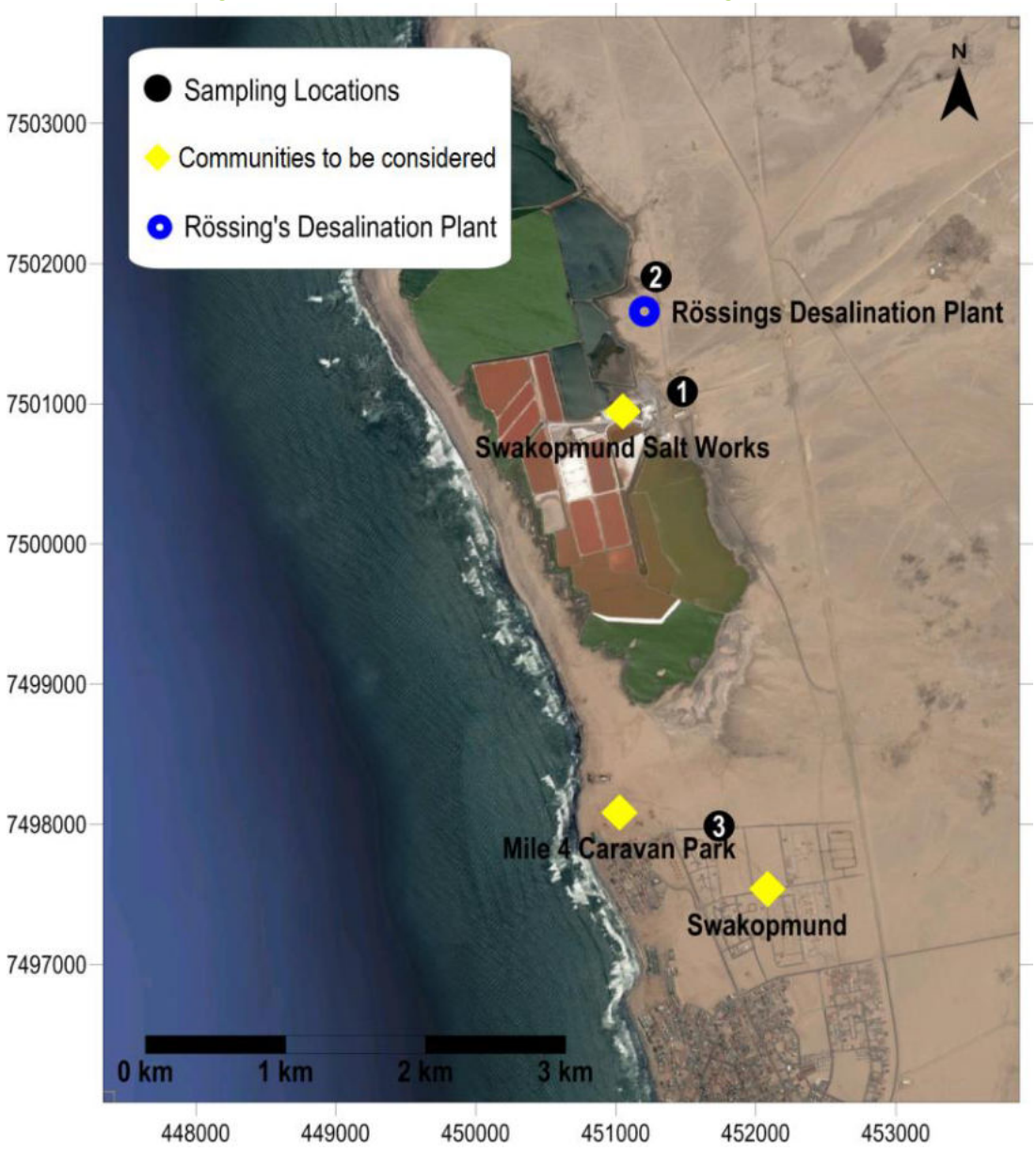


Figure 60: Pictures of sampling locations

(a) Location 1 from the east

(b) Location 1 from the north

(c) Location 2 from the east

(d) Location 2 from the west

(e) Location 3 from the south

(e) Location 3 from the north

Sampled baseline day- and night-time L_{Aeq} and L_{A90} as well as L_{AFmax} values are given in Table 25. Time series and 3rd octave band frequency spectra are graphically presented in Figure 61 to Figure 69. The following is noted:

- Baseline noise levels during the day and notes taken during sampling indicate the Swakopmund Salt Works to be the most notable local noise source. Traffic along the C34 also contributes significantly to local baseline day- and night-time noise levels. At night, ocean surf noise becomes more observable than during the day.
- The International Finance Corporation (International Finance Corporation) day-time guideline of 55dBA for residential areas was only marginally exceeded at Location 1 near the Swakopmund Salt Works.
- Sampled night-time noise levels exceed the International Finance Corporation guideline of 45dBA for residential areas only at Location 3. The exceedance was as a result of a vehicle passing on the C34 at high speed. Without this incidence, the night-time L_{Aeq} (20min) reduces to 40.6dBA. This is illustrated in Figure 68.
- The large difference (more than 5dBA) between sampled L_{Aeq} and L_{A90} at Location 1 and 3 during the day as well as at Location 3 during the night indicate the presence of noisy incidences i.e. passing vehicles and Swakopmund Salt Works activities.
- The large difference between day-and night-time noise levels sampled at Location 1 supports the supposition that the Swakopmund Salt Works is currently the most notable noise source in the local study area. The Swakopmund Salt Works was observed not to be operational at night.
- Day and night levels at Location 2 differed by less than 5dBA indicating the presence of a constant noise source in the area. Frequency spectra also indicate the relative small difference between day-and night-time noise levels. This is typical of noise levels close to the ocean or in areas with little human activity.

Table 25: Summary of sampled baseline noise levels

Sampling Location	Day-time			Night-time			Frequency Spectra
	L_{Aeq} (20 min) (dBA)	L_{A90} (dBA)	L_{AFmax} (dBA)	L_{Aeq} (20 min) (dBA)	L_{A90} (dBA)	L_{AFmax} (dBA)	
1	55.4 (Figure 61)	40.9	79.9	39.9 (Figure 62)	38.6	50.1	(Figure 63)
2	37.4 (Figure 64)	35.3	52.1	41.0 (Figure 65)	39.2	53.6	(Figure 66)
3	51.3 (Figure 67)	42.8	47.2	50.5 (Figure 68)	38.5	80.7	(Figure 69)

Figure 61: 20-minute day-time sample at Location 1, the Swakopmund Salt Works on 20-Aug-14

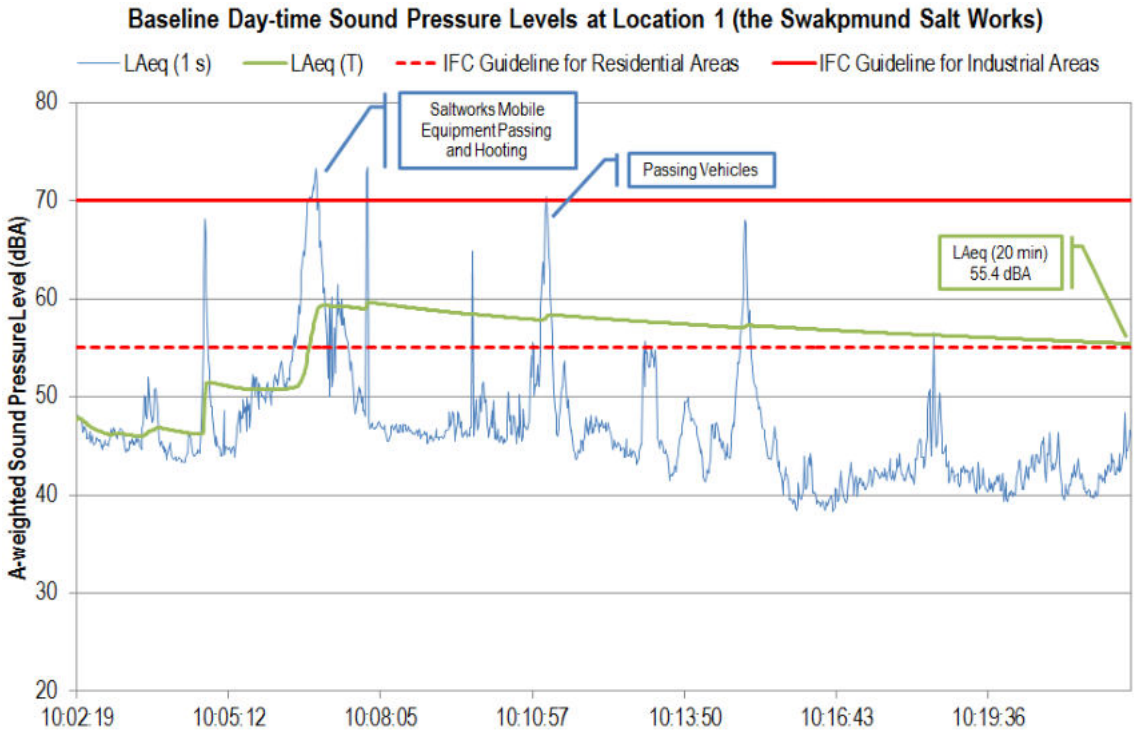


Figure 62: 20-minute night-time sample at Location 1, the Swakopmund Salt Works on 20-Aug-14

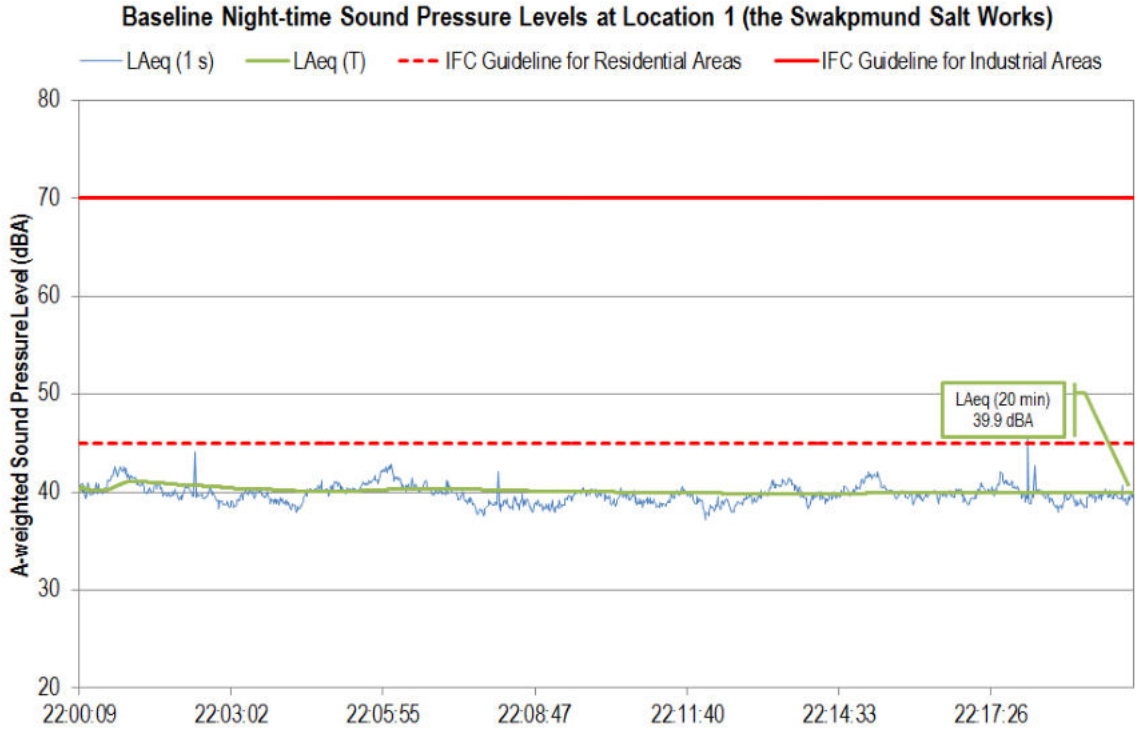


Figure 63: 3rd octave band frequency spectra at Location 1, the Swakopmund Salt Works

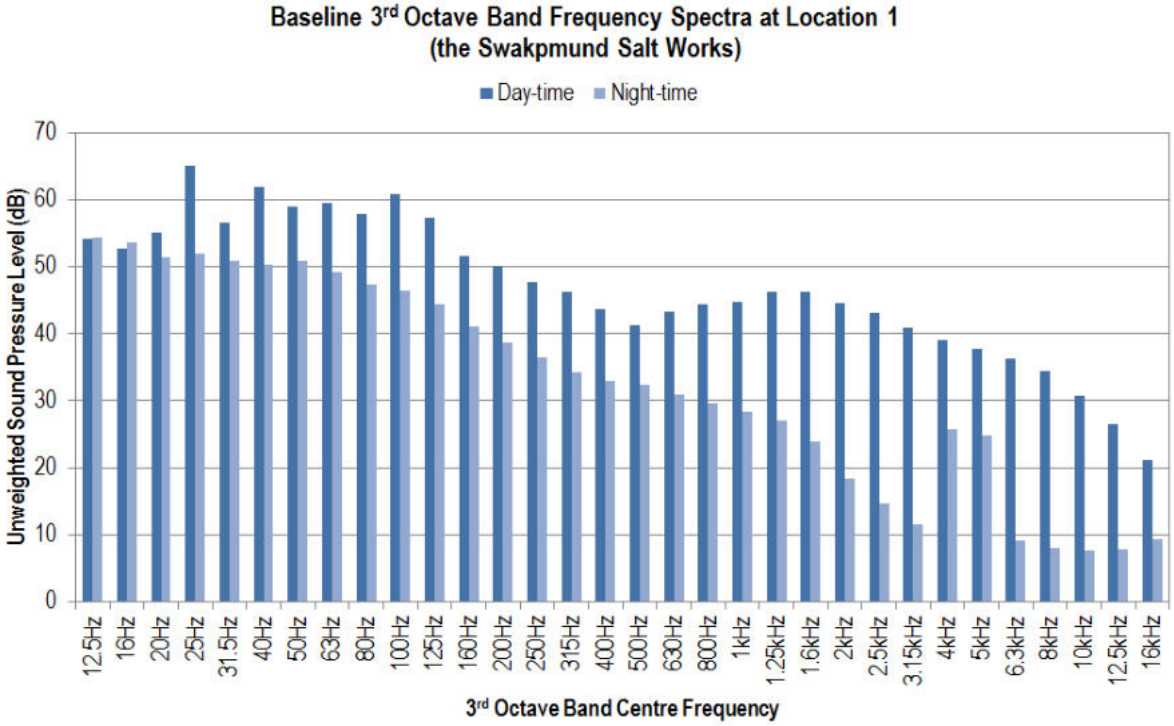


Figure 64: 20-minute day-time sample at Location 2, the desalination plant site on 20-Aug-14

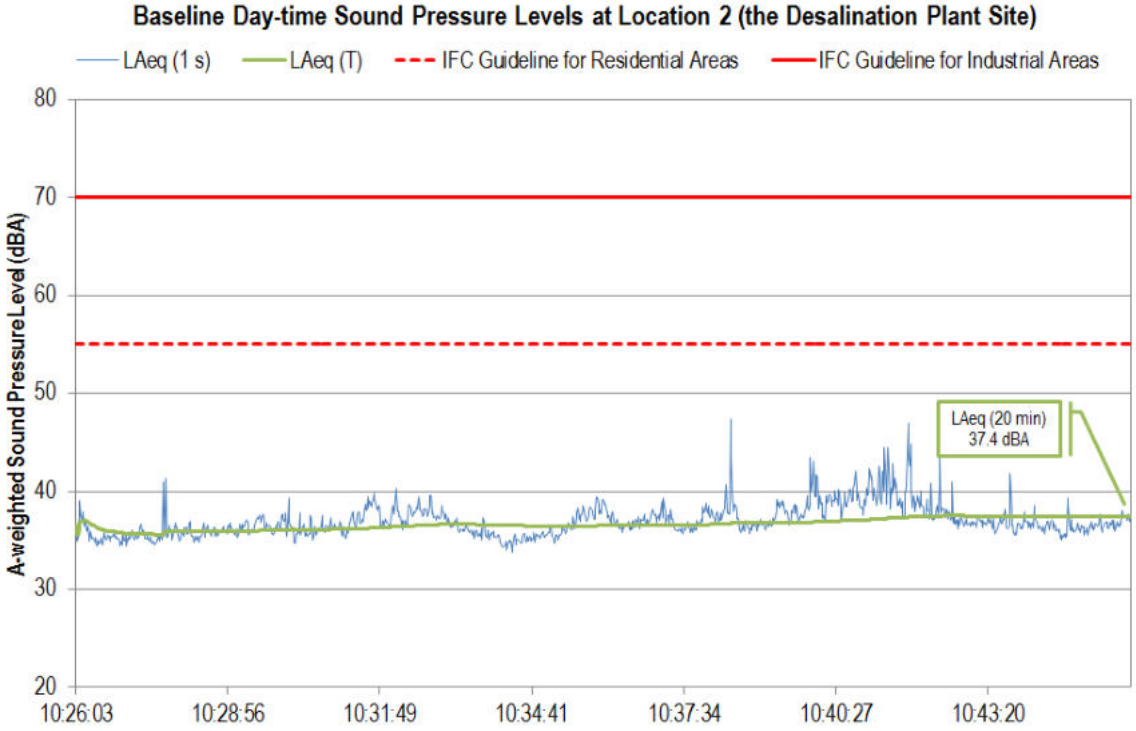


Figure 65: 20-minute night-time sample at Location 2, the desalination plant site on 20-Aug-14

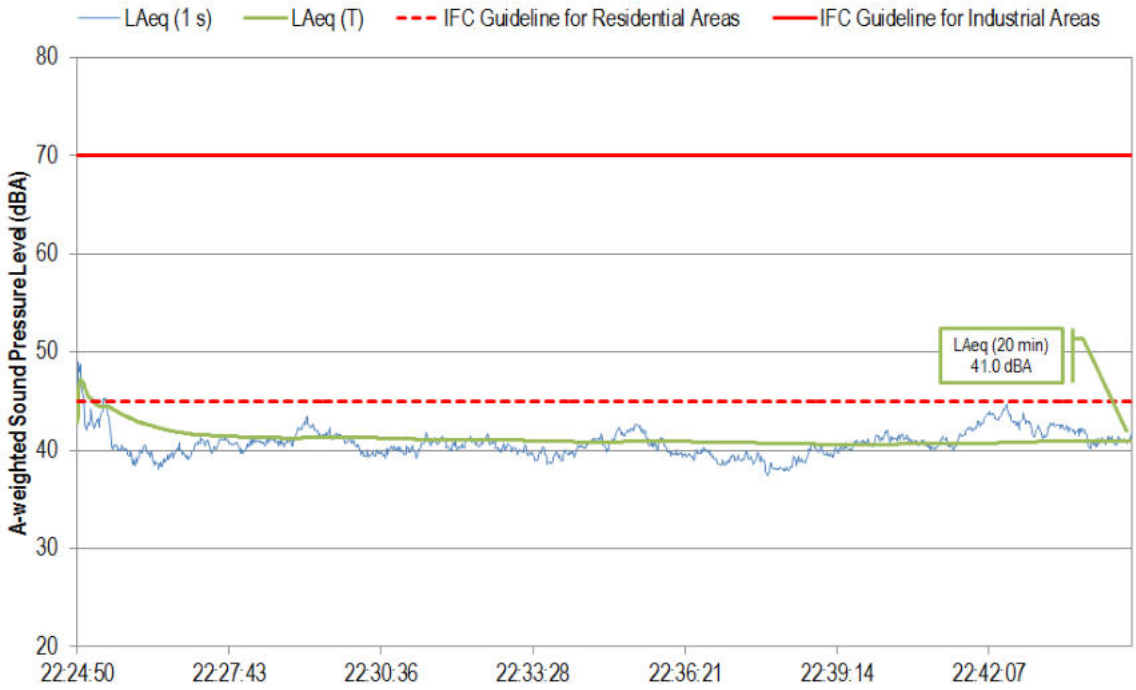


Figure 66: 3rd octave band frequency spectra at Location 1, the Swakopmund Salt Works

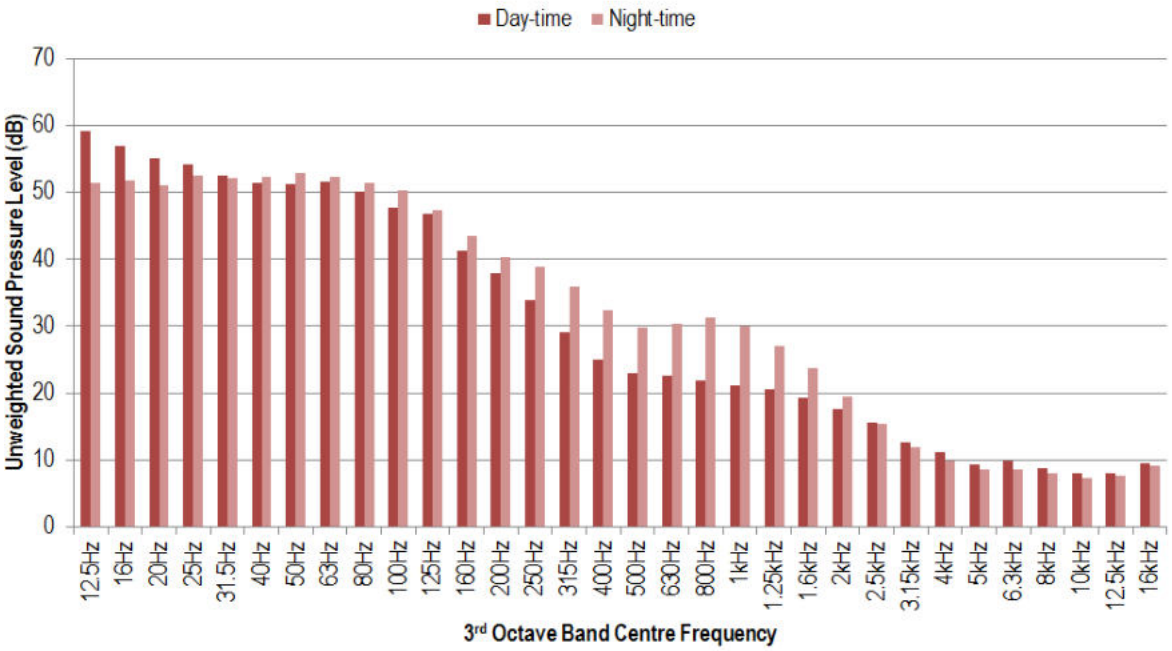


Figure 67: 20-minute day-time sample at Location 3, Swakopmund on 20-Aug-14

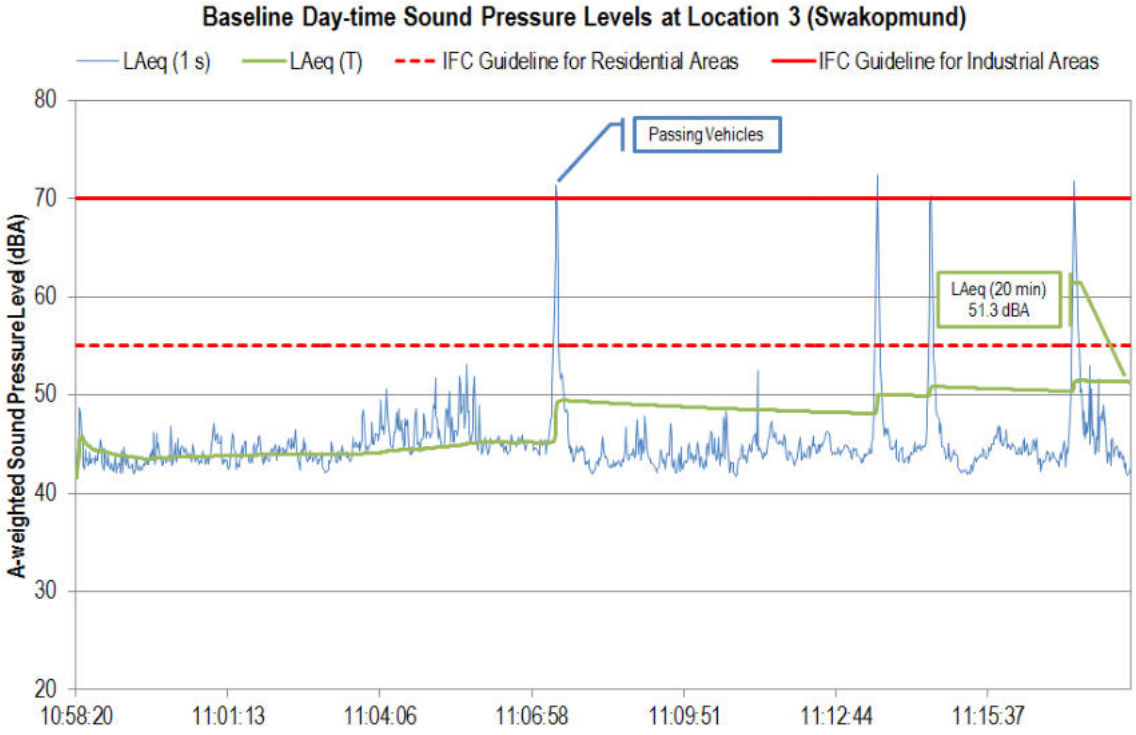


Figure 68: 20-minute night-time sample at Location 3, Swakopmund on 20-Aug-14

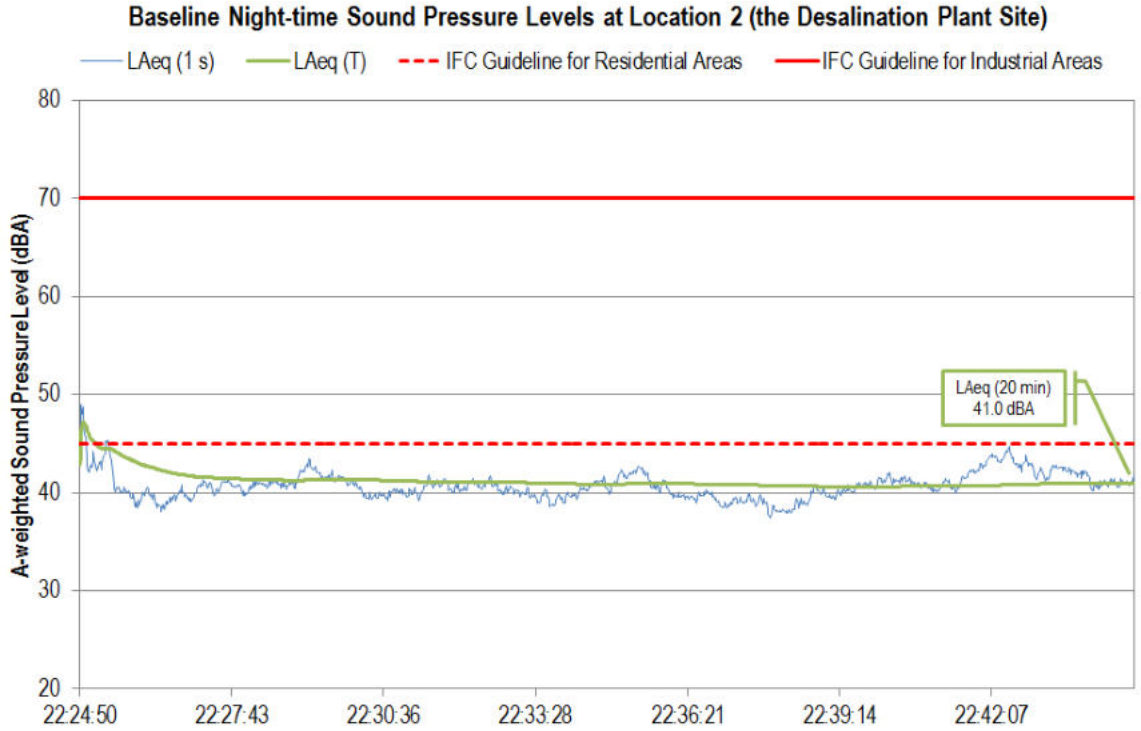
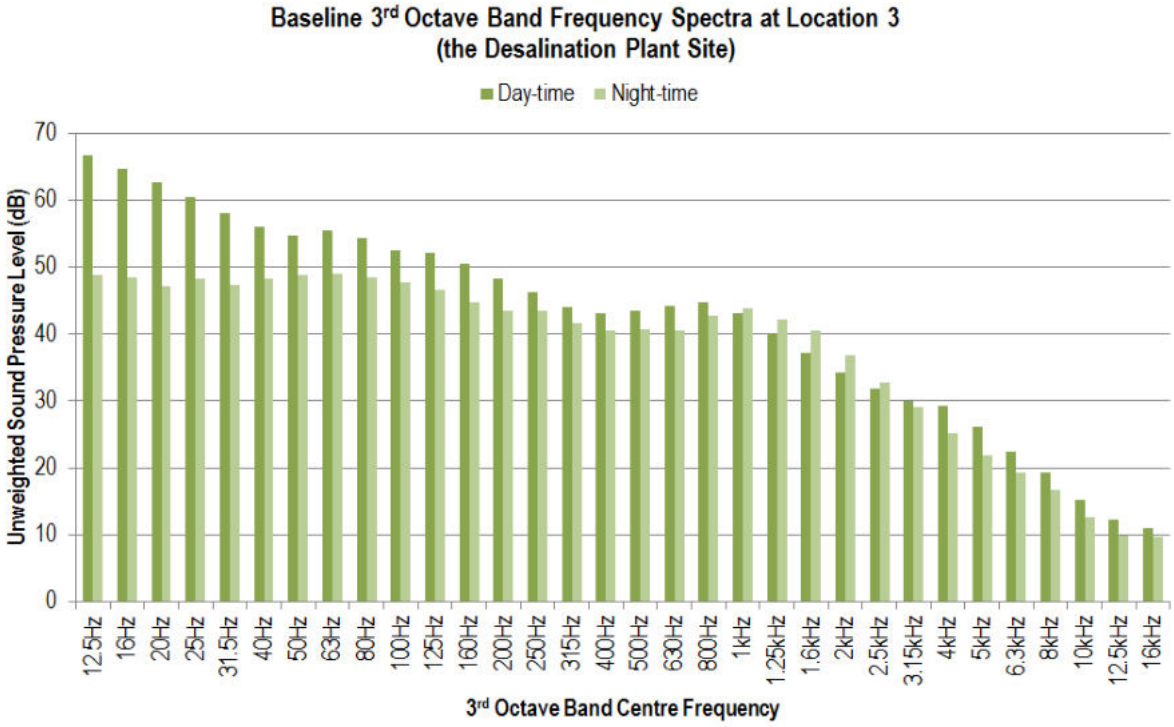


Figure 69: 3rd octave band frequency spectra at Location 2, Swakopmund



5.3 ECOLOGICAL ENVIRONMENT

5.3.1 Flora

The study area lies within the Central Namib Desert Biome. The dominant vegetation structure is sparse shrubs and grasses (Mendelsohn *et al*., 2002); the vegetation cover, however is extremely limited. The specific proposed site for the Rössing Uranium desalination plant can be described as a disturbed site generally devoid of vegetation. This characteristic is partially due to the repetitive disturbance (which has occurred over a period of time, since 1933) by vehicles, equipment and

activities associated with the Swakopmund Salt Works and other activities in the area. The other influencing factor is the harsh saline environment created by the site's proximity to the ocean and the salt evaporation ponds which creates a very saline environment in which only the hardiest of plants can survive.

Just over 400 plant species occur in the Central Namib, making up to 10% of the flora of Namibia. The northern Namib supports approximately 100 to 200 plant species and the southern Namib is home to well over 600 species of plants, making the region a global biodiversity hotspot (CSIR, 2009).

Botanical Surveys in similar habitats indicate that shrubs and herbs such as Blepharis grossa, and *Arthraerua leubnitziae* (pencil bush), *Zygophyllum stapfii*, *Zygophyllum clavatum*, *Psilocaulon kuntzei* and *Salsola sp*. are likely to occur. Occasional specimens of *Commiphora saxicola* and *Sarcocaulon marlothi* (bushman's candle) occur, often in patches in the lower lying areas (CSIR, 2009).

Some plain areas, especially closer to the coast, are characterised by lichen fields and are considered to have a high biodiversity and conservation value. Lichens play a dominant role with respect to structure, cover and biomass and are an important component of arid to semi-arid ecosystems. They form biological soil crusts together with other organism groups (e.g. cyanobacteria and bryophytes), which occur in all hot, cool, cold arid and semi-arid regions of the world. They play an important role in these ecosystems, since they are able to retain soil moisture, reduce wind and water erosion of the soil, reduce deflation, fix atmospheric nitrogen (cyanolichens), and contribute to soil organic matter and nutrient richness. They have a host of other important roles, i.e. they provide food for beetles and ungulates and provide shelter for the nests of the vulnerable breeding endemic Damara Tern (Barnard, 1998). Lichens are among the most important ecological indicators and can be used to monitor various kinds of environmental impacts. None of the main lichen fields occur on the site for the proposed Rössing Uranium Desalination Plant.

The Namib coastal zone's lichen community encrustations cover nearly the whole area of the central Namib Desert (CSIR, 2009), but are concentrated to numerous larger lichen fields in a globally unique way (Wessels & van Vuuren, 1986) (Ullman & Brudel, 2001). Large lichen fields include the lichen community north-east of Wlotzkasbaken (approximately 200km^2), the lichen fields east of Cape Cross (more than 400km^2) and the soil crust lichen community north and east of Swakopmund (especially those situated around Mile 8 and Mile 12 and inland).

Frequent and intense disturbances may alter lichen distribution patterns due to slow recovery rates, while other disturbances may only cause fluctuations in ecosystem equilibrium. Disturbance can severely affect the cover, species composition, and the physiological functioning of a biological soil crust (Belnap & et al, 2001). In a typical biological soil crust, more than 75% of the photosynthetic biomass and almost all photosynthetic productivity are located within organisms in the top 3mm of the soil, making it very vulnerable to mechanical disturbance (natural and anthropogenic) (Garcia-Pichel & Belnap, 1996). Major natural disturbances impacting lichen communities of the Central Namib Desert result from a severe increase of soil erosion rates following erosion and deflation by windstorms as well as water run-off, with the aeolian processes prevailing (Belnap & Gillette, 1998) (Belnap & Elridge, 2001). Anthropogenic disturbances include mechanical disturbance caused by off-road driving, dust due to vehicles, legal or illegal mining activities and powerline or pipeline maintenance activities. The ability of lichens to absorb water from fog will also be reduced and even prevented by an increase of sand/dust deposition on affected species. None of the known lichen fields of the central Namib occur on the site for the proposed Rössing Uranium Desalination Plant.

Given the disturbed nature of the study site, a detailed botanical assessment will not be undertaken as part of the SEIA, since the potential impacts are not deemed to play a significant role in a decision on project acceptability. Given however, that desert plants are highly susceptible to disturbance and

can take many years or decades to recover from such disturbances, the SEMP will make recommendations aimed at reducing and controlling potential disturbances so that the disturbances of the local flora is kept to a reasonable minimum and that activities are restricted to already disturbed areas as far as possible.

5.3.2 Avifauna[34]

In 1995 Namibia acceded to the Ramsar Convention, an international treaty to protect waterbird habitat that covers all aspects of wetland conservation and wise use. Four wetlands have been designated to the *List of Wetlands of International Importance*, namely Walvis Bay, Sandwich Harbour and the Orange River Mouth on the coast, and the Etosha Pan; other sites also qualify but have not been awarded this status as yet.

The Walvis Bay Ramsar Site lies about 45 km south of the study site. It is regarded as the most important coastal wetland in the southern Sub-region and is probably one of the most important coastal wetlands in Africa. This area regularly supports over 100,000 birds (up to 150,000 birds) in summer; these comprise mostly non-breeding intra-African and Palearctic migrant species: between 80-90% of the Sub-region's flamingos over-winter here. The Swakopmund Salt Works is the only man-made wetland in Namibia qualifying for, but yet to be awarded, the above international Ramsar status. The central coastal wetlands (including Sandwich Harbour, Walvis Bay, Swakopmund Salt Works and Cape Cross) form an important inter-linked system of critical importance for large numbers of waterbirds.

Namibia also boasts 21 Important Bird Areas (IBAs), ten of which lie on the coast. IBAs are places of international significance for the conservation of birds at the Global, Regional (Continental) or Sub-regional (southern African) level, selected according to stringent criteria. One of the main criteria for which the Mile 4 Saltworks is accorded Global IBA status is the presence of three globally threatened species: the Damara Tern, Lesser Flamingo and African (Black) Oystercatcher. Subsequent to the IBA publication, the globally threatened Cape Cormorant may now be added to this list. Further criteria for which the site qualifies as an IBA are the presence of 1% or more of the population of Cape Cormorants, Greater Flamingo and Kelp Gull; and 0.5% or more of the population of Chestnut-banded Plover. The ecological sensitivities of these species are mentioned below.

Some 75 species of birds flock to this coast, with nearly 1.6 million birds recorded here at times. Apart from several Ramsar listed wetlands, the Dorob NP has been included under the category of Important Bird Areas (IBAs) by BirdLife International (see below).

5.3.2.1 Damara Tern

The Damara Tern is a breeding endemic seabird, globally Near Threatened and also Near Threatened in Namibia (Figure 70).

The Damara Tern was the subject of recent in-depth study (Braby 2011) that has provided updated information on ecology and numbers for a species that is little known and faces several conservation issues. These findings contribute to the first baseline demographic information for the Damara Tern, providing a more scientific basis for conservation management recommendations.

[34] *Section written by Mike and Ann Scott of African Conservation Services CC.*

Figure 70: The Damara Tern

The above study included a review of all accessible information of breeding populations in Angola, Namibia and South Africa and identified 70 breeding colonies globally for the species. Most of the population (98%) breeds in Namibia, where overall breeding success (measured as the probability of fledging one chick per pair per season) is estimated at only 0.36.

In 2011 the total breeding population of Damara Terns was estimated at 1,001-2,685 breeding pairs or 5,370 breeding individuals. This estimate is substantially lower than the 13,500 individuals initially estimated, which is now considered a probable over-estimate (Braby 2011). A more recent (conservative) estimate places the entire breeding population at a minimum of only 900 pairs (R Braby pers. comm. July 2014).

Estimates for the species at Mile 4 Salt Works include 24 adults in 1977; and 10-20 pairs in 2008-2010 and 10-15 pairs in 2013-2014. The terns arrived for the current breeding season (2014-2015) on 8-11 October 2014, and their numbers still await confirmation at the time of writing this report. However, long term monitoring data indicate the regular use of the area proposed for the desalination plant (Site alternative 1) by 10-20 breeding pairs. This amounts to 0.4-2.0% of the global population of 1,001-2,685 breeding pairs. There is regular disturbance in the breeding area by vehicles and people, including revellers at night.

Damara Terns feed off the highly productive Benguela Upwelling System. They breed on the coastal desert mainland of Namibia where development and off-road driving are threatening breeding areas. The breeding season extends from October to March. Most nests are close to feeding sites, although breeding colonies may sometimes be found up to 11.5 km inland on gravel plains between the dunes. The highest densities of breeding pairs are found in the central coast between Sandwich Harbour and the Ugab River. Nesting pairs and their single chicks are highly sensitive to human disturbance.

Damara Terns migrate c. 8,000 km each year and breed in harsh desert environments with high rates of predation, but feed in highly productive waters where food is abundant. Low breeding success (probability of less than 0.4 of nests surviving predation per season per pair), high annual survival and fidelity to breeding sites may have evolved as a response to these conditions. Understanding the spatial dynamics of populations is essential for conservation of species at the landscape level. Species that have adapted to stable environments may not move from their breeding areas even if these have become sub-optimal due to anthropogenic disturbances. Instead, they may breed unsuccessfully or choose not to breed at all. If they do leave, e.g. due to increased predation or disturbance, they would move to another established breeding colony where they would be less successful due to their limited knowledge of and experience of the site and its predators.

Threats faced by Damara Terns throughout their breeding range include the following:

- Coastal development causing colony extinctions; coastal development has been the major cause of declines in similar species;
- Off-road driving causing disturbance to breeding areas, resulting in low reproductive success;
- Predation is the most common cause of nest failure in Namibia, and Black-backed Jackals are the most common predators of tern eggs and chicks at most colonies (Braby 2011). Anthropogenic activities may result in increases in predator densities (e.g. offal from fishing that attracts larger numbers of black-backed jackals; artificial light may increase opportunities for predation). These jackals appear to follow human footprints in search of prey (R Braby pers. comm.; pers. obs.); and
- In Angola, Damara Terns are captured by humans for food; almost the entire global population passes through this area during annual migrations.

In the light of the above findings, the most important management approach for the population viability for seabirds such as the Damara Tern, which display high rates of site fidelity, may be long-term maintenance and protection of current colony sites.

Conservation actions should thus focus on the protection of important breeding colony sites in Namibia, and also at the extremities of the range in South Africa and Angola; disturbance-free areas on nesting beaches should be designated, and population trends monitored. Although at least 95% of the breeding population can be found in protected areas, their conservation remains difficult. This is mainly because human activities that create disturbances are still allowed in these areas. Colonies that make up more than 1% of the breeding population should be protected from human disturbance.

5.3.2.2 Lesser Flamingo

The Lesser Flamingo is also classed as Globally Near Threatened according to the IUCN, and Vulnerable in Namibia. In 1997, the Mile 4 Salt Works area witnessed the first recorded event of Lesser Flamingo and Greater Flamingo breeding in coastal areas. Eggs were laid in just over 100 nests (including 36 Lesser Flamingo), but presumed disturbance by blackbacked jackals led to early failure.

The population is estimated at 15,000-25,000 individuals in West Africa; 1,500,000-2,500,000 in East Africa; 55,000-65,000 in South Africa and Madagascar; and 650,000 in South Asia (IUCN 2014). The population estimate for Namibia is 40,000-64,500 adults. This local population fluctuates, with recent increases in the 1990s.

Threats include low breeding frequency and success, and water abstraction from the breeding sites. Collisions are frequently reported with cattle fences that cross Sua Pan in Botswana, and with overhead power lines in both Botswana and Zimbabwe.

In Namibia, direct threats include low level organochlorine pesticide residues used extensively in the catchment area of the Ekuma River against malaria mosquitoes. A growing number of records of collisions with power lines (hitherto underestimated) are also cause for concern. Flamingos are prone to such impacts due to their flying habits in groups and at night, when overhead lines present an unexpected obstacle in their flight paths. The risk is exacerbated in the areas where they come in to land and take off.

5.3.2.3 African (Black) Oystercatcher

The African (Black) Oystercatcher is classed as Globally Near Threatened (IUCN 2014), and also Near Threatened in Namibia.

The species has a coastal breeding range that stretches from Mazeppa Bay in South Africa to Lüderitz in Namibia. In the early 1980s the global breeding population was estimated at less than 2,000 pairs and 4,800 individuals, making it the third rarest, as well as one of the most range restricted oystercatcher species in the world. The total population is now estimated at 5,000-6,000 individuals, with about half occurring along the Western Cape (South Africa) coastline, and half of these on its near-shore islands.

In Namibia, recent research has increased the Namibian population estimates (originally 1,200 birds: Hockey 1983) to 1,840 birds, or 38% of the world population. This is considered to represent a real increase (rather than enhanced census), given the increased chick production in South Africa, 40% of which are estimated to make their way to Namibian nurseries, as well as increases in bird densities in South Africa and the increased food resource in the form of the alien invasive Mediterranean mussel *Mytilus galloprovincialis* throughout the region.

The four largest nurseries for the oystercatchers (three situated north of Lüderitz around Hottentot's Point, Caravan Beach and Douglas Point, and the fourth at Walvis Bay) support 300-350 juvenile birds. Estimates at Mile 4 Salt Works, a roosting area, include a mean of 18 ± 11 and a maximum of 34 for seven counts; in July 2014, 43 individuals were counted at this site.

The single largest cause of breeding failure in this species is human disturbance. Off-road vehicles enable more people to reach otherwise remote stretches of coast, exacerbating disturbance effects and reducing productivity. Non-breeding birds, such as those at Mile 4 Salt Works, are relatively less sensitive to such disturbance. It is presumed that the high frequency of jackals on Namibia's coast keeps the number of breeding birds on all but the islands at very low levels. Disturbance of Namibian nurseries is minimal at present, but predation by gull populations on the islands can be detrimental to the few pairs that do breed.

Oystercatchers feed in the intertidal zone, in both rocky and sandy habitats. They are confined to a limited feeding time, at low tide, when their prey (mussels, limpets and other marine invertebrates) is accessible; this restricted feeding time could be further decreased by human disturbance in the area. The impacts of the proposed development on these non-breeding African Oystercatchers are anticipated to be minimal, however.

Numbers of oystercatchers were monitored opportunistically during the field work for the present study, the highest count to date being 10 individuals. However, counts are normally done during periods when the oystercatchers are foraging on the coast.

5.3.2.4 Cape Cormorant

The Cape Cormorant is Globally Near Threatened (IUCN 2014), and also Near Threatened in Namibia. It is near-endemic to southern Africa, and common to locally abundant. More than 1% of the global population (average 45,000, maximum 700,000) is found at the Mile 4 Salt Works IBA, where it breeds on extensive guano platforms.

In the early 1970s, prior to the collapse of the Namibian sardine *Sardinops sagax* stocks, the global population numbered more than one million birds. By 1973 this had declined to an estimated 107,000 pairs, and in 1996 to 72,000 pairs or 220,000 to 330,000 birds. The largest Namibian colonies are on Ichaboe Island (45,805 birds), followed by the Swakopmund platforms (Mile 4 Salt Works; 43,542), compared to the largest in South Africa, Dyer Island (35,580) and Jutten Island (24,277).

The proportion of adults breeding each year depends on food availability. Age at first breeding is 2-3 years; annual juvenile survival is estimated at 44%, and longevity is at least 15 years. Occasional

die-offs (involving thousands of birds) due to a number of causes can be exacerbated by hunger stress, often with the greatest effects on chicks and juveniles.

The Red Data status for this cormorant is based on the recorded decline from 277,000 pairs in 1977-1981 to 72,000 pairs in 1996 (see above). This trend may be part of a natural cycle, as the breeding population is linked to the cycle of anchovy *Engraulis encrasicolus*, which experiences large natural fluctuations. Human disturbance leads to nest desertion, and loss of eggs and chicks to avian predators. The construction of guano platforms in Namibia in 1930-1971 provided alternative breeding space after islands in Cape Cross Lagoon and Sandwich Harbour were linked to the mainland. The species is occasionally affected by oil spills; rehabilitation success is low.

Breeding Cape Cormorants have the potential to be impacted by noise disturbance from the operation of the plant in the proposed development. Any reduction in breeding success or abandonment of nests would also have economic implications.

5.3.2.5 Greater Flamingo

The Greater Flamingo is classed as Vulnerable in Namibia. More than 1% of the global population (average 1,305, maximum 2,688) is found at the Mile 4 Salt Works IBA. In 1997, the area witnessed the first recorded event of Lesser Flamingo and Greater Flamingo breeding in coastal areas. Eggs were laid in just over 100 nests (including 64 Greater Flamingo), but presumed disturbance by Blackbacked Jackals led to early failure.

Direct threats in Namibia include low level organochlorine pesticides used extensively in the catchment area of the Ekuma River against malaria mosquitoes. Naturally low breeding frequency and success in Etosha may be exacerbated by possible reduction of water into Etosha Pan due to mining activities, as well as reduced rainfall for large parts of southern Africa. At one of few breeding sites in southern Africa, soda ash mining around the main breeding site in Sua Pan, Botswana, may reduce water levels on the pan. Night-time collisions with game fences and overhead powerlines in Botswana and Zimbabwe frequently. Mass die-offs take place including on the Namibian coast, associated in part with hydrogen-sulphide eruptions. Low-flying aircraft cause disturbance to feeding birds. A growing number of records of collisions with power lines in Namibia (hitherto underestimated) are also cause for concern (see above). Flamingos are prone to such impacts due to their nocturnal flying habits, when overhead lines present an unexpected obstacle in flight paths. The risk is exacerbated in the areas where they come in to land and take off.

5.3.2.6 Kelp Gull

More than 1% of the overall population of Kelp Gulls is found at Mile 4 Salt Works, comprising 372 (average) and 706 (maximum) individuals, and 120 breeding pairs.

The Kelp Gull is not included on the Red Data list and is not regarded as being under threat from the present development.

5.3.2.7 Chestnut-banded Plover

This small wetland bird species feeds and breeds on highly saline pans, coastal flats and in artificial evaporation pans, including mainly the area south of the main Salt Works at Mile 4. The potential sensitivity of this species is related to the fact that it is highly specialised and adapted to these saline habitats.

Its core non-breeding quarters include the central Namibian coastal, namely the Ramsar sites of Walvis Bay and Sandwich Harbour. Here up to 96% of the known population of 11,486 birds of the southern race often congregates. At the Mile 4 IBA 50-200 birds have been counted, including 20 breeding pairs and, more recently, 100 breeding pairs. Numbers of Chestnut-banded Plovers were monitored opportunistically during the field work for the present study in September-October 2014, the highest count to date being 123 individuals, all in the area south of the proposed development.

The dependence of over 90% of this species' population on just two coastal sites puts the Chestnut-banded Plover at risk. The southern African race (*pallidus*) is designated as Near-Threatened in Namibia because the population fluctuates around 10 000 individuals, and the majority are, at critical times of year, concentrated in only two locations on the Namibian coast.

This species uses mainly the saltpan area south of the Swakopmund Salt Works and is therefore not considered at risk by the proposed development.

5.3.2.8 Local and site context

The Swakopmund Salt Works is the only man-made wetland in Namibia qualifying for Ramsar status, although as yet undeclared. Mile 4 Saltworks is also an Important Bird Area (IBA N012) of 3,400 ha in total, and described as fully protected. This coastal IBA comprises a private nature reserve (the aquatic portion of 400 ha, known as "Panther Bake") and a Salt Works. It is accorded Global IBA status on account of the following criteria:

- A1: Globally threatened species;
- A4 i: Site known to hold or thought to hold, on a regular basis, more than 1% of a biogeographic population of congregator waterbird species; and
- A4 iii: Site known or thought to hold, on a regular basis, more than 20,000 waterbirds or more than 10,000 pairs of seabirds of one or more species.

Micro-habitats at Mile 4 Saltworks that appear to be important/attractive to birds are shown in Figure 71. These include:

- Established core Damara Tern breeding area (potentially a highly sensitive site) and secondary/ breeding areas in surrounds to the north and east; feeding areas over pans that contain small fish, especially the Oyster Pond;
- Chestnut-banded Plover roosting/feeding area (breeding early 2000s);
- Flamingos roosts and feeding areas, including a once-off breeding site (1997);
- Guano platforms: large numbers of Cape Cormorants roosting and breeding; main flight paths are
- between the platforms and the coast to the north/west. Breeding attempts by White-backed Pelican are dissuaded by the owners;
- African (Black) Oystercatcher roosts and feeding areas;
- Tern roosts and feeding areas (varying sites and species and numbers);
- Cormorant roost on present inlet pipe;
- Red-capped Lark and (seldom) Gray's Lark on gravel plains; and
- Other shoreline birds on the coast (roosting, feeding, breeding).

Figure 71: Some microhabitats for birds in the Swakopmund Salt Works area

Chestnut-banded Plover (large breeding effort early 2000s)

Regular Damara Tern breeding area

Secondary Damara Tern breeding area; Red-capped Lark and (seldom) Gray's Lark on gravel plains

Flamingos: feeding and roosting; Damara Tern feeding

(Lesser) Flamingo: feeding and roosting; African (Black) Oystercatcher and tern roost; guano platforms in the left background

Cormorant roost on present inlet pipe

5.3.2.9 Potential sensitivity of bird species

The potential sensitivity of the bird species for the study area QDS (2214Da) is assessed according to the following criteria: Red Data status, endemism/habitat specialisation and nomadic/migrant habits, together with other physiological, behavioural and/or ecological sensitivities, all of which act synergistically to increase the likelihood of impacts becoming cumulative.

RED DATA BIRD SPECIES

The 233 bird species recorded for the broad study area include 26 (11%) that are classified as Threatened in Namibia; eight of these (3%) are also globally classified as 'Threatened'. Red data status is an indication of the potentially increased vulnerability of a species to negative impacts.

The following species are included in each Red Data category:

- Endangered (7):
  - Great Crested Grebe, Cape Gannet, African Penguin, Black-browed Albatross, Atlantic Yellow-nosed Albatross, Martial Eagle, Black Stork;
- Near Threatened (11);
  - Damara Tern, African (Black) Oystercatcher, Chestnut-banded Plover, Black-necked Grebe, Maccoa Duck, Cape Cormorant, Crowned Cormorant, Bank Cormorant, Peregrine Falcon, Verreauxs' Eagle, Rüppell's Parrot ;
- Vulnerable (8);
  - Lesser Flamingo, Greater Flamingo, Great White Pelican, Caspian Tern, Hartlaub's Gull, White-chinned Petrel, Lappet-faced Vulture, African Fish-eagle ;
- Species above that are also Globally Threatened (9); and
  - Damara Tern, Lesser Flamingo, African (Black) Oystercatcher, Cape Cormorant, Crowned Cormorant, Bank Cormorant, Cape Gannet, African Penguin, Lappet-faced Vulture.

ENDEMIC BIRD SPECIES

The broad study area is home to 42 endemic/near-endemic species (18% of the total species occurring here). These species have a restricted distribution range. Such habitat specialisation increases the vulnerability of a species to impacts such as disturbance and habitat destruction.

Seven of the above species are endemic/near-endemic to Namibia. The Damara Tern is a breeding endemic with a very restricted habitat. The Dune Lark is endemic to the Namib Desert. Near-endemics are Gray's Lark, Rüppell's Korhaan, Rüppell's Parrot, Rosy-faced Lovebird and Bradfield's Swift.

Thirty-five species are endemic/near-endemic to southern Africa. These include Red-billed Spurfowl, South African Shelduck, Cape Shoveler, Monteiro's Hornbill, Southern Yellow-billed Hornbill, Namaqua Sandgrouse, Hartlaub's Gull, Cape Cormorant, Crowned Cormorant, Bank Cormorant, Southern Pale Chanting Goshawk and a diversity of other smaller species.

RESIDENT, MIGRANT AND NOMADIC BIRD SPECIES

Of the total species occurring here, 150 species (64%) are resident, 80 (34%) are nomadic at times and 72 (31%) are migrant at times.

Migrant species undertake large-scale, regular seasonal movements, usually to the northern hemisphere and back. In contrast, nomadic species generally remain within the southern African Sub region, moving around widely and in no fixed pattern to exploit patchy and unpredictable food, water and other environmental resources, mainly in response to climatic conditions. Numbers of species and abundance may thus vary markedly over time. Both migrant and nomadic movements increase the vulnerability of species to impacts such as collisions with overhead structures.

Among the migrant aquatic birds are Damara Tern, Southern Pochard, Lesser Moorhen, Black-tailed and Bar-tailed Godwit, Common Whimbrel, Eurasian Curlew, Common Redshank, Marsh Sandpiper,

Wood Sandpiper, Terek Sandpiper, Common Sandpiper, Common Greenshank, Ruddy Turnstone, Red Knot, Sanderling, Little Stint, Curlew Sandpiper, Ruff, two phalaropes, Greater Painted-snipe, African Jacana, Black-winged Stilt, Pied Avocet, nine plovers (including Grey Plover, Common Ringed Plover, Kittlitz's plover, Chestnut-banded Plover), two lapwings, Subantarctic Skua, nine terns (including Swift, Sandwich, Common), two jaegers, four cormorants (including Cape, Bank, Crowned), Little Egret, two flamingos and White Stork.

Species that are nomadic (at times) in the study area include aquatic species such as White-faced Duck, White-backed Duck, Maccoa Duck, Egyptian Goose, South African Shelduck, Cape Teal, Cape Shoveler, Red-billed Teal, Hottentot Teal, Rüppell's Parrot, Rosy-faced Lovebird, Common Moorhen, Red-knobbed Coot, Namaqua sandgrouse, African (Black) Oystercatcher, Black-winged Stilt, Pied Avocet, three plovers, African Wattled Lapwing, Grey-headed Gull, Hartlaub's Gull, Caspian Tern, Little Grebe, Black-necked Grebe, Cape Gannet, Reed Cormorant, White-breasted Cormorant, Cape Cormorant, Bank Cormorant, three egrets, two flamingos, African Spoonbill, Great White Pelican, Black Stork, two storm-petrels, three albatrosses, two petrels, Sooty Shearwater, Pied Crow and a number of other smaller species.

5.3.3 Fauna

The Namib Desert is one of five coastal deserts world-wide. The frequent coastal fog is a significant source of moisture and supports a unique terrestrial ecology. The Namib Desert is estimated to be around 80 million years old. The long evolutionary history and occurrence of diverse ecological niches have given rise to an exceptional biodiversity (Seely, 2004) with a high level of endemism (Barnard, 1998). In this hyper-arid environment species redundancy is low and the ecosystem is highly susceptible to disturbance and slow to recover.

The protection of the coastline has a high priority on the political agenda at all levels. More than 90% of the two northern coastal regions (Kunene and Erongo) fall within Namibia's national protected areas system (NACOMA, 2008). The coast of Namibia falls within a series of contiguous protected and recreational areas, namely the Skeleton Coast National Park, the recently proclaimed Dorob National Park, the Namib-Naukluft National Park and the proposed Sperrgebiet National Park, formerly a mining concession completely off-limits to the public and accessible to only a few scientists. The coastline of Namibia is, in fact, part of a continuum of protected areas that stretches from Southern Angola into Namaqualand in South Africa and is considered to enjoy a relatively high level of protection.

The strip north of Swakopmund between the beach and the C34 road includes coastal plains which host Damara Tern breeding areas, dune hummocks which contain endemic coastal invertebrates and reptiles, as well as marine life and surf zone species. (Environmental Managment Plan for the Town of Swakopmund, 2010). Terrestrial invertebrates include insects such as tenebrionid beetle and tan beetles, arachnids, isopods. These invertebrates form the lower level of the food chain along the coast and are critical as food for birds and small terrestrial mammals (CSIR, 2009). The coastal plains around the Swakopmund Salt Works have been highly disturbed by a range of human activities including the ongoing operations associated with the Salt Works, guano harvesting and oyster farming operations. Vehicle tracks are abundant and human activity disturbances frequent, and the current levels of disturbance are extremely high.

The marine birds and associated biodiversity in the evaporation pans may serve to attract predator species of the region and may encourage intermittent visits from aardwolf (*Proteles cristatus*), brown hyena (*Hyaena brunnea*), African wild cat (*Felis sylvestris*), bat-eared fox (*Otocyon megalotis*) and Cape fox (*Vulpes chama*), all of which are considered vulnerable.

The West Coast Recreation Area (now part of the Dorob National Park) is host to a distinct reptile and amphibian fauna. Approximately 60 reptile species (approximately 23% of all Namibian reptile species and 50% of Namibian endemic reptile species) are endemic to, or found mainly in, the Namib Desert (Barnard, 1998). Overall, 77 indigenous reptile species occur in the larger Skeleton Coast area.

5.3.4 Marine ecology[35]

The following section is technical in nature and so we have provided a glossary of terms to assist the reader in understanding the various technical terms used here.

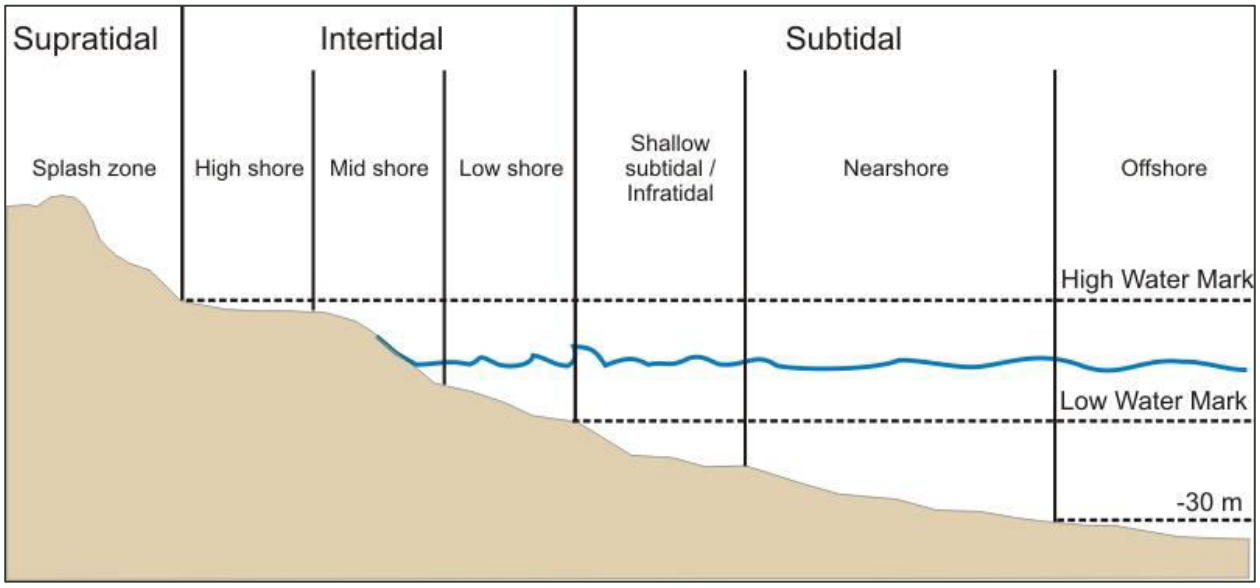
Benthic	Referring to organisms living in or on the sediments of aquatic habitats (lakes, rivers, ponds, etc.).
Benthos	The sum total of organisms living in, or on, the sediments of aquatic habitats.
Benthic organisms	Organisms living in or on sediments of aquatic habitats.
Biodiversity	The variety of life forms, including the plants, animals and micro-organisms, the genes they contain and the ecosystems and ecological processes of which they are a part.
Biomass	The living weight of a plant or animal population, usually expressed on a unit area basis.
Biota	The sum total of the living organisms of any designated area.
Bivalve	A mollusk with a hinged double shell.
Community structure	All the types of taxa present in a community and their relative abundance.
Community	An assemblage of organisms characterized by a distinctive combination of species occupying a common environment and interacting with one another.
Dilution	The reduction in concentration of a substance due to mixing with water.
Effluent	A complex waste material (e.g. liquid industrial discharge or sewage) that may be discharged into the environment.
Epifauna	Organisms, which live at or on the sediment surface being either attached (sessile) or capable of movement.
Ecosystem	A community of plants, animals and organisms interacting with each other and with the non-living (physical and chemical) components of their environment.
Guideline trigger values	These are the concentrations (or loads) of the key performance indicators measured for the ecosystem, below which there exists a low risk that adverse biological (ecological) effects will occur. They indicate a risk of impact if exceeded and should 'trigger' some action, either further ecosystem specific investigations or implementation of management/remedial actions.
Habitat	The place where a population (e.g. animal, plant, micro-organism) lives and its surroundings, both living and non-living.
Infauna	Animals of any size living within the sediment. They move freely through interstitial spaces between sedimentary particles or they build burrows or tubes.
Inter-specific	Biological stress between co-existing species

[35] *Section authored by Dr Andrea Pulfrich of Pisces Environmental Services.*

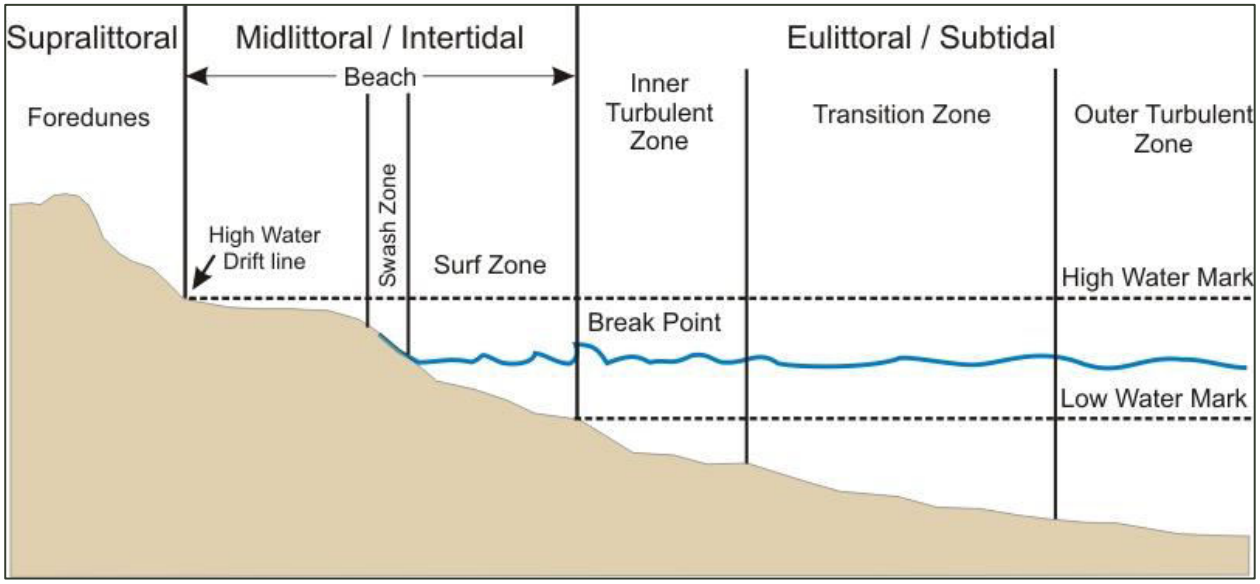
stress	
Macrofauna	Animals >1 mm.
Macrophyte	A member of the macroscopic plant life of an area, especially of a body of water; large aquatic plant.
Meiofauna	Animals <1 mm.
Mariculture	Cultivation of marine plants and animals in natural and artificial environments.
Marine discharge	Discharging wastewater to the marine environment either to an estuary or the surf-zone or through a marine outfall (i.e. to the offshore marine environment).
Marine environment	Marine environment includes estuaries, coastal marine and near-shore zones, and open-ocean-deep-sea regions.
Pollution	The introduction of unwanted components into waters, air or soil, usually as result of human activity; e.g. hot water in rivers, sewage in the sea, oil on land.
Population	Population is defined as the total number of individuals of the species or taxon.
Dissolved oxygen	Oxygen dissolved in a liquid, the solubility depending upon temperature, partial pressure and salinity, expressed in milligrams/litre or millilitres/litre.
Effluent	Liquid fraction after a treatment process (i.e. preliminary, primary, secondary or tertiary) in a wastewater treatment works.
Environmental impact	A positive or negative environmental change (biophysical, social and/or economic) caused by human action.
Environmental quality objective	A statement of the quality requirement for a body of water to be suitable for a particular use (also referred to as Resource Quality Objective).
Recruitment	The replenishment or addition of individuals of an animal or plant population through reproduction, dispersion and migration.
Sediment	Unconsolidated mineral and organic particulate material that settles to the bottom of aquatic environment.
Species	A group of organisms that resemble each other to a greater degree than members of other groups and that form a reproductively isolated group that will not produce viable offspring if bred with members of another group.
Sludge	Residual sludge, whether treated or untreated, from urban wastewater treatment plants.
Subtidal	The zone below the low-tide level, i.e. it is never exposed at low tide.
Surf-zone	Also referred to as the ‘breaker zone’ where water depths are less than half the wavelength of the incoming waves with the result that the orbital pattern of the waves collapses and breakers are formed.
Suspended material	Total mass of material suspended in a given volume of water, measured in mg/ℓ.
Suspended matter	Suspended material.
Suspended sediment	Unconsolidated mineral and organic particulate material that is suspended in a given volume of water, measured in mg/ℓ.
Taxon (Taxa)	Any group of organisms considered to be sufficiently distinct from other such groups to be treated as a separate unit (e.g. species, genera, families).
Turbidity	Measure of the light-scattering properties of a volume of water, usually measured in nephelometric turbidity units.
Vulnerable	A taxon is vulnerable when it is not Critically Endangered or Endangered but is facing a high risk of extinction in the wild in the medium-term future.

The following illustration provides a reader with an overview of the physiological construct and habitat types found in the littoral zone which will aid understanding of the sections to follow.

Figure 72: Cross-section of the coastal zone showing the typical habitats and morphology



Morphology and habitat zones of a typical rock shore



Morphology and habitat zones of a typical sandy shore

Biogeographically the central Namibian coastline falls into the warm-temperate Namib which extends northwards from Lüderitz into southern Angola (Emanuel *et al*., 1992). The coastal, wind-induced upwelling characterising the Namibian coastline, is the principle physical process which shapes the marine ecology of the central Benguela region.

The coastline of central Namibia is dominated by sandy beaches, with rocky habitats being represented only by occasional small rocky outcrops. Consequently, marine ecosystems along the coast comprise a limited range of habitats that include:

- Sandy intertidal and subtidal substrates;
- Intertidal rocky shores and subtidal reefs; and
- The water body.

The benthic communities within these habitats are generally ubiquitous throughout the southern African west coast region, being particular only to substratum type, wave exposure and/or depth zone. They consist of many hundreds of species, often displaying considerable temporal and spatial variability. The biological communities “typical” of each of these habitats are described briefly below,

focusing both on dominant, commercially important, and conspicuous species, as well as potentially threatened or sensitive species, which may be affected by the proposed project.

5.3.4.1 Rocky Habitats and Biota

INTERTIDAL ROCKY SHORES

The central and northern coasts of Namibia are bounded to the east by the Namib Desert and are characterised primarily by gravel plains and shifting dunes. In common with most semi-exposed to exposed coastlines on the southern African west coast, the rocky shores that occur in the region are strongly influenced by sediments, and include considerable amounts of sand intermixed with the benthic biota. This intertidal mixture of rock and sand is referred to as a mixed shore, and constitutes 40% of the coastline between the Kunene River and Walvis Bay (Bally *et al*., 1984). In the study area, mixed shores are limited to small low-shore outcrops that are exposed only at low water spring, which alternate with stretches of low-shore platform reefs and extensive pebble and sandy beaches.

Typically, the intertidal area of rocky shores can be divided into different zones according to height on the shore. Each zone is distinguishable by its different biological communities, which is largely a result of the different exposure times to air. The level of wave action is particularly important on the low shore. Generally, biomass is greater on exposed shores, which are dominated by filter-feeders. Sheltered shores support lower biomass, and algae form a large portion of this biomass (McQuaid and Branch 1984 and McQuaid *et al*., 1985).

Mixed shores incorporate elements of the trophic structures of both rocky and sandy shores. As fluctuations in the degree of sand coverage are common (often adopting a seasonal affect), the fauna and flora of mixed shores are generally impoverished when compared to more homogenous shores. The macrobenthos is characterised by sand-tolerant species whose lower limits on the shore are determined by their abilities to withstand physical smothering by sand (Daly and Mathieson, 1977; Dethier, 1984 and van Tamelen, 1996). The rocky shores along the coastline of the Salt Works appear to be heavily influenced by mobile sediments as large expanses of rock are barren of biota and appear scoured. Patchy dominance in the mid- and low-shore by ephemeral green algae (*Ulva* spp., *Cladophora* spp.) also suggest that these shores are periodically smothered by sands, as these algae proliferate as soon as sediments are eroded away.

The published data on rocky intertidal biota is restricted to the areas south of Lüderitz (Penrith and Kensley, 1970a; Pulfrich *et al*., 2003a, 2003b; Pulfrich, 2004b, 2005, 2006, 2007a; Clark *et al*. 2004, 2005, 2006; Pulfrich and Atkinson, 2007), and north of Rocky Point (Penrith and Kensley, 1970b and Kensley and Penrith, 1980), with only a single published study documenting the area between Walvis Bay and Swakopmund (Nashima, 2013). The information sourced from these publications, is complemented by unpublished data on rocky biota in the Wlotzkasbaken area supplied by Ministry of Fisheries and Marine Resources (MFMR) (Currie, MFMR, unpublished data), an unpublished student report on invertebrate macrofauna occurring at three shores between Walvis Bay and Swakopmund (Ssemakula, 2010) and visual observations by the author.

Typical species in the high shore include the tiny snail *Afrolittorina knysnaensis*, the false limpet *Siphonaria capensis*, the limpet *Scutellastra granularis*, and often dense stands of the barnacle *Chthamalus dentatus*. Further down the shore the mytilid mussels, *Semimytilus algosus*, *Choromytilus meridionalis*, and *Perna perna* occur. The invasive alien Mediterranean mussel *Mytilus galloprovincialis* is also present. Foliose algae are represented primarily by the red algae *Caulacanthus ustulatus*, *Ceramium* spp., *Plocamium* spp. and *Mazzaella capensis* and the ephemeral green algae *Ulva* spp. and *Cladaphora* spp. In sand influenced areas the sand-tolerant algae *Nothogenia erinacea* and *Gelidium capense* and the anemone *Aulactinia reynaudi* also occur.

The species encountered at the rocky outcrops in the study area were similar to those recorded from rocky intertidal areas in southern Namibia, and further to the north.

Although not directly harbouring any rare faunal or floral species, rocky intertidal shores are food-rich habitats for seabirds and wetland birds, attracting higher numbers of birds than the surrounding sandy beaches. Rocky intertidal fauna most sensitive to disturbance are the large limpet species. They tend to be the first ones eliminated by disturbance and the last to recover because of possible narrow tolerance limits to changes in environmental conditions. They act as keystone species on rocky shore, controlling the abundance of foliose algae and hence many other species (Branch, 1981).

Figure 73: Intertidal rocky communities[36]

ROCKY SUBTIDAL REEFS

Reports on the benthic biota of nearshore reefs are restricted primarily to research undertaken in the vicinity of Lüderitz (Beyers, 1979; Tomalin, 1995; Pulfrich, 1998 and Pulfrich and Penney 1998, 1999, 2001) and information on rocky subtidal habitats in central Namibia is lacking. No scientific surveys have been undertaken of rocky subtidal habitats in the study area, and no information exists on the faunal and floral communities (Basson, pers. com.).

A hydrographical and geophysical survey conducted indicates that the area is characterised by gently sloping, low-relief rock outcrops intersected by sandy gullies and depressions (CSIR, 2008). The flat and featureless nature of the reefs suggests that they may intermittently be covered by a veneer of unconsolidated sediments. Although kelp occurs sparsely for up to 100m offshore, the benthic communities inhabiting these reefs can be expected to be dominated by sand-tolerant and deposit feeding species.

A diving survey with the purpose of investigating the sea floor communities in the vicinity of the proposed brine discharge points of the then proposed NamWater Desalination Plant was conducted 2008 (Pulfrich and Steffani, 2008). Unfortunately only limited information on the benthic communities

[36] *Notes: Intertidal rocky communities in the vicinity of the proposed desalination plant area showing intertidal zonation (left) and inundation by mobile sediments (right).*

in the area could be gathered due to poor underwater visibility, however, it was ascertained that the seabed in the area was primarily bedrock covered by sand of various thickness. Benthic organisms present included tube worms, which had constructed compact sandy reefs of 0.75m to 1.0m in diameter and up to 0.6m in height, inhabited by various rocky bottom species including polychaetes, amphipods, isopods, rock boring bivalves and sea anemones. Sparse clumps of large mussels (*Perna perna*) were interspersed among the tube-worm colonies. Rocky outcrops or larger boulders were densely covered by red filamentous and foliose algae, with clumps of very large *Perna* (up to 135mm in length) occurring between the algal patches. The predatory gastropod *Thais haemastoma*, which apparently can occur in large numbers, was also recorded.

5.3.4.2 Sandy Substrate Habitats and Biota

The benthic biota of soft bottom substrates constitutes invertebrates that live on (epifauna), or burrow within (infauna), the sediments, and are generally divided into megafauna (animals larger than 10mm), macrofauna (larger than 1mm) and meiofauna (less than 1mm).

INTERTIDAL SANDY BEACHES

Sandy beaches are one of the most dynamic coastal environments. The composition of their faunal communities is largely dependent on the interaction of wave energy, beach slope, and sand particle size, which is called beach morphodynamics. Three morphodynamic beach types are described: dissipative, reflective, and intermediate beaches (McLachlan *et al.* 1993 and Defeo and McLachlan 2005). Generally, dissipative beaches are relatively wide and flat with fine sands and high wave energy. Waves start to break far from the shore in a series of spilling breakers that “dissipate” their energy along a broad surf-zone. This generates slow swashes with long periods, resulting in less turbulent conditions on the gently sloping beach face. These beaches usually harbour the richest intertidal faunal communities. Reflective beaches have low wave energy, and are coarse grained (larger than 500µm sand) with narrow and 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. The result is faunal communities is lacking in numbers and variety. Intermediate beach conditions exist between these extremes and have a very variable species composition (McLachlan *et al.* 1993 and Jaramillo *et al.,* 1995). This variability is mainly attributable to the amount and quality of food available. Beaches with a high input of e.g. kelp wrack have a rich and diverse drift-line fauna, which is sparse or absent on beaches lacking a drift-line (Branch and Griffiths, 1988; Field and Griffiths, 1991).

In the area between Walvis Bay and the Kunene River, beaches make up 44% of the coastline (Bally *et al*., 1984). A number of studies have been conducted on sandy beaches in central Namibia, including Sandwich Harbour (Stuart, 1975; Kensley and Penrith, 1977), the Paaltjies (McLachlan, 1985) and Langstrand (McLachlan, 1985, 1986; Donn and Cockcroft 1989), beaches near Walvis Bay and Cape Cross (Donn and Cockcroft, 1989), and recently a beach survey was conducted near Wlotzkasbaken as part of the baseline study for the Areva desalination plant (Pulfrich, 2007b). A further study by Tarr *et al*. (1985) investigated the ecology of three beaches further north on the Skeleton Coast. The results of these studies are summarised below.

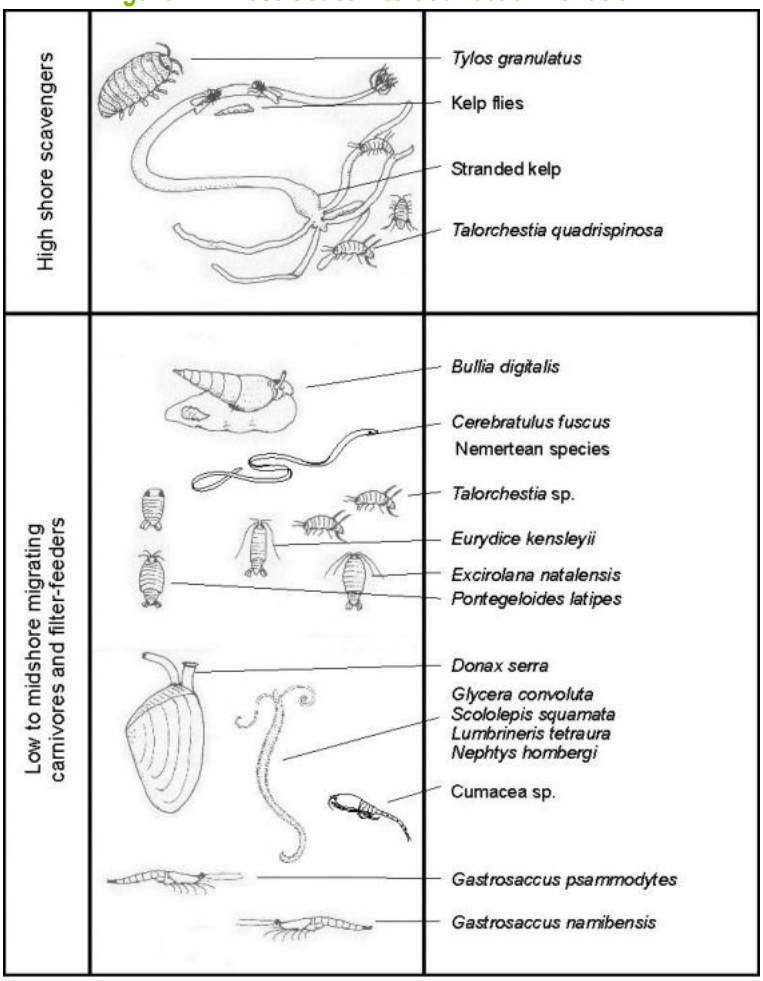
Most beaches on the central Namibian coastline are open ocean beaches receiving continuous wave action. They are classified as “exposed” to “very exposed” on the 20-point exposure rating scale (McLachlan 1980), and intermediate to reflective and composed of well-sorted medium to coarse sands. The beaches tend to be characterised by well-developed berms, and are well-drained and oxygenated.

Numerous methods of classifying beach zonation have been proposed, based either on physical or biological criteria. The general scheme proposed by Branch and Griffiths (1988) is used below, supplemented by data from central Namibian beach studies (Stuart 1975; Kensley and Penrith 1977; McLachlan 1985, 1986; Donn 1986 and Donn and Cockcroft 1989) (Figure 74).

Supralittoral zone - The supralittoral zone is situated above the high water spring (HWS) tide level, and receives water input only from large waves at spring high tides or through sea spray. The supralittoral is characterised by a mixture of air breathing terrestrial and semi-terrestrial fauna, often associated with and feeding on kelp deposited near or on the driftline. Terrestrial species include a diverse array of beetles and arachnids and some oligochaetes, while semi-terrestrial fauna include the oniscid isopod *Tylos granulatus*, and the talitrid amphipod (Amphipoda, Crustacea) *Talorchestia quadrispinosa*. Community composition depends on the nature and extent of wrack, in addition to the physical factors structuring beach communities, as described above.

Midlittoral zone - The intertidal zone, also termed the mid-littoral zone, has a vertical range of about 2m. This mid-shore region is characterised by the cirolanid isopods *Pontogeloides latipes*, *Eurydice (longicornis) kensleyi*, and *Excirolana natalensis*, the deposit-feeding polychaete *Scolelepis squamata* (Polychaeta) and various species of the polychaete genus *Lumbrineris* and the amphipods of the families Lysianassidae and Phoxocephalidae. In some areas, juvenile and adult sand mussels *Donax serra* (Bivalvia, Mollusca) may also be present in considerable numbers.

Figure 74: West Coast intertidal beach zonation[37]



Inner turbulent zone - The inner turbulent zone extends from the low water spring tide level to about -2m depth, and is characterised by highly motile specie. The bentho-planktic mysids *Gastrosaccus namibensis* and *G. psammodytes* (Mysidacea, Crustacea), the ribbon worm *Cerebratulus fuscus* (Nemertea) and the cumacean *Cumopsis robusta* (Cumacea) are typical of this zone, although they generally extend partially into the midlittoral above. In areas where a suitable swash climate exists, the gastropod *Bullia digitalis* (Gastropoda, Mollusca) may also be present in considerable numbers.

Transition zone - The transition zone spans approximately 2m to 3m depth and marks the area to which the break point might move during storms. Extreme turbulence is experienced in this zone, and as a consequence this zone typically harbours the lowest diversity on sandy beaches. Typical fauna of this zone include the polychaetes *Nephtys hombergi*, *Diopatra neopolitana* and *Glycera convoluta*, nemertean worms, amphipods such as *Urothoe elegans* and *Mandibulophoxus stimpsoni*, and the isopods *Cirolana hirtipes* and *Eurydice (longicornis=) kensleyi*.

Outer turbulent zone - Below 3m depth extends the outer turbulent zone, where turbulence is significantly decreased, and which is marked by a sudden increase in species diversity and biomass. In addition to the polychaetes found in the transition zone, other polychaetes in this zone include

[37] *Notes: Schematic representation of the West Coast intertidal beach zonation (adapted from Branch & Branch 1981). Species commonly occurring on the central Namibian beaches are listed.*

Diopatra neopolitana and *Glycera convoluta*. The abundance of nemertean worms increases significantly from that in the transition zone. Amphipods such as *Urothoe elegans* and *Mandibulophoxux stimpsoni* are also more abundant, as are the isopods *Cirolana hirtipes* and *Pontogeloides latipes*, the mysid *G. namibensis*, the decapods *Diogenes extricatus* and *Ogyrides saldanhae*, and the three spot swimming crab *Ovalipes punctatus*, as well as the gastropods *Bullia laevissima* and *Natica forata*.

The surf-zone in the study area is rich in phytoplankton (primarily dinoflagellates and diatoms) and zooplankton. Particulate organic matter is commonly deposited on the beaches as foam and scum. The organic matter, both in suspension and deposited on the sand, are thought to represent the main food input into these beaches, thereby accounting for the dominance of filter-feeders in the macrofaunal biomass (McLachlan 1985).

Most of the macrofaunal species recorded from beaches in central Namibia are ubiquitous throughout the biogeographic province, and no rare or endangered species are known. The invertebrate communities are similar to those recorded from beaches in southern Namibia (McLachlan and De Ruyck, 1993; Nel *et al*., 1997; Meyer *et al*., 1998; Clark and Nel, 2002; Clark *et al.,* 2004; Pulfrich, 2004a; Clark *et al.,* 2005, 2006; Pulfrich and Atkinson, 2007 and Pulfrich *et al*. 1013). The beaches are characterised by a relatively depauparate invertebrate fauna, both with regard to species diversity and biomass, which is typical of high-energy west coast beaches.

SUBTIDAL SANDY HABITATS

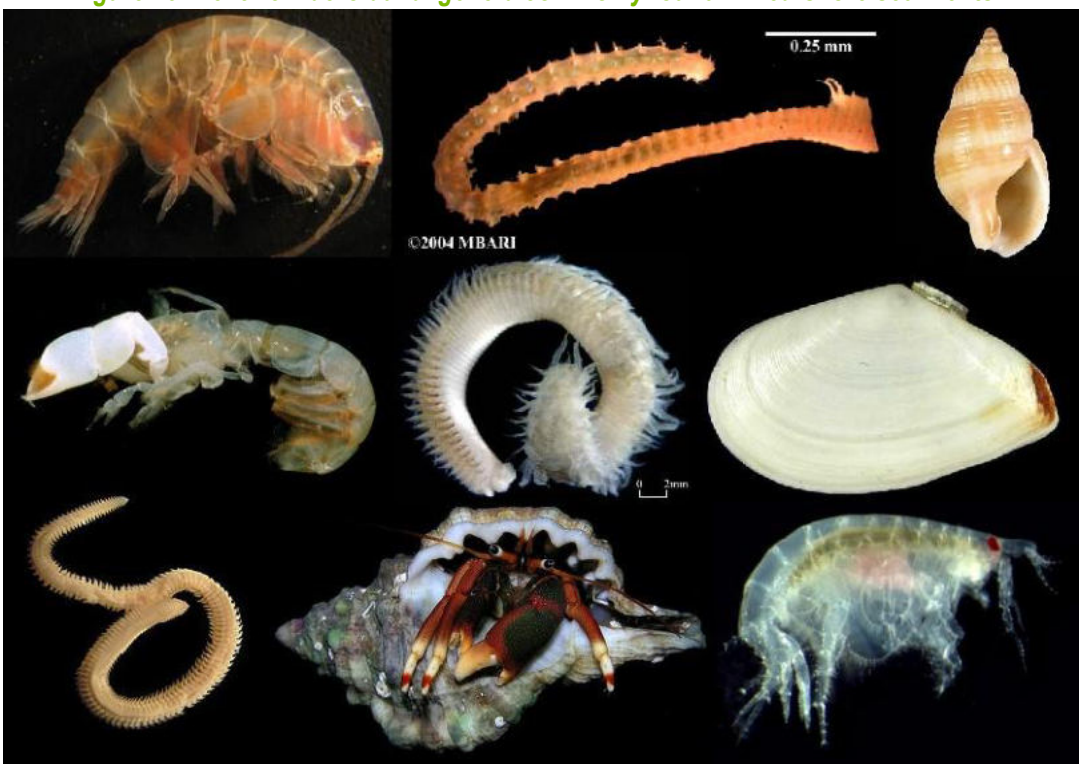
In the subtidal region, the structure and composition of benthic soft bottom communities is primarily a function of water depth and sediment grain size, but other factors such as current velocity, organic content, and food abundance also play a role (Snelgrove and Butman, 1994; Flach and Thomsen, 1998; Ellingsen, 2002).

With the exception of numerous studies on the benthic fauna of Walvis Bay lagoon (Kensley, 1978; CSIR, 1989, 1992 and Cowi, 2003; Tjipute and Skuuluka, 2006), there is a noticeable scarcity of published information on the subtidal soft sediment biota along the rest of the central Namibian coast. The only reference sourced was that of Donn and Cockcroft (1989) who investigated macrofauna to 5m depth at Langstrand (see description for outer-turbulent zone above). In general, almost no scientific work on subtidal benthic communities has been done in the vicinity of the study area, or within the general region (Basson, MFMR, pers. comm.) and no further information could be obtained.

Beyond the outer turbulent zone to 80m depth, species diversity, abundance, and biomass generally increases with communities being characterised equally by polychaetes, crustaceans, and molluscs. The midshelf mudbelt is a particularly rich benthic habitat where biomass can attain 60g/m^2 dry weight (Christie, 1974; see also Steffani, 2007b). The comparatively high benthic biomass in this mudbelt region represents an important food source to carnivores such as the mantis shrimp, cephalopods, and demersal fish species (Lane and Carter, 1999). In deeper water beyond this rich zone biomass declines to 4.9g/m^2 at 200m depth and then is consistently low (less than 3g/m^2) on the outer shelf (Christie, 1974).

Typical species occurring at depths of up to 60m included the snail *Nassarius* spp., the polychaetes *Orbinia angrapequensis*, *Nepthys sphaerocirrata*, several members of the spionid genera *Prionospio*, and the amphipods *Urothoe grimaldi* and *Ampelisca brevicornis*. The bivalves *Tellina gilchristi* and *Dosinia lupinus orbignyi* are also common in certain areas. All these species are typical of the southern African west coast (Christie, 1974; 1976; McLachlan, 1986; Parkins and Field, 1998; Pulfrich and Penney, 1999b; Goosen *et al.,* 2000; Steffani and Pulfrich, 2004a; 2007 and Steffani, unpublished data) (Figure 75).

Figure 75: Benthic macrofaunal genera commonly found in nearshore sediments[38]



Whilst many empirical studies related community structure to sediment composition (e.g. Christie, 1974; Warwick *et al,.* 1991; Yates *et al.,* 1993; Desprez, 2000 and van Dalfsen *et al.,* 2000), other studies have illustrated the high natural variability of soft-bottom communities, both in space and time, on a scale of hundreds of metres to metres (e.g. Kenny *et al.,* 1998; Kendall and Widdicombe, 1999; van Dalfsen *et al.,* 2000; Zajac *et al.* 2000 and Parry *et al,.* 2003), with evidence of mass mortalities and substantial recruitments (Steffani and Pulfrich, 2004a). It is likely that the distribution of marine communities in the mixed deposits of the coastal zone is controlled by complex interactions between physical and biological factors at the sediment–water interface, rather than by the granulometric properties of the sediments alone (Snelgrove and Butman, 1994 and Seiderer and Newell, 1999). For example, off central Namibia it is likely that periodic intrusion of low oxygen water masses is a major cause of this variability (Monteiro and van der Plas, 2006 and Pulfrich *et al.,* 2006). Although there is a poor understanding of the responses of local continental shelf macrofauna to low oxygen conditions, it is safe to assume that in areas of frequent oxygen deficiency the communities will be characterised by species able to survive chronic low oxygen conditions, or colonising and fast-growing species able to rapidly recruit into areas that have suffered complete oxygen depletion. Local hydrodynamic conditions, and patchy settlement of larvae, will also contribute to small-scale variability of benthic community structure.

It is evident that an array of environmental factors and their complex interplay is ultimately responsible for the structure of benthic communities. Yet the relative importance of each of these factors is difficult to determine as these factors interact and combine to define a distinct habitat in which the animals occur. However, it is clear that water depth and sediment composition are two of the major components of the physical environment determining the macrofauna community structure

[38] *Notes: (top: left to right) Ampelisca, Prionospio, Nassarius; (middle: left to right) Callianassa, Orbinia, Tellina; (bottom: left to right) Nephtys, hermit crab, Bathyporeia.*

off southern Namibia (Steffani and Pulfrich, 2004a, 2004b, 2007 and Steffani 2007a, 2007b, 2009a, 2009b, 2009c, 2010).

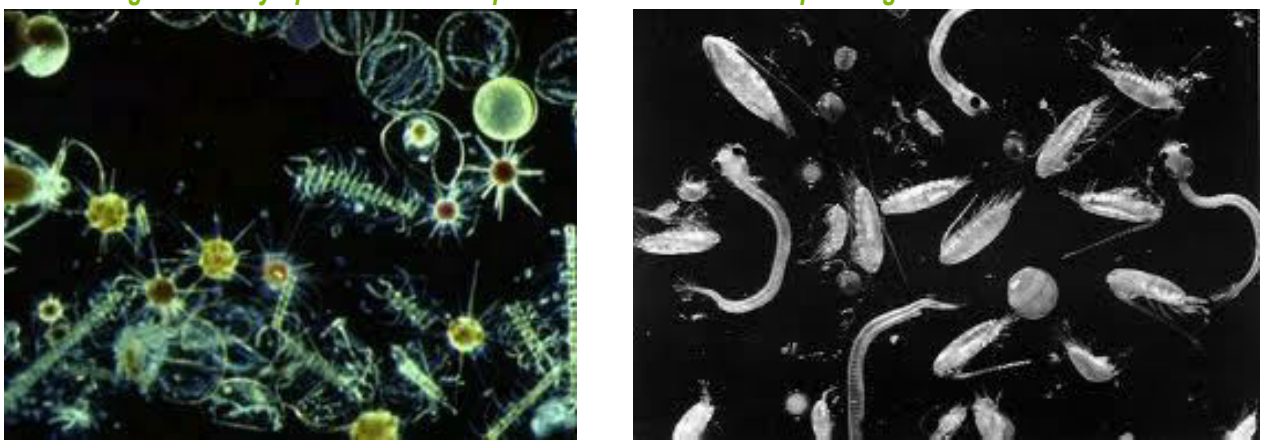
5.3.4.3 Pelagic Communities

The pelagic communities are typically divided into plankton and fish, and their main predators, marine mammals (seals, dolphins, and whales), seabirds and turtles. Seabirds are dealt with in a separate specialist study and will thus not be discussed further here.

PLANKTON

Plankton is particularly abundant in the shelf waters off Namibia, being associated with the upwelling characteristic of the area. Plankton range from single-celled bacteria to jellyfish of 2m diameter, and include bacterio-plankton, phytoplankton, zooplankton, and ichthyoplankton (Figure 76).

Figure 76: Phytoplankton and zooplankton associated with upwelling on the Namibian shelf[39]



Off the Namibian coastline, phytoplankton is the principle primary producers with mean annual productivity being comparatively high at 2g C/m^2/day. The phytoplankton is dominated by diatoms, which are adapted to the turbulent sea conditions. Diatom blooms occur after upwelling events, whereas dinoflagellates are more common in blooms that occur during quiescent periods, since they can grow rapidly at low nutrient concentrations (Barnard, 1998). A study on phytoplankton in the surf zone off two beaches in the Walvis Bay and Cape Cross area showed relatively low primary production values of only 10mg to 20mg C/m^2/day compared to those from oceanic waters. This was attributed to the high turbidity in this environment (McLachlan, 1986). In the surf-zone, diatoms and dinoflagellates are nearly equally important members of the phytoplankton, and some silicoflagellates are also present. Characteristic species belong to the genus *Gymnodinium*, *Peridinium*, *Navicula*, and *Thalassiosira* (McLachlan, 1986).

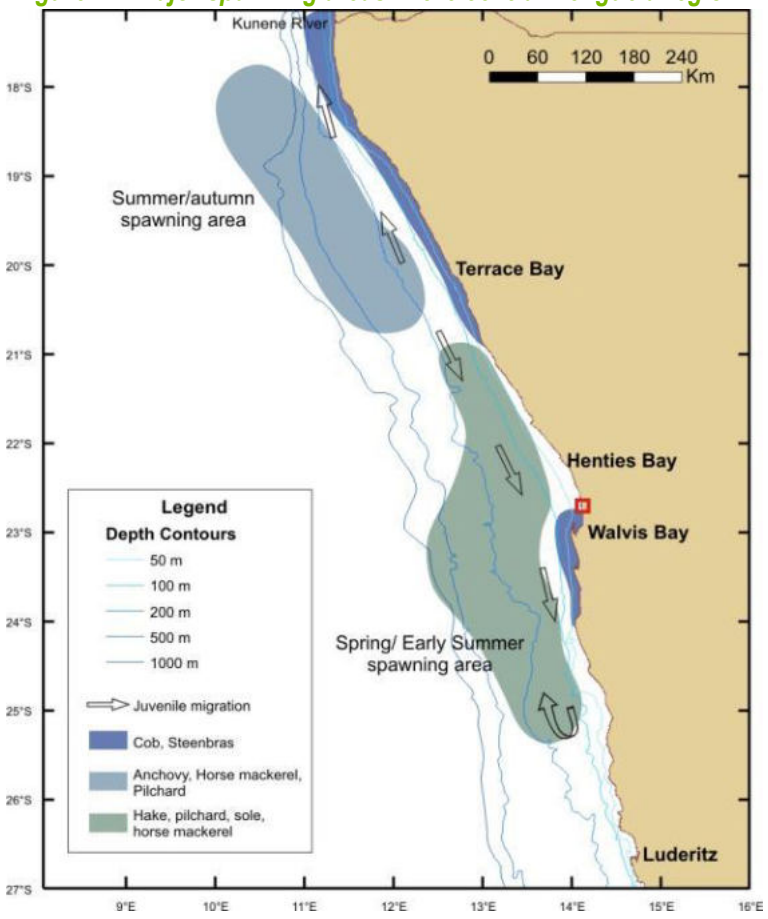
Namibian zooplankton reaches maximum abundance in a belt parallel to the coastline and offshore of the maximum phytoplankton abundance. Samples collected over a full seasonal cycle (February to December) along a 10 to 90-nautical-miles transect offshore Walvis Bay showed that the mesozooplankton (less than 2mm body width) community included egg, larval, juvenile and adult stages of copepods, cladocerans, euphausiids, decapods, chaetognaths, hydromedusae and salps, as well as protozoans and meroplankton larvae (Hansen *et al*., 2005). Copepods are the most

[39] *Notes: Phytoplankton (left, photo: hymagazine.com) and zooplankton (right, photo: mysciencebox.org) is associated with upwelling cells on the Namibian shelf.*

dominant group making up *70 to 85%* of the zooplankton. The four dominant calanoid copepod species, in order of abundance, are *M. lucens*, *C. carinatus*, *R. nasutus,* and *Centropages* spp. During the period of intense upwelling, the two herbivorous species, *C. carinatus* and *R. nasutus*, increase in abundance in the inshore area, leading to a shift in dominance from *C. carinatus* to *M. lucens* with increasing distance offshore. Seasonal patterns in copepod abundance, with low numbers during autumn (March–June) and increasing considerably during winter/early summer (July–December), appear to be linked to the period of strongest coastal upwelling in the northern Benguela (May–December), allowing a time lag of about 3 to 8 weeks, which is required for copepods to respond and build up large populations (Hansen *et al*., 2005). This suggest close coupling between hydrography, phytoplankton and zooplankton. Timonin *et al*. (1992) described three phases of the upwelling cycle (quiescent, active, and relaxed upwelling) in the northern Benguela, each one characterised by specific patterns of zooplankton abundance, taxonomic composition, and inshore-offshore distribution. It seems that zooplankton biomass closely follows the changes in upwelling intensity and phytoplankton standing crop. Consistently higher biomass of zooplankton occurs offshore to the west and northwest of Walvis Bay (Barnard, 1998).

Ichthyoplankton constitutes the eggs and larvae of fish. As the preferred spawning grounds of numerous commercially exploited fish species are located off central and northern Namibia, their eggs and larvae form an important contribution to the ichthyoplankton in the region.

Figure 77: Major spawning areas in the central Benguela region[40]



[40] *Notes: Major spawning areas in the central Benguela region (adapted from Cruikshank 1990) in relation to the study area (red rectangle – not to scale).*

FISH

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 and 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 coast of southern Namibia have been studied by Clark *et al.* (1998) and Meyer *et al.* (1998), who reported only five species occurring off exposed and very exposed beaches, these being southern mullet/harders (*Liza richardsonii*), white stumpnose (*Rhabdosargus globiceps*), False Bay klipfish (*Clinus latipennis*), Super klipvis (*C. superciliosus*) and galjoen (*Dichistius capensis*). Linefish species common off the central Namibian coastline include snoek (*Thyrsites atun*), silver kob (*Argyrosomus inodorus*), West Coast Steenbras (*Lithognathus aureti*), blacktail (*Diplodus sargus*), white stumpnose, Hottentot (*Pachymetopon blochii*), and galjoen (*Dichistius capensis*). From the surf zone off Langstrand beach near Walvis Bay, McLachlan (1986) recorded galjoen, West Coast steenbras, flathead mullet (*Mugil cephalus*), and southern mullet. Off Cape Cross, only two species were recorded, those being sandsharks (*Rhinobatos annulatus*) and the West Coast Steenbras.

No systematic surveys of the fish fauna of Walvis Bay, the lagoon and surrounding areas appear to have been undertaken. Glasson and Branch (1997) refer to the presence of the sandshark in Walvis Bay. Both mullet species enter the lagoon in large shoals, often pursued by flocks of Great White Pelicans or Cape Cormorants. Other fish species reported as occurring in the lagoon include silver kob, barbel (*Galeichthys feliceps*) and west coast steenbras. However, angling competition records for the lagoon indicate that no bony fishes have been caught since 2000 (Walvis Bay Angling Club), with only sandsharks, bull rays (*Pteromylacus bovinus*), blue sting rays (*Dasyatis pastinaca*) and hound sharks (*Mustelis mustelis)* being caught.

The biological, behavioural and life-history characteristics of the three most important linefish species in Namibian coastal waters are summarised below.

Silver kob, *Argyrosomus inodorus,* is distributed from northern Namibia to the warm temperate / subtropical transition zone on South Africa's east coast (Griffiths and Heemstra, 1995). Four stocks have been identified, one in Namibia, with its core distribution from Cape Frio in the north to Meob Bay in the south, a distance of 850km (Kirchner 2001). Maturity is reached at a length of 35cm and age of 1.5 years with a maximum recorded size of 36 kg (Kirchner *et al.,* 2001). Spawning occurs throughout the year but mostly in the warmer months from October to March when water temperatures are above 15°C and large adult fish occur in the nearshore, particularly in the identified spawning areas of Sandwich Harbour and Meob Bay. Adults are migratory whereas juveniles are resident in the surf zone.

The Namibian stock of *A. inodorus* is exploited by the commercial linefishery (deck and skiboats) and recreational shore angling with, until recently, a mean annual catch of 500t and 350t respectively. There is also a small recreational boat fishery (Kirchner, 2001). The stock is regarded as overexploited and near collapse with less than 25% of pristine spawner biomass remaining. The availability of *A. inodorus* and other fish species to shore and boat fishers is driven by environmental conditions. For example, strong south-westerly winds, large swells and upwelling all have a negative impact on catches. Warm-water events and sulphur eruptions inhibit feeding and the catchability of most species (Holtzhausen *et al.* 2001).

West Coast Dusky Kob, *Argyrosomus coronus,* is distributed from northern Namibia to northern Angola (Griffiths and Heemstra 1995), but do occur as far south as St Helena Bay in South Africa (Lamberth *et al.* 2008). Maturity is reached at a total length of 87cm and 4.5 years of age and a maximum size of 80kg attained (Potts *et al.,* 2012). Early juveniles frequent muddy sediments in 50-

100m depth, moving inshore once they reach 300mm total length. These juveniles and adolescents are resident in the nearshore, and are especially abundant in the turbid plume off the Cunene River Mouth and in selected surf zones of northern and central Namibia (Potts *et al.* 2010). The adults are migratory according to the movement of the Angola-Benguela frontal zone, moving northwards as far as Gabon in winter and returning to southern Angola in spring where spawning occurs in the offshore (Potts *et al.* 2010).

In Angola and Namibia, *A. coronus* are exploited by the shore- and boat-based commercial, artisanal, and recreational line fisheries. The Angolan beach-seine, gillnet and purse-seine fisheries also land this species. Overexploitation in its northern range is likely exacerbated by a distributional shift of adult fish out of Angolan waters. Ten years ago, the ratio of *A. inodorus* to *A. coronus* in the Namibian fishery was 10:1 (Kirchner and Beyer1999) compared to 10:15 in the present day (Potts *et al.* in prep). This is largely due to a distributional shift southwards also evidenced by a 58% reduction in relative abundance and a 27% reduction in mean length in Angolan waters (Potts *et al.* in prep). The overall forcer is thought to be warmer coastal waters in the northern Benguela coastal zone.

The populations of both kob species are under stress from fishing, climate change, distributional shifts, and an increase in inter-specific interactions. Inter-specific stress has also become a factor. *A. inodorus* and *A. coronus* now overlap in distribution and hybridisation, which may at least partly be due to a stress-induced breakdown in mate recognition, has occurred. In fish, hybridisation is usually associated with increased resistance to disease and physiological tolerance of environmental stresses, and often allows species to expand their ranges to invade new niches. However, molecular support for potential reduced fitness in hybridized fish under environmental stress exists (David *et al.* 2004), providing a plausible explanation for the relatively rare occurrence of interspecies hybridisation in sympatric environments. Behavioural and biological responses such as distributional shifts and hybridisation make it clear that some population thresholds have already been reached and even low-level anthropogenic forcers may precipitate further change.

Similar to the kob species described above, white steenbras, *Lithognathus lithognathus,* and west coast steenbras *Lithognathus aureti* are sister species and sympatric from St Helena Bay to the Orange River Estuary. White steenbras occur from the Orange River to the Umtamvuna River on South Africa's eastern seaboard, but spawning habitat appears to be restricted to less than 50ha throughout its range (Sink *et al.,* 2011). Adults undertake an annual spawning migration to the edge of the species's distribution on the east coast. There is, however, circumstantial evidence for the "extinction" of a separate west coast spawning population due to overexploitation in the last century (Lamberth *et al.* 2011).

West coast steenbras, *Lithognathus aureti,* are endemic to the west coast of southern Africa, but rarely found outside Namibia's territorial waters (Holtzhausen 2000). However, they do occur as far south as St Helena Bay and historical abundance in South African waters is thought to have been a lot higher prior to the advent of the commercial beach-seine fishery (Lamberth *et al.,* 2008). In Namibia, *L. aureti* are exploited by commercial and recreational boat-based linefishers, as well as by recreational shore-anglers with a total landed catch of approximately 600t per annum (Holtzhausen and Mann 2000). Overexploitation in the early 1990s was arrested by the closure of the gillnet fishery for this species. Tagging studies have indicated that *L. aureti* comprise two separate closed populations; one in the vicinity of Meob Bay and one from central Namibia northwards (Holtzhauzen *et al.* 2001). Spawning localities are as yet unknown but tagging evidence suggests that males migrate considerable distances in search of gravid females (Holtzhausen, 2000).

The parallels between *L. aureti* and *L. lithognathus* suggest that the spawning habitat of west coast steenbras may also be limited. The bulk of the population exists in the nearshore at less than 10m depth, with juveniles occurring in the intertidal surf zone (McLachlan 1986). By inference, spawning occurs in the surf zone and eggs and larvae from both populations drift northwards (Holtzhausen,

2000). The fact that both populations of *L. aureti* exist entirely in the nearshore would make them susceptible to any coastal development that lies in the path of alongshore movement. Whereas juveniles occur in the surf zone throughout its range, spawning habitat may be extremely limited and has yet to be clearly identified.

Small pelagic species include the sardine/pilchard (Sadinops ocellatus) (Figure 78, left), anchovy (Engraulis capensis), chub mackerel (Scomber japonicus), horse mackerel (Trachurus capensis) (Figure 78, right) and round herring (Etrumeus whiteheadi). These species typically occur in mixed shoals of various sizes (Crawford et al,. 1987), and generally occur within the 200m contour, although they may often be found very close inshore, just beyond the surf zone. 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. The Namibian pelagic stock is currently considered to be in a critical condition due to a combination of over-fishing and unfavourable environmental conditions as a result of Benguela Niños.

Figure 78: Small pelagic Fish of the area[41]

Since the collapse of the pelagic fisheries, jellyfish biomass has increased and the structure of the Benguelan fish community has shifted, making the bearded goby (*Sufflogobius bibarbatus*) the new predominant prey species. However, despite increased predation pressure, the gobies are thriving. Recent research has shown that gobies have a very high tolerance of low oxygen and high H_2S levels, which enables them to feed on benthic fauna within hypoxic waters during the day, and then move to oxygen-richer pelagic waters at night, when predation pressure is lower, to feed on live jellyfish (Utne-Palm *et al.,* 2010 and van der Bank *et al.,* 2011).

TURTLES

Five of the eight species of turtle worldwide occur off Namibia (Bianchi *et al,.* 1999). Turtles that are occasionally sighted off central Namibia, include the Leatherback Turtle (*Dermochelys coriacea*), the largest living marine reptile. Limited information is available on marine turtles in Namibian waters, although leatherback turtles, which are known to frequent the cold southern ocean, are the most commonly-sighted turtle species in the region. Observations of Green (*Chelonia mydas*),

[41] *Notes: Cape fur seal preying on a shoal of pilchards (left). School of horse mackerel (right) (photos: www.underwatervideo.co.za; www.delivery.superstock.com).*

Loggerhead (*Caretta caretta*), Hawksbill (*Eretmochelys imbricata*) and Olive Ridley (*Lepidochelys olivacea*) turtles in the area are rare.

Leatherbacks turtles inhabit deeper waters and are considered a pelagic species, travelling the ocean currents in search of their prey (primarily jellyfish). While hunting they may dive to over 600m and remain submerged for up to 54 minutes (Hays *et al,.* 2004). Their large size allows them to maintain a constant core body temperature and consequently they can penetrate colder temperate waters.

The south Atlantic population of leatherback turtles is the largest in the world, with as many as 40,000 females thought to nest in an area centred on Gabon, yet the trajectory of this population is currently unknown (Witt *et al,.* 2011). Namibia is gaining recognition as a feeding area for leatherback turtles that are either migrating through the area or undertaking feeding excursions into Namibian waters. The turtles are thought to be attracted by the large amount of gelatinous plankton in the Benguela ecosystem (Lynam *et al,.* 2006). Based on tag returns from animals found dead in Namibia, these turtles are thought to come mainly from Gabonese and Brazilian nesting grounds (R. Braby, pers. comm., Namibia Coast Conservation and Management Project – NACOMA, 25 August 2010).

Although they tend to avoid nearshore areas, they may be encountered in the area around Walvis Bay between October and April when prevailing north wind conditions result in elevated seawater temperatures. Elwen and Leeney (2011) reported 21 sightings of leatherback turtles in Walvis Bay between 2009 and 2010. Anecdotal evidence suggests that sightings of leatherback turtles have been fewer in the past two years (Leeney, pers. comm. with tourism industry operators). Leatherback turtles have recently washed up in significant numbers on the central Namibian shore (Figure 79), with some being recorded as far south as Mining Area 1 in the Sperrgebiet (28°27'S) (Pulfrich, pers. obs.). During the past five years 200 to 300 dead turtles were found (www.nacoma.org.na). The shell of a green turtle was found in Sandwich Harbour in March 2012 (NDP data).

Several anthropogenic factors threaten sea turtle populations including entanglement in fishing gear, incidental catches in fisheries, vessel strikes, ingestion of marine debris, pollution, decline of habitat along the western atlantic coast and loss of nesting habitat (Carr, 1987; National Research Council (NRC) 1990; Lutz and Alfaro-Shulman, 1991; Lutcavage *et al.,* 1997; Witzell 1999; Witherington and Martin, 2000; Dwyer *et al,.* 2003 and James *et al.,* 2005). Anthropogenic noise is also thought to be detrimental to sea turtles (Samuel *et al.,* 2005), with likely effects on their behaviour and ecology.

Figure 79: Dead Leatherback Turtle washed up at a beach north of Swakopmund, March 2008

Leatherback Turtles are listed as “Critically Endangered” worldwide by the IUCN and are in the highest categories in terms of need for conservation in CITES (Convention on International Trade in Endangered Species), and Convention on Migratory Species (Convention on Migratory Species). Although Namibia is not a signatory of Convention on Migratory Species, Namibia has endorsed and signed a Convention on Migratory Species International Memorandum of Understanding specific to the conservation of marine turtles. Namibia is thus committed to conserve these species at an international level.

MARINE MAMMALS

Marine mammals occurring off the Namibian coastline include cetaceans (whales and dolphins) and seals. The cetacean fauna of the Namibian coast comprises between 22 and 31 species (Cetus Projects 2008; Currie *et al.,* 2009), the diversity reflecting both species recorded from the waters of Namibia (Williams *et al.,* 1990; Rose and Payne, 1991; Findlay *et al.* 1992; Griffin and Coetzee, 2005) and species expected to be found in the region based on their distributions elsewhere along the southern african west coast (Best, 2007; Elwen *et al.,* 2011a). The diversity is comparatively high, reflecting the cool inshore waters of the Benguela Upwelling system and the occurrence of warmer oceanic water offshore of this. The species confirmed to be present in Namibian waters are listed in Table 26.

Of the species recorded the endemic Heaviside’s Dolphin *Cephalorhynchus heavisidii* (Figure 80, left) is found in the extreme nearshore region of the project area. Although there are no population estimates for Heaviside’s dolphins as a whole, the size of the population utilising Walvis Bay in 2009 was estimated at 505 (Elwen and Leeney, 2009), and a degree of site fidelity of the species to Pelican Point was confirmed from images taken in 2008 and 2009. Sightings of this species in Walvis Bay occur mostly at Pelican Point; the few sightings in other parts of the bay occur more commonly in summer (January to March), when sightings at Pelican Point decrease, suggesting that these animals have a different primary habitat during those months. The range of the Heaviside’s dolphins in this area is unknown, although aerial surveys (Leeney in prep.) have revealed that they utilises nearshore habitat along much of the Namibian coastline including south of Walvis Bay, with a hotspot of abundance just south of Sandwich Harbour. Acoustic detections of the species at Pelican Point are most numerous during the night, decreasing to a minimum in the early afternoon (Leeney, *et al.* 2011). This pattern is likely linked with prey availability at this site. Although considered numerous in South African waters, Heaviside’s dolphins are vulnerable due to their use of human-impacted coastal habitats, the small home ranges of individuals and the restricted geographic range of the species.

Figure 80: Marine mammals[42]

The bottlenose dolphin (*Tursiops truncatus*) is found in the extreme nearshore region between Lüderitz and Cape Cross (including the Sandwich Harbour lagoon) (Elwen *et al.,* 2011b; Leeney in prep.), as well as offshore of the 200 m isobath along the Namibian coastline. This species has been a key element of the research conducted by the Namibian Dolphin Project in Walvis Bay, with the population in 2008 estimated (via photo-identification techniques) at 77 individuals. Since then there has been a *6 to 8%* annual reduction in the number of animals identified in the bay (Elwen *et al.* 2011b), with 19 individuals identified in 2008 not been seen since. This suggests some degree of emigration from the population. The reduction in the population is a serious concern and suggests that the species is under pressure in at least part of its range. Roughly twice as many individuals are identified in Walvis Bay in winter than during the summer months, suggesting that other habitats are more frequently utilised during the summer. A number of mother-calf pairs have been observed in Walvis Bay between 2008 and 2011. The reef north of Bird Island has been identified as an area used by these animals primarily for resting (Elwen and Leeney, 2009; Elwen *et al.,* 2011b), and has informally been designated as a No-Go zone for tour boats.

Although common bottlenose dolphins are found worldwide, they often live in isolated populations that number up to a few hundred individuals only. If such localised populations decline due to human impacts they can potentially die out, as numbers are not supplemented by animals from elsewhere. The Namibian population is unique within the Benguela ecosystem as it occurs close inshore, with their nearest neighbours being in central Angola.

Table 26: Cetacean species present in Namibian waters

Species name	Common name	Source
Mysticetes (baleen whales)		
Eubalaena australis	Southern right whale	Bianchi *et al.* 1999; Roux *et al.* 2001 ; Best 2007 ; Roux *et al.* 2010
Caperea marginata	Pygmy right whale	Bianchi *et al.* 1999; Best 2007 ; Leeney *et al.* in rev.
Balaenoptera edenii	Bryde's whale	Best 2007; NDP
Balaenoptera bonaerensis	Antarctic minke whale	Best 2007
Balaenoptera acutorostrata subsp.	Dwarf minke whale	Bianchi *et al.* 1999; Best 2007
Megaptera novaeangliae	Humpback whale	Bianchi *et al.* 1999; Best 2007; Barendse *et al.* 2011
Balaenoptera physalus	Fin whale	Bianchi *et al.* 1999; Best 2007
Balaenoptera musculus	Blue whale	Bianchi *et al.* 1999; Best 2007
Balaenoptera borealis	Sei whale	Best 2007
Odontocetes (toothed whales)		

[42] *Notes: The endemic Benguela Dolphin* Cephalorhynchus heavisidii *(left) (Photo: De Beers Marine Namibia), and Southern Right whale* Eubalaena australis *(right) (Photo: www.divephotoguide.com; www.aad.gov.au.*

Physeter macrocephalus	Sperm whale	Bianchi *et al.* 1999; Best 2007
Kogia sima	Dwarf sperm whale	Findlay *et al.* 1992; NDP
Kogia breviceps	Pygmy sperm whale	Ross 1984; Findlay *et al.* 1992; NDP
Globicephala melas and Globicephala macrorhynchus	Long-finned pilot whale and short-finned pilot whale	Findlay *et al.* 1992; Bianchi *et al.* 1999; Best 2007; NDP
Cephalorhynchus heavisidii	Heaviside's dolphin	Bianchi *et al.* 1999; Best 2007; Elwen and Leeney 2008
Tursiops truncatus	Bottlenose dolphin	Bianchi *et al.* 1999; Best 2007; Elwen and Leeney 2008
Delphinus delphis	Short-beaked common dolphin	Findlay *et al.* 1992; Best 2007
Pseudorca crassidens	False killer whale	Findlay *et al.* 1992; Best 2007; NDP
Lagenorhynchus obscurus	Dusky dolphin	Findlay *et al.* 1992; Bianchi *et al.* 1999 ; Best 2007
Feresa attenuata	Pygmy killer whale	Findlay *et al.* 1992; Best 2007
Lissodelphis peronii	Southern right whale dolphin	Rose and Payne 1991; Findlay *et al.* 1992; Bianchi *et al.* 1999; Best 2007
Grampus griseus	Risso's dolphin	Findlay *et al.* 1992
Orcinus orca	Killer whale/ orca	Bianchi *et al.* 1999; Findlay *et al.* 1992
Ziphius cavirostris	Cuvier's beaked whale	Findlay *et al.* 1992; Best 2007
Hyperoodon planifrons	Southern bottlenose whale	Best 2007
Mesoplodon europaeus	Gervais' beaked whale	Griffin and Coetzee 2005; Best 2007
Mesoplodon grayi	Gray's beaked whale	Findlay *et al.* 1992; Best 2007
Mesoplodon layardii	Layard's beaked whale (/strap-toothed whale)	Findlay *et al.* 1992; Griffin 1998; Best 2007
Mesoplodon densirostris	Blainville's beaked whale	Best 2007

Note: NDP refers to information collected and held, if not published, by the Namibian Dolphin Project, in reports or in stranding's database.

The dusky dolphin (*Lagenorhynchus obscurus*) is considered a pelagic species and often sighted by fishermen working in deeper waters. However, it is an occasional visitor to Walvis Bay, where they may beach (e.g. Elwen *et al.* 2011). Southern right-whale dolphins (*Lissodelphis peronii*) have an extremely localised year-round distribution associated with the continental shelf and the shelf-edge in the region between 24° and 28°S. A further 11 species are resident within the offshore area of the Namibian coastline in water depths of over 500m. Killer whales (*Orcinus orca*) are found throughout Namibian waters and likely range along the entire coastline (Elwen and Leeney, 2011). Pilot whales (*Globicephala* spp.) are commonly seen by fishermen in considerable numbers, and have also frequently been observed during offshore seismic surveys.

Of the southern hemisphere migratory whale species, blue whales (*Balaenoptera musculus*), fin whales (*B. physalus*), sei whales (*B. borealis*), minke whales (*B. acutorostrata*), Bryde's whale (*B. edeni*) and humpback whales (*Megaptera novaeangliae*) (Figure 80, right), and two species of balaenid whale, the southern right whale (*Eubalaena australis*) and the pygmy right whale (*Caperea marginata*) have been recorded in Namibian waters, primarily off the continental shelf during winter months. Humpback whales commonly have a summer distribution in polar waters (feeding grounds) and a winter distribution lower latitudes (breeding/calving grounds), and these whales have become frequent visitors to Walvis Bay during the austral winter (June to August). Barendse *et al.* (2011) identified 35 individual humpback whales from photo-identification images taken in Walvis Bay, comparing these whales with catalogues of humpbacks from Angola, South Africa, Gabon, and the Antarctic Humpback Whale Catalogue. No matches were found, however. Humpback whales off southern Africa were seriously depleted during the whaling era, but have since recovered well (Collins *et al.* 2008).

Southern right whales have also been documented in coastal waters (Roux *et al.* 2001; Leeney in prep) and are known to frequent Walvis Bay, particularly during the winter (June-September). The population was seriously depleted during the whaling era, but has recovered well and been increasing at 7% per year, with the African population estimated at approximately 4,600 animals in 2008 (Brandão *et al.* 2011). More frequent sightings of right whales off Namibia suggest that right whales are extending back into their old range, although most sightings within Namibia are still in the southern 400 km of the country (Roux *et al.* 2010). In recent years a number of the sheltered bays

between Chameis Bay (27°56'S) and Conception Bay (23°55'S) have become popular calving sites for Southern Right whales (Roux *et al.,* 2010).

Minke whales are also commonly sighted in Namibian waters, but mostly in the Lüderitz area. Pygmy right whales have stranded on numerous occasions in Walvis Bay, both as live animals and as carcasses (Leeney *et al.* in rev), with the high proportion of juvenile animals in stranding's records suggesting that a breeding ground or nursery area for this little-known, and possibly rare species may be located off the Namibian coast. Similarly, Pygmy right whales strand regularly along the Namibian coast, particularly in Walvis Bay. As the majority of strandings are juvenile individuals, there may likewise be a nursery ground offshore of the Walvis Bay area (Leeney *et al.* (in rev)). Stranding or skeletal records of southern bottlenose whales, rough toothed dolphin, and Gervais' beaked whale have been recorded from the Namibian coast, although the level to which these may be extra-limital records is unknown. There are no data on the population status of these species off the southern African coast.

Of the migratory cetaceans, the blue, sei and fin whales are listed as "Endangered" and the Southern Right and Humpback whales as "Least Concern" in the International Union for Conservation of Nature (IUCN) Red Data book. All whales and dolphins are given absolute protection under the Namibian Law.

The Cape fur seal (*Arctocephalus pusillus pusillus*) (Figure 81) is common along the Namibian coastline, occurring at numerous breeding sites on the mainland and on nearshore islands and reefs. Currently the largest breeding site in Namibia is at Cape Cross north of Walvis Bay where about 51,000 pups are born annually (MFMR unpubl. Data). The colony supports an estimated 157,000 adults (Hampton, 2003), with unpublished data from Marine and Coastal Management (South Africa) suggesting a number of 187,000 (Mecenero *et al.,* 2006). A further colony of approximately 9,600 individuals exists on Hollamsbird Island south of Sandwich Harbour. The colony at Pelican Point is primarily a haul-out site. The mainland seal colonies present a focal point of carnivore and scavenger activity in the area, as jackals and hyena are drawn to this important food source.

Seals are highly mobile animals with a general foraging area covering the continental shelf up to 120 nautical miles offshore (Shaughnessy, 1979), with bulls ranging further out to sea than females. The timing of the annual breeding cycle is very regular occurring between November and January. Breeding success is highly dependent on the local abundance of food, territorial bulls, and lactating females being most vulnerable to local fluctuations as they feed in the vicinity of the colonies prior to and after the pupping season (Oosthuizen, 1991). Namibian populations declined precipitously during the warm events of 1993/94 (Wickens, 1995), as a consequence of the impacts of these events on pelagic fish populations. Population estimates fluctuate widely between years in terms of pup production, particularly since the mid-1990s (MFMR unpubl. Data; Kirkman *et al.,* 2007).

There is a controlled annual quota, determined by government policy, for the harvesting of Cape fur seals on the Namibian coastline. The Total Allowable Catch (TAC) currently stands at 60,000 pups and 5,000 bulls, distributed among four licence holders. The seals are exploited mainly for their pelts (pups), blubber and genitalia (bulls). The pups are clubbed and the adults shot. These harvesting practices have raised concern among environmental and animal welfare organisations (Molloy and Reinikainen, 2003).

Figure 81: Cape Fur Seals[43]

[43] *Notes: Colony of Cape fur seals* Arctocephalus pusillus pusillus *(Photo: Dirk Heinrich).*

6 ENVIRONMENTAL ASSESSMENT METHODOLOGY

The section provides the assessment methodology employed in this impact assessment and which was used by the various specialists in the determination of impact significance ratings. Using a common methodology assists with ensuring consistency in impact rating across the various specialist disciplines.

The following section comprises the methodology that has been adopted when assessing impacts in the SEIA phase, and the issues identified by the specialist components which had to be assessed.

The preferred, and any feasible alternative/s (refer to section 4.12), were taken through to the assessment phase for detailed study, to determine the associated impacts, and to look at ways to mitigate negative impacts and optimise positive impacts. The SEIA was undertaken in terms of the standard accepted impact assessment methodology outlined below and includes the following components:

- An assessment of the full range of potential impacts identified during the Project Initiation and Scoping Phase[44], including all impacts identified in the Terms of Reference for this study. This includes construction and operational impacts, as well as the decommissioning of old structures, and cumulative impacts. It also addresses impacts both on and off site, as relevant (e.g. construction camps).
- Identification of potential mitigation measures to avoid negative impacts, or to reduce significance where avoidance is not possible.
- Release of an SEIA report (this report).

Assessment of predicted significance of impacts for a proposed development is by its nature, inherently uncertain – social and environmental assessment is thus an imprecise science. To deal with such uncertainty in a comparable manner, standardised and internationally recognised methodology[45] has been developed. Such accepted methodology is applied in this study to assess the significance of the potential environmental impacts of the proposed development, outlined as follows:

Table 27: Assessment criteria for the evaluation of impacts

CRITERIA	CATEGORY	DESCRIPTION
Extent or spatial influence of impact	National	Greater than 100km of the impact site
	Regional	Within 100km of the impact site
	Local	On site or within 5km of the impact site
*Magnitude of impact (at the indicated spatial scale)	High	Social and/or natural functions and/ or processes are severely altered (i.e. function is severely hampered and processes are unlikely to function)
	Medium	Social and/or natural functions and/ or processes are notably altered (i.e. function is affected to a noticeable degree and processes struggle to function effectively)
	Low	Social and/or natural functions and/ or processes are slightly altered (i.e. while function is affected in a measurable way, processes are likely to function, albeit sub-optimally)
	Very Low	Social and/or natural functions and/ or processes are negligibly altered (i.e. function is slightly affected and processes are likely to function effectively)
	Zero	Social and/or natural functions and/ or processes remain unaltered

[44] *Based on specialist assessment, the scope of which is to be determined at the end of the Scoping Phase, in consultation with the project proponent and the lead project managers.*

[45] *As described, inter alia, in the South African Department of Environmental Affairs and Tourism's Integrated Environmental Management Information Series (Gov of SA, 2002).*

Duration of impact	Long Term	More than 5 years after construction
	Medium Term	Up to 5 years after construction
	Short term (construction period)	6 months

*NOTE: Where applicable, the magnitude of the impact has to be related to the relevant standard (threshold value specified and source referenced). The magnitude of impact is based on specialist knowledge of that particular field.

For each impact, the EXTENT (spatial scale), MAGNITUDE (size or degree scale) and DURATION (time scale) are described. These criteria are used to ascertain the SIGNIFICANCE of the impact, firstly in the case of no mitigation and then with the most effective mitigation measure(s) in place. The decision as to which combination of alternatives and mitigation measures to apply lies with Rössing Uranium as the proponent, and their acceptance and approval ultimately with the relevant environmental authority. The tables on the following pages show the scale used to assess these variables, and defines each of the rating categories.

The SIGNIFICANCE of an impact is derived by taking into account the temporal and spatial scales and magnitude. Such significance is also informed by the context of the impact, i.e. the character and identity of the receptor of the impact. The means of arriving at the different significance ratings is explained in the following table, developed by Ninham Shand (now part of Aurecon) in 1995 as a means of minimising subjectivity in such evaluations, i.e. to allow for replicability in the determination of significance.

Table 28: Definition of significance ratings

SIGNIFICANCE RATINGS	LEVEL OF CRITERIA REQUIRED
High	High magnitude with a regional extent and long term duration. High magnitude with either a regional extent and medium term duration or a local extent and long term duration. Medium magnitude with a regional extent and long term duration.
Medium	High magnitude with a local extent and medium term duration. High magnitude with a regional extent and construction period or a site specific extent and long term duration. High magnitude with either a local extent and construction period duration or a site specific extent and medium term duration. Medium magnitude with any combination of extent and duration except site specific and construction period or regional and long term. Low magnitude with a regional extent and long term duration.
Low	High magnitude with a site specific extent and construction period duration. Medium magnitude with a site specific extent and construction period duration. Low magnitude with any combination of extent and duration except site specific and construction period or regional and long term. Very low magnitude with a regional extent and long term duration.
Very low	Low magnitude with a site specific extent and construction period duration. Very low magnitude with any combination of extent and duration except regional and long term.
Neutral	Zero magnitude with any combination of extent and duration.

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

Table 29: Definition of probability ratings

PROBABILITY RATINGS	CRITERIA
Definite	Estimated greater than 95% chance of the impact occurring.
Probable	Estimated 5 to 95% chance of the impact occurring.
Unlikely	Estimated less than 5% chance of the impact occurring.

Table 30: Definition of confidence ratings

CONFIDENCE RATINGS	CRITERIA
Certain	Wealth of information on and sound understanding of the environmental factors potentially influencing the impact.
Sure	Reasonable amount of useful information on and relatively sound understanding of the environmental factors potentially influencing the impact.
Unsure	Limited useful information on and understanding of the environmental factors potentially influencing this impact.

* The level of confidence in the prediction is based on specialist knowledge of that particular field and the reliability of data used to make the prediction.

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

Table 31: Definition of reversibility ratings

REVERSIBILITY RATINGS	CRITERIA
Irreversible	The activity will lead to an impact that is permanent.
Reversible	The impact is reversible, within a period of 5 years.

Despite attempts at providing a completely objective and impartial assessment of the environmental implications of development activities, environmental assessment processes can never escape the subjectivity inherent in attempting to define significance. The determination of the significance of an impact depends on both the context (spatial scale and temporal duration) and intensity of that impact. Since the rationalisation of context and intensity will ultimately be prejudiced by the observer, there can be no wholly objective measure by which to judge the components of significance, let alone how they are integrated into a single comparable measure.

This notwithstanding, in order to facilitate informed decision-making, SEIAs must endeavour to come to terms with the significance of the potential social and environmental impacts associated with particular development activities. Recognising this, Aurecon and SLR have attempted to address potential subjectivity in the current SEIA process as follows:

- Being explicit about the difficulty of being completely objective in the determination of significance, as outlined above.
- Developing an explicit methodology for assigning significance to impacts and outlining this methodology in detail. Having an explicit methodology not only forces the assessor to come to terms with the various facets contributing towards the determination of significance, thereby avoiding arbitrary assignment, but also provides the reader of the SEIA Report with a clear summary of how the assessor derived the assigned significance.
- Wherever possible, differentiating between the likely significance of potential environmental impacts as experienced by the various affected parties.
- Utilising a team approach and internal review of the assessment to facilitate a more rigorous and defendable system.

Although these measures may not totally eliminate subjectivity, they provide context within which to review the assessment of impacts.

Environmental Assessment Policy requires that, “as far as is practicable”, cumulative environmental impacts should be taken into account in all environmental assessment processes. SEIAs have traditionally, however, failed to come to terms with such impacts, largely as a result of the following considerations:

- Cumulative effects may be local, regional or global in scale and dealing with such impacts requires coordinated institutional arrangements; and

- Studies are typically carried out on specific developments, whereas cumulative impacts result from broader biophysical, social and economic considerations, which typically cannot be addressed at the project level.

6.1 CONSIDERING CUMULATIVE IMPACTS IN ERONGO

Cumulative impacts are difficult to deal with on a project SEIA level, since they may occur outside of the geographical area of the particular project being assessed and thus require the collaboration of other institutions, and involve broader social, economic and biophysical considerations outside the scope of the specific project-level assessment. The fact that several other mining companies have been pursuing uranium interests in the Erongo Region emphasized the need for a holistic approach, by means of a strategic or sectoral level assessment. Such a Strategic Environmental Assessment (SEA) of the so-called "Central Namib Uranium Rush" (Uranium Rush) was recently undertaken by the South African Institute for Environmental Assessment, commissioned by the Ministry of Mines and Energy of the Government of Namibia. This section provides a summary of the SEA sections applicable to cumulative impacts.

The SEA (SAIEA, 2010) provides a bird's eye view of cumulative environmental impacts in the Erongo region brought about as a result of the Uranium Rush (and other directly linked developments, and potential developments, such as desalination and chemical plants), and advises on how to avoid negative cumulative impacts and to enhance opportunities for positive impacts, within the uranium sector and between mining and other industries. It should be noted that for some aspects the available environment data was lacking, such as for biodiversity, and that attaining a level of comprehensive data would be an undertaking of many years. To wait for such a time before development could continue would be unreasonable, and the SEA therefore proceeded with information at hand. The SEA found that the cumulative impacts resulting from the Uranium Rush are not limited to the Erongo region, but are wide-ranging, affecting the southern African region as a whole, particularly the Namibian and South African economies.

As far as Rössing Uranium's proposed desalination plant is concerned, a number of impacts that are expected to emerge as having cumulative social and environmental implications on the receiving environment must be considered in the SEIA and recommendations provided regarding their management. The recommendations provided below are applicable to the cumulative situation, i.e. to the Uranium Rush industries as a whole, and not specifically to Rössing Uranium. Hence only those recommendations specific to Rössing Uranium desalination plant will be investigated carried forward to the SEMP where relevant. Although specific references to the SEA were made under the impact discussions above, this summary is provided for ease of reference.

1. **IMPACTS ON TOWNS** ~ impacts on four areas of the receiving environment of towns (including amongst others Arandis, Swakopmund and Walvis Bay) should be considered, namely the town's sense of place, incidents of crime, issues around property availability and effects on prices, and waste management (domestic, special and hazardous).
2. **MACRO ECONOMIC ENVIRONMENT ~** the focus under this section is the potential economic benefits that Namibia could derive from the Uranium Rush on its Gross Domestic Product (GDP), potential income to government, national employment effects, salaries and wages, and income distribution, including issues pertaining to mining industry rehabilitation funds.
3. **EDUCATION AND SKILLS ~** the Uranium Rush industries and developments are expected to result in a number of impacts on education and skills in the Erongo region and nationally. The primary issues, the cumulative impacts of which could be positive or negative, are an increased demand for skilled human resources, access to education for school-aged children and the quality of education.

4. **COMMUNITY HEALTH ~** large-scale mining and associated activities always have health consequences, positive and negative, for workers and the community. Negative health impacts on workers are most commonly accidents, dust-related lung disease and metal toxicity, and positive impacts are related to better economic prospects but sometimes this comes with a separation from family. Negative health impacts on the public include new diseases and social problems carried by the influx of population but again, balanced against this, is the increased prosperity and health care brought by the mining industry.
5. **IMPACTS ON ROAD, RAIL, PORT AND AVIATION INFRASTRUCTURE ~** the ideal condition of transport infrastructure would be an adequate and well maintained state to encourage economic development, public access and safety, without compromising biodiversity functioning.
6. **IMPACTS ON WATER SUPPLY, QUALITY AND BULK INFRASTRUCTURE ~** the preferable condition of environmental aspect:
   a. Supply: There should be an adequate and reliable supply of water at reasonable cost for all consumers.
   b. Bulk infrastructure: The water reticulation network should be optimally planned so as to minimise negative impacts.
   c. Quality: Water quality should not be compromised so as to cause it to be unusable for its current purposes.
7. **IMPACTS ON ENERGY SUPPLY AND BULK INFRASTRUCTURE ~** the preferable condition of environmental aspect should be:
   a. Supply: There should be an adequate and reliable supply of energy at reasonable cost for all consumers, when it is needed, and as far as possible without compromising the state of the environment. However, seen as part of this statement, demand side management should be effectively implemented to reduce pressure on grid electricity and alternative sources of energy should be promoted.
   b. Supply infrastructure: The electricity reticulation network and associated facilities such as substations should be optimally planned so as to minimise negative impacts.
8. **RECREATION AND TOURISM** ~ the tourism industry is of the utmost importance to the Namibian economy, providing over 18,000 direct jobs and earning N$1.6 million per annum revenue (3.7% of Gross Domestic Product). Tourism products offered in the central Namib include adventure, business, consumptive and eco-tourism. In line with MET's vision, "a mature, sustainable and responsible tourism industry that contributes significantly to the economic development of Namibia" is the ideal situation for the recreation and tourism industry. However, to achieve this, environmental conditions need to be conducive to such activities and an alluring; unique sense of place represents many other environmental aspects such as low noise levels, healthy and uncompromised biodiversity, and good services.
9. **BIODIVERSITY ~** the habitats in which plants and animals occur, the species which are most vulnerable due to endemicity or threatened status, the ecological processes which support life in the central Namib, and the areas of high biodiversity value, have been considered in terms of how these will be affected by the combined impacts expected from the Uranium Rush industries. Impacts on biodiversity will have a negative impact on tourism and recreation as well as a number of other significant secondary and tertiary impacts such as public health issues in the case of a predatory species controlling a disease vector such as mosquitoes. In developing, care should be taken that the ecological integrity and diversity of fauna and flora of the central Namib is not compromised by the Uranium Rush.
10. **ARCHAEOLOGICAL HERITAGE ~** the types of archaeological sites that are vulnerable to damage by mining activities include graves, rock shelters with evidence of occupation, scatters of stone artifacts, battlefields and historical mines. Archaeological heritage is differentiated into two types, i.e. sites and landscapes, the latter being a collection/group of related sites similar in particular characteristic(s) (generally referred to as sites in this section). The Erongo region has four National Monument sites (all rock art sites) but none affected by the Uranium Rush Scenario 2. Some sites are virtually invisible and therefore it is very difficult for mining activities to avoid damage if a

specialist study is not undertaken and the sites identified. As a large part of the Erongo region is either currently under uranium exploration or mining licenses, or has renewals pending, detailed studies have been carried out for a large part of the area. These form a good basis to identify archaeological landscapes that can be flagged as areas of differing archaeological significance (similar to tourism and biodiversity) where specific care would need to be taken in considering applications for mining activities. The preferable condition is for the Uranium Rush industries and all related activities, to have as little negative impact on archaeological resources as possible.

11. **AIR QUALITY ~** cumulative impacts in relation to the existing air quality conditions in the central Namib with regards to dust, which includes the coarse particles called Total Suspended Particles (TSP), as well as the finer particles called PM 10. TSP is more nuisance-causing, while PM 10 particles are fine enough to be inhaled and potentially cause health problems. TSP and PM 10 were monitored at various receptor points in the Erongo region to monitor current levels. In general, TSP deposition through the Erongo region is slight, but PM 10 levels can be high, depending on meteorological conditions and human activities such as traffic movement. Particulate air concentrations in the Erongo region should not exceed the particulate threshold at which adverse health effects will be experienced. This threshold is the World Health Organisation's IT-3 guidelines for PM10, which correlates with the South African National Standards (SANS) that developed a limit based on conditions similar to the Namibian environment. Similarly, TSP levels (dust fallout) should not exceed the SANS limit for residential areas.
12. **INSTITUTIONS AND GOVERNANCE ~** managing the Uranium Rush will be a considerable challenge for Namibian institutions, be they government, parastatal, regional and local authority, private sector or civil society. In combination with strong leadership, transparency and consistency in decision making will ensure that the Uranium Rush is a blessing and not a curse. The bottom line is governance.

7 IMPACT ASSESSEMENT

This section provides an assessment of the impacts (by various specialists) identified and described in the Scoping phase of the SIEA associated with each of the alternatives, provided under subsection 4.12, for each of the construction, operation, and decommissioning phases of the project. Also provided here are the specialists' recommendations regarding the mitigation measures that should be implemented to manage direct impacts and reduce the severity of the negative impacts and enhance the benefit of the positive impacts. This section also touches on cumulative environmental impacts or issues that the project links with.

7.1 OVERVIEW OF SPECIALIST STUDIES UNDERTAKEN

Table 32 outlines the specialist studies that were undertaken during the SEIA Phase:

Table 32: Specialist studies undertaken during SEIA Phase

SPECIALIST FIELD	SPECIALIST	DESCRIPTION
Socio-economic	Ms. Auriol Ashby (Social) (Ashby Associates CC) and Dr Jonathan Barnes (Economic) (Design and Development Services CC) and	Identified and assessed the potential socio-economic impacts associated with the construction and operation of the proposed Rössing Uranium desalination plant.
Heritage and Archaeology	Dr John Kinahan (Quaternary Research Services)	This study focused on the potential impacts of the proposed project on heritage and archaeological aspects within the footprint of the proposed project.
Visual	Stephen Stead (Visual Resource Management Africa)	Assessed the potential visual impact caused by the proposed Rössing Uranium desalination plant.
Noise	Nicolette von Reiche (Airshed Planning Professionals)	Identified and assessed the potential noise impacts associated with the construction and operation of the proposed Rössing Uranium desalination plant.
Avifauna	Mike and Ann Scott (African Conservation Services CC)	Identified and assessed the potential impacts on local birdlife associated with the construction and operations of the proposed Rössing Uranium desalination plant and associated infrastructure.
Marine ecology	Dr Andrea Pulfrich (Pisces Environmental Services (Pty) Ltd)	Identifed and assessed the potential impacts to marine and coastal ecology associated with the construction and operation of the proposed Rössing Uranium desalination plant. The study relied on the marine discharge and modelling study undertaken by WSP.
Brine diffusion modelling	Christoph Soltau (WSP Group)	Assessed the marine discharge options and undertook a hydrodynamic modelling exercise to determine the likely movement and dissipation of the discharge plume. Note that this was not an impact assessment but informed the marine ecology impact assessment.
Shoreline dynamics	Christoph Soltau (WSP Group)	Identifed and assessed the potential impacts that may arise as a result of the construction and operation of the desalination plant's seawater intake, brine outfall, and associated structures located on the beach or in the surf on natural coastal processes.

SLR and Aurecon have co-ordinated the specialist terms of reference, the information produced and its interrogation, analysis and interpretation, as reflected in this SEIA Report. The findings of the specialists' studies have been integrated into the SEIA Report, allowing for overall assessment of the risk of the proposal. Where required specialist impact assessments have been adapted to meet the SEIA methodology set out in Section 6, but no attempt was made to alter the specialists findings.

7.2 OVERVIEW OF THE IMPACT ASSESSEMENT

The following table provides a summary of the impact assessment results. This table only shows the post mitigation impact significance ratings. For more detail on the assessments refer to the respective impact assessment subsections to follow.

Table 33: Post-mitigation impact significance ratings summary

Aspect	Phase	Impact Description	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Socio-economic	Construction	Increased traffic and road safety risks.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Reduction in Guano production as a result of disturbance of birds.	Very low (-)	Low (-)	Very low (-)	Very low (-)	Neutral
	Operations	Economic viability of Rössing Uranium Mine.	High (+)	High (+)	High (+)	High (+)	High (-)
		Financial implications for other water users and NamWater.	Medium (-)	Medium (-)	Medium (-)	Medium (-)	Medium (-)
		Financial implications On Langer Heindrich Uranium / Husab.	Low (-)	Low (-)	Low (-)	Low (-)	Low (-)
		Water availability in the region.	High (+)	High (+)	High (+)	High (+)	Low (+)
		Disruptions may result in a lower Guano production rates.	Very low (-)	Low (-)	Very low (-)	Very low (-)	Neutral
	Decommissioning	Bulk water supply options associated with decommissioning.	High (+)	High (+)	High (+)	High (+)	Neutral
Archaeology and heritage	Construction	Loss or damage of archaeological and heritage resources.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
	Operations	No operational phase impacts.	Neutral	Neutral	Neutral	Neutral	Neutral
	Decommissioning	No decommissioning phase impacts.	Neutral	Neutral	Neutral	Neutral	Neutral
Visual impacts	Construction	Intake jetty during construction.	Medium (-)	Medium (-)	Medium (-)	Medium (-)	Neutral
		RO Plant during construction.	Low (-)	Low (-)	Medium (-)	Medium (-)	Neutral
	Operations	Impact of the RO plant and all associated infrastructure.	Low (-)	Medium (-)	Medium (-)	Medium (-)	Neutral
	Decommissioning	Visual impact associated with the decommissioning phase of the project.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
Noise impacts	Construction	Construction noise impact on birds.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Construction noise impact on humans.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
	Operations	Operations phase noise impact on birds.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Operations phase noise impact on humans.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
	Decommissioning	Decommissioning phase noise impact on birds.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Decommissioning phase noise impact on humans.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
Avifauna impacts	Construction	Destruction/modification of Damara Tern breeding habitat.	Low (-)	Very low (-)	Low (-)	Low (-)	Neutral
		Destruction/modification of habitat of other birds.	Low (-)	Low (-)	Low (-)	Low (-)	Neutral
		Physical disturbance to breeding birds, especially Damara Terns.	Low (-)	Very low (-)	Low (-)	Low (-)	Neutral
	Operations	Physical disturbance to breeding birds, especially Damara Terns.	Low (-)	Very low (-)	Low (-)	Low (-)	Neutral
		Physical disturbance to roosting/breeding cormorants.	Very low (-)	Low (-)	Very low (-)	Very low (-)	Neutral
		Collision of birds with power line structures.	Neutral	Neutral	Neutral	Medium (-)	Neutral
		Bird electrocutions on power supply structures.	Neutral	Neutral	Neutral	Medium (-)	Neutral
	Decommissioning	Physical disturbance to breeding birds, especially Damara Terns.	Low (-)	Very low (-)	Low (-)	Low (-)	Neutral
Marine ecology impacts	Construction	Disturbance and destruction of marine biota through alteration and disruption of the coastal zone during construction.	Low(-)	Low(-)	Low(-)	Low(-)	Neutral
		Detrimental effects on marine biota through accidental hydrocarbon spills, concrete works and litter in the coastal zone during construction.	Low(-)	Low(-)	Low(-)	Low(-)	Neutral
		Reduced physiological functioning of marine organisms due to increased turbidity of nearshore waters during excavations.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Smothering of benthos through re-deposition of suspended sediments.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Disturbance of shore birds and marine biota through construction noise.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Disturbance and injury of shore birds and marine biota through blasting.	Low (-)	Low (-)	Low (-)	Low (-)	Neutral
		Elimination of benthic communities through loss of substratum in structural footprint.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
	Operations	Loss of marine species through impingement and entrainment.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Potential flow distortion around the discharge outlet.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Reduced physiological functioning of marine organisms due to elevated salinity.	Low (-)	Low (-)	Low (-)	Low (-)	Neutral
		Avoidance behaviour by invertebrates, fish and marine mammals of the discharge area.	Low (-)	Low (-)	Low (-)	Low (-)	Neutral
		Reduced physiological functioning of marine organisms due to elevated temperature.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Reduced physiological functioning of marine organisms due to reduced dissolved oxygen concentrations.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Detrimental effects on marine organisms due to residual chlorine levels in the mixing zone.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Chronic effects on marine organisms due to formation of halogenated by-products.	Low (-)	Low (-)	Low (-)	Low (-)	Neutral
		Reduction in dissolved oxygen concentrations as a result of dechlorination.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral

Aspect	Phase	Impact Description	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
		Excessive bacterial re-growth in the brine after chlorination.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Detrimental effects on marine organisms through discharge of co-pollutants in backwash waters.	Low (-)	Low (-)	Low (-)	Low (-)	Neutral
		Detrimental effects on marine organisms through discharge of antiscalants in backwash waters.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Detrimental effects on marine organisms or ambient seawater pH through discharge of residual cleaning solutions used periodically for cleaning in place.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Detrimental effects on marine organisms of heavy metals from corrosion processes.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
	Decommissioning	Impacts to marine ecology associated with decommissioning activities.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
Shoreline dynamics impacts	Construction	Intake Jetty: Disruption of coastal processes by marine works.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Intake Jetty: Alteration of beach composition with rock spoil.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Brine outfall: Disruption of coastal processes by marine works.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Brine outfall: Alteration of beach composition with rock spoil.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Brine outfall: Earthworks related flooding or beach erosion.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
	Operations	Intake Jetty: The coastal processes (waves, currents, sediment transport) are affected by the jetty structure.	Low (-)	Low (-)	Low (-)	Low (-)	Neutral
		Intake Jetty: Natural sand movement is impacted by the jetty abutment to shore.	Neutral	Neutral	Neutral	Neutral	Neutral
		Intake Jetty: Wind-blown sand pathways are impacted by the intake structure and pipelines.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
		Brine outfall: The outfall pipeline causing updrift accretion and downdrift erosion of the beach.	Low (-)	Low (-)	Low (-)	Low (-)	Neutral
		Brine outfall: wind-blown sand pathways on the upper beach are impacted by the brine outfall pipeline.	Neutral	Neutral	Neutral	Neutral	Neutral
		Brine outfall: The high velocity flow from the outfall causes scouring of the sandy seabed.	Low (-)	Low (-)	Low (-)	Low (-)	Neutral
	Decommissioning	Impacts to shoreline dynamics during decommissioning would be comparable with those experienced during the construction phase.	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral

7.3 INTRODUCTION TO ASSESSMENT TABLES

The following sections provide the findings from the various specialist studies. Each impact is described and then followed by a table indicating the assessment findings (in line with the methodology presented in section 6).

Please note the following regarding the assessment tables:

- Only the “Base Case - pre-mitigation” column reflects the assessment of impacts in the unmitigated scenario.
- The “Base Case – post-mitigation” as well as the alternatives 1 to 3 columns all assess the impacts in the mitigated scenario.
- Alternative 4 (last column) summarises the assessment findings relating to the ‘no-go’ option.
- The following (colour) legend is applicable to the significant ratings in all the Tables:

Legend	High (-)	Medium (-)	Low (-)	Very low (-)	Neutral	Very low (+)	Low (+)	Medium (+)	High (+)

7.4 SOCIO-ECONOMIC IMPACTS

The following subsection is a modified summary of the socio-economic assessment undertaken by Ashby Associates CC. The assessment is largely dependent on existing literature for the region, interviews with key stakeholders and data supplied by Rössing Uranium. The original report is attached here as Annexure D1 and can be referred to for added detail.

7.4.1 Construction phase

7.4.1.1 Traffic and Road Safety

IMPACT DESCRIPTION:

During construction, traffic volumes on the C34 between Swakopmund and the desalination plant are likely to increase with the transport of a maximum of approximately 50 construction workers, construction material, and equipment to site.

During operations, the volume of traffic will be significantly less as only 12 to 18 employees are anticipated, and the delivery of chemicals and other products should not be daily. As a result of this, the assessment below focusses on the construction phase traffic and road safety related impacts.

IMPACT ASSESSMENT: INCREASED TRAFFIC AND ROAD SAFETY IMPACTS

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	~
Extent	Regional	Regional	Regional	Regional	Regional	~
Magnitude	Low (-)	Low (-)	Low (-)	Low (-)	Low (-)	~
Duration	Short term	Short term	Short term	Short term	Short term	~
SIGNIFICANCE	Very Low (-)	Very Low (-)	Very Low (-)	Very Low (-)	Very Low (-)	Neutral
Probability	Definite	Definite	Definite	Definite	Definite	~
Confidence	Certain	Certain	Certain	Certain	Certain	~
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	~

Slow construction traffic turning at the C34 and site junction will be the most hazardous point. Such traffic could originate in Walvis Bay and Swakopmund so the extent could be regional. Walvis Bay and Swakopmund are already used to high volumes of traffic so the increased impact brought about by this project will be mostly at the site junction and will be of low magnitude. Increased traffic volumes and therefore increased impacts to road safety will definitely occur. The most risk is during the construction period which is estimated to be up to 18 months and therefore short term. Once construction is complete, the volume of operational traffic will be insignificant therefore this impact is reversible. The above ratings of low magnitude, regional extent and short term duration results in a very low significance rating.

PROPOSED MITIGATION MEASURES:

- Temporarily for the construction phase, widen the C34 road at the turn-off point to the desalination plant to allow slow traffic to get off the C34 without causing other vehicles to overtake.
- Erect appropriate road hazard / information signage to warn road users of the turning of heavy vehicles.
- Ensure that construction vehicles switch their headlights on, at all times.

7.4.1.2 Impact on Guano production

IMPACT DESCRIPTION:

There is a possibility that noise generated during the construction phase will disrupt the roosting patterns of birds which will reduce the production rate of guano over 18 months. At current figures, Peruvian seabird guano retails for fertiliser at N$53 to N$80/kg (US$5[46] to US$7.5[47]).

The negative economic impact on guano production during the construction phase of the Rössing Uranium desalination plant would be equivalent to the reduction of collecting costs and of sales.

IMPACT ASSESSMENT: REDUCTION IN GUANO PRODUCTION AS A RESULT OF DISTURBANCE OF BIRDS

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	~
Extent	National	National	National	National	National	~
Magnitude	Very Low (-)	Very low (-)	Low (-)	Very low (-)	Vey low (-)	~
Duration	Long term	Long term	Long term	Long term	Long term	~
SIGNIFICANCE	Very Low (-)	Very Low (-)	Low (-)	Very Low (-)	Very Low (-)	Neutral
Probability	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	~
Confidence	Certain	Certain	Certain	Certain	Certain	~
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	~

According to the Noise Assessment and the Avifaunal Assessment, the increase in noise levels during construction will have a very low negative impact on the birds roosting at the guano platform. Based on these findings, the significance of impacts on guano production being impacted is very low. The significance is low for site Alternative 1 (Plant site 2) as it is relatively closer to the guano platforms (0.5 km), and some disturbance is possible.

For an assessment of the significance of the physical disturbance to roosting/breeding cormorants as well as noise-related impacts of the proposed activities on the birds roosting on the platform, refer to subsections 7.6 and 7.7.

PROPOSED MITIGATION MEASURES:

The noise and light pollution mitigation measures present under section 7.6 and 7.7 shall apply.

7.4.2 Operations phase

7.4.2.1 Economic viability of Rössing Uranium Mine

IMPACT DESCRIPTION:

The proposed desalination plant will enable Rössing Uranium to continue production. Thus the economic impact of the Rössing Uranium desalination plant is reflected by assessing the benefits derived from Rössing Uranium continuing to operate. The impact of the desalination plant would

[46] http://www.hydroponics.net/i/133735
[47] http://www.planetnatural.com/product/original-seabird-guano/

enable the survival of Rössing Uranium and would retain the benefits that Rössing Uranium currently brings to the local, regional, and national economy.

In addition to the continued operations of the mine, the construction of the proposed Rössing Uranium desalination plant will contribute to the economy in several ways. Construction is planned to start in 2015 and the investment cost for the plant is estimated to be between N$220 million and N$275 Million[48]. As Rössing Uranium will purchase a prefabricated desalination plant which will be imported, approximately N$100 million of the cost will be imported, benefitting government through import taxes and NamPort. This cost does not include constructing a Rössing Uranium own pipeline from the plant to the mine. Rössing Uranium's cost of capital is much cheaper than that of NamWater or a project company, and accordingly, the financing portion would be much cheaper as well.

The construction period is estimated to be 18 months and will create approximately 50 jobs at peak times. Indirect economic benefits will include purchases of local supplies such as concrete which will require cement (assumed to be Namibian), gravel, sand and transport.

The operational cost estimate of the desalination plant is N$26.1 million per year. The plant operation will require approximately 12 to 18 contract staff working on a shift basis as required, of which most is likely to be in highly skilled positions with only a marginal number of unskilled or semi-skilled positions. It is likely that the plant will be operated by Gecko under an Operation and Maintenance Contract with Rössing Uranium.

The estimated value of inputs required to operate the plant annually includes roughly N$2.4 million in wages/salaries, N$1.6 million for electricity to NamPower, N$4 million in chemicals and N$2.1 million of parts and consumables which would include those produced locally (requiring the backward chain of inputs) and others to be imported through NamPort.

Rössing Uranium's preliminary indications are that it can produce water at below ~N$22/$m^3$ (US$2/$m^3$), before conveyancing costs. For 3Mm^3 of water from the proposed desalination plant Rössing Uranium is expecting to save between N$40 million to N$60 million per year. It anticipates recovering the cost of constructing the plant within four years.

The Rössing Uranium desalination plant will have immediate commercial benefits to Rössing Uranium on the current situation as it will be more economical to run and it will be under Rössing Uranium control. Since the desalination plant will be modular, it would be easy to increase or decrease capacity in line with mine requirements that may vary from month to month, without having to incur a take or pay penalty.

The No-Go alternative has been assessed as there is a realistic chance of the project not being implemented. The reason for this is that NamWater informed the specialist that their shareholder, Government, was not in favor of the proposal.

In order to survive on-going, low uranium prices, Rössing Uranium is implementing a "curtailment strategy" whereby it only produces sufficient quantities to supply existing long term contracts where official prices are US$45/lb. This will still keep options open in the event that spot prices increase significantly and operations could be expanded. As part of this survival strategy, Rössing Uranium was forced to retrenched 276 people who brought an operational cost saving of approximately N$100 million. With the current water purchase agreement, Rössing Uranium is expecting to pay N$132 million

[48] *Rio Tinto 1 August 2014. Employee Brief "Update - Rössing considering own desalination plant".*

in 2014 for water so the savings made from retrenchments are being transferred to pay the new (Areva's desalinated water) high water charges.

NamWater is contracted to supply a certain volume of water to Rössing Uranium monthly. If Rössing Uranium does not use its full volume, the unit price becomes more expensive. When Rössing Uranium takes its full allocation of water in terms of the take or pay arrangement with NamWater, the average cost of the water is approximately N$33/$m^3$ before conveyancing costs and N$47.5/$m^3$ inclusive of conveyancing costs. However, in the two months where Rössing Uranium suffered curtailed operations, the unit cost of water became approximately over N$90/$m^3$.

Since 2009, despite negotiations, Areva has not been willing to adjust the tariff and NamWater has not produced a feasible commercially viable alternative solution. In order to continue operating Rössing Uranium has no alternative but to reduce its water costs; further redundancies will not be sufficient.

When the uranium price dipped to US$28/lb, Rössing Uranium evaluated all the options and concluded that with only 10 years life of mine remaining, it would be too expensive to adopt a "Care and Maintenance strategy" as Areva has done. It implemented the curtailment strategy and made plans to build a cheaper water supply.

The No-Go alternative could force Rössing Uranium to close ten years before necessary due to financial reasons. This would not only affect the whole Rössing Uranium workforce but would be a loss to the local, regional and national socio-economic economy.

When fully operating, as in 2013, Rössing Uranium reported a profit for the first time in three years, amounting to a net profit of N$32 million with a turnover of N$2.96 billion. Its spending in Namibia leads to a long chain of value addition throughout the economy. In 2013 Rössing Uranium:

- Spent N$1.9 billion on goods and services;
- Generated N$83 million in royalty payments;
- Generated N$143 million in PAYE payments;
- Made N$289 million of payments to state owned enterprises; and
- Paid N$783 million in employment costs.

Closure of the Rössing mine would mean these socio-economic contributions to the country would be lost as it would be too costly to re-commission the mine after closure.

A No-Go option could result in redundancy for Rössing Uranium's current 901 direct employees which would be a loss of N$650 million per annum in employment costs to the economy.

Also at stake are the indirect economic impacts arising through the provision of all inputs purchased by the mine (N$1.9 billion in 2013) in order to produce uranium oxide, as well as the inputs purchased by their suppliers to produce their inputs, and so on, along the production chain. This backward chain is usually very extensive and includes the energy needed to produce inputs, the replacement parts, and a wide variety of scientific, financial, accounting and technical services. State Owned Enterprises such as NamPower a major customer and NamWater would lose income through Rössing Uranium's conveyancing costs; Government would lose millions of N$ from lost royalties and a range of other taxes including PAYE.

Simonis Storm surveyed a large number of suppliers of goods and services in the uranium mining industry in Namibia and calculated that for every N$1.00 spent by a uranium mining company as part of their cost of sales, 81 cents will be injected into the economy via the multiplier. It also calculated that for every job created by a mine, a further additional 1.5 job opportunities are created by suppliers and contractors. Thus closure of Rössing Uranium employing 901 people could result in a loss of a further 1,350 jobs in staff of suppliers and contractors. However the mining sector has been increasing effort to procure from local suppliers and producers and Husab calculates the multiplier is seven additional

jobs are created to every mining job. In this scenario, the closure of Rössing Uranium could result in job losses of over 6,300 indirect jobs.

A further layer below indirect impacts is the induced economic impact. These are products and services purchased by employees and contractors as a result of their continued employment and therefore spending power stemming from salaries and wages. If they buy Namibian products and services, they create a greater economic impact on the Erongo Region and nationally. Moreover, this induced level has its own backward chain, as these purchased goods and services require further inputs to be produced.

At a local level, although Arandis has made great efforts to diversify its economy, the town is still very reliant on Rössing Uranium for its well-being as the majority of its breadwinners work for Rössing Uranium. The impact of Rössing Uranium closure on Swakopmund will be felt through the unemployment of Rössing Uranium's employees and through the reduced business turnover of companies which supplied Rössing Uranium and their employees with goods and services. Thus an early closure of Rössing Uranium would have severe impacts for over an estimated 2,250 breadwinners and their families directed affected, and through the multiplier effect on the wider community in the coastal region.

While this immediate uncertainty lasts, employees may move to other more secure employment opportunities, adding to the cost if Rössing Uranium is able to resume full operations.

IMPACT ASSESSMENT: ECONOMIC VIABILITY OF RÖSSING URANIUM MINE

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Positive	Positive	Positive	Positive	Positive	Negative
Extent	National	National	National	National	National	National
Magnitude	High (+)	High (+)	High (+)	High (+)	High (+)	High (-)
Duration	Long term	Long term	Long term	Long term	Long term	Long term
SIGNIFICANCE	High (+)	High (+)	High (+)	High (+)	High (+)	High (-)
Probability	Probable	Probable	Probable	Probable	Probable	Probable
Confidence	Certain	Certain	Certain	Certain	Certain	Sure
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	Irreversible

This positive impact will be felt at all levels of the society and economy as it will enable Rössing Uranium to continue mining. The remaining operations phase for the mine is 10 years and that will bring about permanent improvements in the quality of life of the workers and their families through being able to afford better livelihoods, education and housing. The impact of Rössing Uranium being able to operate for a further 10 years and the positive benefits this bring to employees, their families, businesses and government is a long-term. Service companies and the government will also gain revenue which could be invested. Thus, the magnitude of the impacts is rated as high. The high magnitude, national extent, and long term duration ratings given to this impact result in a high, positive significance rating.

Rössing Uranium is confident that it will be able to meet its long term sales agreements with the reduced operating costs which the desalination plant provides. Its survival is estimated at greater than 95% chance that the impact will occur.

Areva has built one desalination plant which has resulted in a monopoly situation where it can charge high prices. In the absence of a NamWater plant, it makes economic sense for Rössing Uranium to build one and the cumulative impact will be that other mines, e.g. Husab may want to follow suit. This would reduce the current monopoly on the supply of desalinated water which would benefit all future consumers.

The impact of a No-Go option could mean closure of Rössing Uranium ten years earlier than necessary. This would create direct and indirect negative impacts. NamWater, other State Owned Enterprises, Government, regional industry, towns, communities, and families would lose the economic benefits outlined above. These impacts are direct, indirect and induced; all negative.

The impact of Rössing Uranium closure will be felt at all levels of the society and the economy with social and economic processes being either severely altered or ceasing altogether. The loss of employment can have indirect lifelong impacts on families, not just through financial losses but also through missed opportunities such as education and family support. The duration of this impact is therefore long-term. The high magnitude rating, with a national extent, and medium to long term impact duration results in a high significance rating.

Namibia has high unemployment levels as jobs are scarce and job creation does not match the number of school leavers entering the market. The loss of more than 2,000 jobs will contribute to more unemployment.

The revised impact assessment (project implementation) is based on the assumption that the mitigating measures described below are successful and that a more realistic cost of desalinated water is available which would enable Rössing Uranium to resume full operations and mine feasibility.

The residual impacts would then be positive as Rössing Uranium and businesses down the supply chain would remain operating and their employees and contractors would retain their jobs. State Owned Enterprises would obtain income by selling their services to Rössing Uranium and their service providers and Government would receive taxes.

PROPOSED MITIGATION MEASURES:

- Rössing Uranium should contractually ensure that the company which builds its plant gives preference to Erongo Region-based companies and employees.

The objective of the mitigation measures described below is to limit the impacts associated with running Rössing Uranium at an operating loss in the event that Rössing Uranium is not permitted to build its own desalination plant (i.e. no go alternative).

- Inform all stakeholders which would be affected by closure or severely reduced operations to lobby NamWater and the Government of the Republic of Namibia to reverse the No-Go decision and approve the Rössing Uranium desalination plant
- Lobby NamWater and the Government of the Republic of Namibia to:
  - Hold high level negotiations with the French Government to contract a neutral assessor to ascertain a realistic price for Areva's water. The assessor should be an experienced and respected worldwide leader in desalination plants and Veolia or Degrémont are suggested as they are both based in Paris.
  - Obtain finance to fast-track the development of the Mile 6 desalination plant which will improve the viability and profitability of Rössing Uranium and Husab mines. This would strengthen the Government of the Republic of Namibia's hand when negotiating a fairer price for Areva's water.

7.4.2.2 Impact on NamWater and other users

IMPACT DESCRIPTION:

At present, the two sources of water available for mining, industrial, and domestic use are the Omdel aquifer and Areva's desalination plant. Only the mines pay for desalinated water as the Omdel aquifer's permissible offtake of 4.5Mm^3/a can supply all the municipalities' needs.

Under the Namibia Water Corporation Act (12 of 1997), NamWater is legally bound to supply bulk water, based on need and availability and it sells water to the mines and municipalities. The average cost of desalinated water to Rössing Uranium is approximately N$33/m^3 before conveyancing costs and N$47.5/m^3 inclusive of conveyancing costs. Rössing Uranium is convinced that NamWater does not mark-up the price of Areva water; NamWater profits through the conveyance cost, which it would gain whether it supplies Areva or Rössing Uranium-produced water. However NamWater would lose some revenue as it could no longer charge Rössing Uranium for conveying water between the Areva or its potential Mile 6 plant and the proposed plant.

NamWater would lose conveyancing revenue for the loss of volume piped between the Areva plant, its potential Mile 6 plant and the junction with Rössing Uranium's proposed supply source. Should NamWater build the Mile 6 desalination plant, Rössing Uranium will not be one of their customers.

MET:DEA asked if the presence of the proposed Rössing Desalination plant and the associated brine discharges would impact on the water quality for the planned Mile 6 NamWater desalination plant. Based on the diffusion modelling, elevated salinity levels should fall back to undetectable levels (i.e. near ambient) within 50m of the diffuser (point discharge), therefore the potential for the Rössing's brine discharges to prejudice water quality for the planned Mile 6 desalination are considered negligible.

There should be no impact on the municipalities as their water source is from Omdel and not from Areva.

IMPACT ASSESSMENT: FINCANCIAL IMPLICATIONS NAMWATER AND OTHER USERS

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	Negative
Extent	National	National	National	National	National	National
Magnitude	Low (-)	Low (-)	Low (-)	Low (-)	Low (-)	Low (-)
Duration	Long term	Long term	Long term	Long term	Long term	Long term
SIGNIFICANCE	Medium (-)	Medium (-)	Medium (-)	Medium (-)	Medium (-)	Medium (-)
Probability	Probable	Probable	Probable	Probable	Probable	Probable
Confidence	Sure	Sure	Sure	Sure	Sure	Unsure
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	Irreversible

The low magnitude, national extent, and long term duration of this impact results in a medium negative significance rating. This rating is based on a reasonable amount of useful information being made available and on a relatively sound understanding of the economic factors potentially influencing the impact.

As far as the no go option is concerned, it is assumed that, in the worst case scenario, Rössing Uranium mine would need to close prematurely, and thus the impacts felt by other water users and NamWater would equivalent to Rössing pursuing its own source of water, only that in the no go, NamWater would also lose out on all conveyance fees.

IMPACT ASSESSMENT: FINCANCIAL IMPLICATIONS ON LANGER HEINRICH URANIUM / SWAKOP URANIUM (I.E. HUSAB MINE)

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	Negative
Extent	National	National	National	National	National	National
Magnitude	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Very low (-)
Duration	Long term	Long term	Long term	Long term	Long term	Long term
SIGNIFICANCE	Low (-)	Low (-)	Low (-)	Low (-)	Low (-)	Low (-)
Probability	Probable	Probable	Probable	Probable	Probable	Probable
Confidence	Sure	Sure	Sure	Sure	Sure	Sure
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	Reversible

By the time Rössing Uranium's desalination plant becomes operational, earliest in 2016, the Husab mine will have come into production which should noticeably reduce the unit cost of water for all Areva's consumers. However, Swakop Uranium and Langer Heinrich Uranium would have to cover Rössing Uranium's missing contribution to Areva's financing costs which would be approximately one fifth of the share of total water ($3Mm^3/13.6Mm^3$). However, the potential competition and additional supply of water at visibly lower cost could have a favourable impact on overall prices.

These impacts would be felt regionally by the two mines and nationally on the reduced profits of NamWater and the mines. NamWater would lose some conveyancing income. Langer Heinrich Uranium and Swakop Uranium would experience a small increase in operating costs (approximately a fifth share charged of Areva's financing costs); Swakop Uranium would be charged the bulk of this as their water requirement will be considerably more than Langer Heinrich Uranium. Compared with their other operating costs, the overall magnitude is estimated to be low and negative. The impact would last the expected remaining lifespan of the Rössing Uranium mine, i.e. 10 years, which is long term.

As far as the no go option is concerned, it is assumed that, in the worst case scenario, Rössing Uranium mine would need to close prematurely, and thus the impacts felt by the other mines would equivalent to Rössing pursuing its own source of water in that they would bear the tariff increases associated with Rössing Uranium's withdrawal.

PROPOSED MITIGATION MEASURES:

- The mitigation measure to ascertain a realistic price for Areva's water which would benefit the other mines is applicable.
- NamWater will be gaining from the increased conveyancing costs of supplying Husab with more water so they would be making more profit during the period. No mitigation measure is therefore proposed.

7.4.2.3 Increased capacity for desalination in the region

IMPACT DESCRIPTION:

The following scenarios are assessed together as they both bring positive economic benefits.

- Short-term: In the first two years of operating Rössing Uranium's plant, the mine will only require about 2.3 – $2.4Mm^3/a$. As the plant can produce $3Mm^3/a$, NamWater could purchase the surplus at a cheaper cost than Areva's water which would benefit Langer Heindrich Uranium and Husab.

- Medium term: If the uranium price increases and other mines come into operation, the Areva plant would not have capacity to provide enough water. Rössing Uranium's plant would save NamWater, and its sole shareholder the Government of the Republic of Namibia, from building its required capacity 3Mm^3/a. The cost of such a module will obviously be less than the N$220 - 275 million which Rössing Uranium will pay for a stand-alone plant but nevertheless it will be a capital saving to NamWater / the Government of the Republic of Namibia.

IMPACT ASSESSMENT: WATER AVAILIBILITY IN THE REGION

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Positive	Positive	Positive	Positive	Positive	Positive
Extent	National	National	National	National	National	National
Magnitude	High (+)	High (+)	High (+)	High (+)	High (+)	Low (+)
Duration	Long term	Long term	Long term	Long term	Long term	Long term
SIGNIFICANCE	High (+)	High (+)	High (+)	High (+)	High (+)	Low (+)
Probability	Definite	Definite	Definite	Definite	Definite	Definite
Confidence	Sure	Sure	Sure	Sure	Sure	Sure
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	Reversible

Legend								
High (-)	Medium (-)	Low (-)	Very low (-)	Neutral	Very low (+)	Low (+)	Medium (+)	High (+)

The Rössing Uranium-built plant will impact positively on the national economy as any surplus will reduce operating costs of Langer Heindrich Uranium and Husab. The NamWater/the Government of the Republic of Namibia will be spared financing a module of 3Mm^3/a capacity which will free up the state's money for other projects. The positive benefits this project will bring to the coastal economy are therefore long-term. Affordable desalinated water is essential for the growing coastal economy and its people. Thus, the magnitude of the impact for both phases is rated as high positive.

The high magnitude, national / regional extent, and long term duration results in a high, positive significance rating. The probability that the Rössing Uranium RO plant will be an asset to NamWater and other users is rated at over 95% or definite.

In the case of the no go, assuming Rössing closes, its water allocation would become available for other uses, having a similar result to the building of the RO plant. However, at the end of the ten year period, after Rössing mine closure, there would be no "affordable" plant opportunity for NamWater or another mine to take over, and thus the magnitude of the no go is reduced to low.

MET:DEA asked if the presence of the proposed Rössing Desalination plant and the associated brine discharges would impact on the water quality for the planned Mile 6 NamWater desalination plant. Based on the diffusion modelling, elevated salinity levels should fall back to undetectable levels (i.e. near ambient) within 50m of the diffuser (point discharge), therefore the potential for the Rössing's brine discharges to prejudice water quality for the planned Mile 6 desalination are considered negligible.

PROPOSED MITIGATION MEASURES:

No enhancement measures are recommended.

7.4.2.4 Impacts on Guano production

IMPACT DESCRIPTION:

It is possible that the fairly constant noise generated during operations may disturb birds roosting at the guano platform and impact production rates. It should however be noted that this bird colony is accustomed to the movement and noise generated by the Salt Works activities and may therefore be more resistant to this type of disturbance than a bird colony in a more secluded, natural environment.

IMPACT ASSESSMENT: DISRUPTIONS BY THE RO PLANT OPERATIONS MAY RESULT IN A LOWER GUANO PRODUCTION RATES

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	
Extent	National	National	National	National	National	
Magnitude	Very low (-)	Very low (-)	Low (-)	Very low (-)	Very low (-)	
Duration	Long term	Long term	Long term	Long term	Long term	
SIGNIFICANCE	Very Low (-)	Very Low (-)	Very Low (-)	Very Low (-)	Very Low (-)	Neutral
Probability	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	
Confidence	Certain	Certain	Certain	Certain	Certain	
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	

According to the Noise Assessment (section 7.7) and the Avifaunal Assessment (section 7.8), the increase in noise levels during operations will have a very low negative impact on the birds roosting at the guano platform. Based on these findings, the significance of impacts on guano production being impacted is very low. The significance is low for site Alternative 1 (Plant site 2) as it is relatively closer to the guano platforms (0.5 km), and some disturbance is possible.

For an assessment of the significance of the physical disturbance to roosting/breeding cormorants as well as noise-related impacts of the proposed activities on the birds roosting on the platform, refer to subsections 7.6 and 7.7.

PROPOSED MITIGATION MEASURES:

Apply all measures, as dealt with under sections 7.6 and 7.7 shall apply.

7.4.3 Decommissioning phase

7.4.3.1 Future bulk supply option

IMPACT DESCRIPTION:

The plant's design life of 10 years corresponds to the current remaining lifespan of the Rössing Uranium mine. The Rössing Uranium plant would probably need some asset replacement to continue beyond its design life but this would be feasible and the plant would then be available to provide water for a growing coastal economy and population at a greatly reduced cost for government.

At this stage the use of the plant after closure of the Rössing Mine cannot be determined. Decisions in this regard will be influenced by discussion/negotiations with NamWater and other users.

IMPACT ASSESSMENT: BULK WATER SUPPLY OPTIONS ASSOCIATED WITH DECOMMISIONING

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Positive	Positive	Positive	Positive	Positive	~
Extent	National	National	National	National	National	~
Magnitude	High (+)	High (+)	High (+)	High (+)	High (+)	~
Duration	Long term	Long term	Long term	Long term	Long term	~
SIGNIFICANCE	High (+)	High (+)	High (+)	High (+)	High (+)	Neutral
Probability	Probable	Probable	Probable	Probable	Probable	~
Confidence	Uncertain	Uncertain	Uncertain	Uncertain	Uncertain	~
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	~

Affordable desalinated water is essential for the growing coastal economy and its people. Thus, the magnitude of the impact for both phases is rated as high positive. The high magnitude, national to regional extent, and long term duration of the impact results in a high positive significance rating.

PROPOSED MITIGATION MEASURES:

No enhancement measures are recommended at this stage. The Rössing Mine Closure Plan will have to be amended to include provisions relating to the desalination plant.

7.4.4 Cumulative impacts

It is important to note that the socio-economic assessments presented above take into account cumulative impacts. However, the cumulative impacts associated with the proposed project are summarised below.

With reference to the No-Go alternative, where the mine closes due to financial reasons, the cumulative impact would be the resultant loss of more than 2,000 jobs, which would in turn lead to an increase in the already high levels of unemployment in Namibia. The low uranium price and the slowdown in the uranium rush has resulted in lower than expected income for NamWater. This, in addition to the potential premature closure of Rössing, could exert additional financial pressure on NamWater.

In the absence of a NamWater plant, it makes economic sense for RUL to build one and the cumulative impact will be that other mines, e.g. Husab may want to follow suit in order to reduce costs and secure water supply. This could result in a reduction in income for NamWater as large-scale users would provide for their own needs. On the other hand, this could place less pressure on NamWater's already threatened water supplies. Another potential cumulative effect of the development of multiple plants would be impacts on the local environment, particularly the marine environment. MET:DEA asked if the presence of the proposed Rössing Desalination plant and the associated brine discharges would impact on the water quality for the planned Mile 6 NamWater desalination plant. Based on the diffusion modelling, elevated salinity levels should fall back to undetectable levels (i.e. near ambient) within 50m of the diffuser (point discharge), therefore the potential for the Rössing's brine discharges to prejudice water quality for the planned Mile 6 desalination are considered negligible.

With reference to the reduction in guano production, the disturbance of 18 months of construction at the Salt Works may coincide with the disturbance caused to the guano platform north of Walvis Bay when the second harbour is built. However, it seems that the cape cormorant's population can recover quickly in good feeding years and it seems likely that the birds will return to the guano platforms during operations.

7.5 ARCHAEOLOGY AND HERITAGE IMPACTS

The following subsection is a modified summary compiled using the Heritage and Archaeology impact assessment undertaken by Quaternary Research Services. The original report is attached here as Annexure D2 and can be referred to for added detail.

7.5.1 Construction phase

7.5.1.1 Loss or damage of archeological and heritage resources

IMPACT DESCRIPTION:

A detailed inspection of the site was carried out on 6th August, 2014, covering the entire eastern margin of the Salt Works as far as the M0044 road reserve (C34 to Henties Bay), and the entire seaward side of the Salt Works including the current and disused pump-station facilities. No trace of any archaeological or historical remains as relevant to the National Heritage Act 27 of 2004, were found in this area.

Concerning evidence of shoreline processes associated with gross sea level fluctuations on the Namib coast, it is possible that the site of the proposed desalination plant will affect these features although disturbance of the area through previous industrial activity would have already compromised any such evidence. Evidence relating to sea level fluctuations is well represented elsewhere on the Namib coast.

It is unlikely that significant archaeological evidence of precolonial occupation will be found at the site, mainly due to the absence of fresh water in the immediate area. More recent evidence of historical activity including both salt mining and possible shipwrecks may well occur at the site, although there are no records to indicate these.

The old Salt Works intake structure is not considered to be a valuable heritage item worth preserving. However, a photographic record of the structure must be taken prior to the construction of the project.

This assessment is based on the presence or absence of visible surface indications, on inference from other parts of the Namib coast that have been surveyed in detail, and on a perusal of historical records especially concerning shipwrecks. None of these sources suggest that the project area is in any way sensitive archaeologically.

IMPACT ASSESSMENT: LOSS OR DAMAGE OF ARCHEOLOGICAL AND HERITAGE RESOURCES

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	~
Extent	Site specific	Site specific	Site specific	Site specific	Site specific	~
Magnitude	Low	Very low	Very low	Very low	Very low	~
Duration	Long term	Long term	Long term	Long term	Long term	~
SIGNIFICANCE	Low (-)	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
Probability	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Definite
Confidence	Sure	Sure	Sure	Sure	Sure	Certain
Reversibility	Irreversible	Irreversible	Irreversible	Irreversible	Irreversible	~

Due to the relative homogeneity of archaeological resources across the study area, the assessment provided below relates to all project alternatives described for this project in the SEIA, namely the three project site alternatives, the two brine discharge location alternatives and the overhead powerline vs buried cable electrical supply alternative.

In the case of the No-Go alternative, no disturbance of the site would occur and therefore the impact on archaeological would not occur, and so the No-Go alternative has not been assessed here. From the cumulative impact perspective and given the disturbed nature and low sensitivity of the site, it is expected that the project will have a negligible cumulative impact on Namibia's archaeology resource base and so this too is not assessed here.

In the unlikely event that archaeological traces are exposed during site works, the expected nature of impact would be in the form of direct physical disturbance or destruction. The expected magnitude of this impact would be low. Due to the fact that impacts on archaeological sites are irreversible, these would be high, with a local spatial scale. The consequence of the impact would be localised, and its significance would be low. The interpretation of this assessment would indicate a low significance, indicating that the risk of archaeological impact is so low as to have no influence on the project decision.

Proposed mitigation measures:

- A photographic record of the old Salt Works intake structure must be taken prior to the construction of the project.
- For purposes of the project SEMP, the client and contractors should be made aware of the provisions of Section 55 (4) of the National Heritage Act setting out the requirement that any sites or remains found in the course of construction and related work should be reported to the authorities as soon as possible. The SEMP should also include the standard archaeological chance finds procedure as set out below.

Chance finds procedure:

Areas of proposed mining and infrastructure development are subject to heritage survey and assessment at the planning stage. These surveys are based on surface indications alone, and it is therefore possible that sites or items of heritage significance will be found in the course of development work. Personnel and contractor heritage awareness training is intended to sensitize people so that they may recognize heritage "chance finds" in the course of their work. The procedure set out here covers the reporting and management of such finds.

The "chance finds" procedure covers the actions to be taken from the discovery of a heritage site or item, to its investigation and assessment by a trained archaeologist or other appropriately qualified person. The "chance finds" procedure is intended to ensure compliance with the relevant provisions of the National Heritage Act (27 of 2004), especially Section 55 (4): *"a person who discovers any archaeological…object…must as soon as practicable report the discovery to the Council".* The procedure of reporting set out below must be observed so that heritage remains reported to the NHC are correctly identified in the field:

- Responsibilities:
  - Operator — To exercise due caution if archaeological remains are found.
  - Foreman — To secure site and advise management timeously.
  - Superintendent — To determine safe working boundary and request inspection.
  - Archaeologist — To inspect, identify, advise management, and recover remains.

- Procedure:
  - Action by person (operator) identifying archaeological or heritage material:
    - If operating machinery or equipment: stop work;
    - Identify the site with flag tape;
    - Determine GPS position if possible; and
    - Report findings to foreman.
  - Action by foreman:
    - Report findings, site location and actions taken to superintendent; and

- Cease any works in immediate vicinity.
- Action by superintendent:
  - Visit site and determine whether work can proceed without damage to findings;
  - Determine and mark exclusion boundary; and
  - Site location and details to be added to Archaeological Heritage Geographical Information System AH GIS for field confirmation by archaeologist.
- Action by archaeologist:
  - Inspect site and confirm addition to AH GIS;
  - Advise National Heritage Council (NHC) and request written permission to remove findings from work area; and
  - Recovery, packaging and labelling of findings for transfer to National Museum.

- In the event of discovering human remains:
  - Actions as above;
  - Field inspection by archaeologist to confirm that remains are human;
  - Advise and liaise with NHC and Police; and
  - Recovery of remains and removal to National Museum or National Forensic Laboratory, as directed.

7.5.2 Cumulative impacts

From the cumulative impact perspective and given the disturbed nature and low sensitivity of the site, it is expected that the project will have a negligible cumulative impact on Namibia's archaeology resource base and is therefore not assessed here.

7.6 VISUAL IMPACTS

The following subsection is a modified summary compiled using the visual impact assessment undertaken by VRMA. The original report is attached here as Annexure D3 and can be referred to for added detail in understanding the visual impacts and the methodologies employed in assessing their significance.

The identified impacts have been categorised into construction, operations, decommissioning phase and cumulative impacts. The impacts are dealt with in that order, and are briefly described here.

A site visit was undertaken on the 5th and 6th of August 2014 by the visual specialist. During the site visit the regional landscape character was assessed, the site surveyed and Key Observation Points defined. Preliminary findings regarding the visibility were that the C34 and the northern Swakopmund residential areas as well as birders visiting the pans would be exposed to views of the proposed project.

The following locations should be utilised to assess the degree of contrast as depicted in the following map (Figure 82):

- C34 southbound views towards the proposed transmission line road crossing;
- C34 northbound views towards the proposed plant and substation; and
- Swakopmund residential views towards the proposed transmission line.

The yellow areas in Figure 83 indicate the approximate coverage area from which the proposed plant, with a 6 m height, will be visible.

Photomontages were generated to portray an illustrative representation of the proposed landscape modification. It's recommended that the existing Salt Works warehouse be utilised as a good example for design and colour.Therefore the existing Salt Works warehouse was utilised as the model in the

following photomontage to portray the proposed structural landscape modifications. As indicated on the photographs, this is for illustrative purposes only.

Figure 82: Key Observation Points overlaid onto Open Source Satellite Image Map

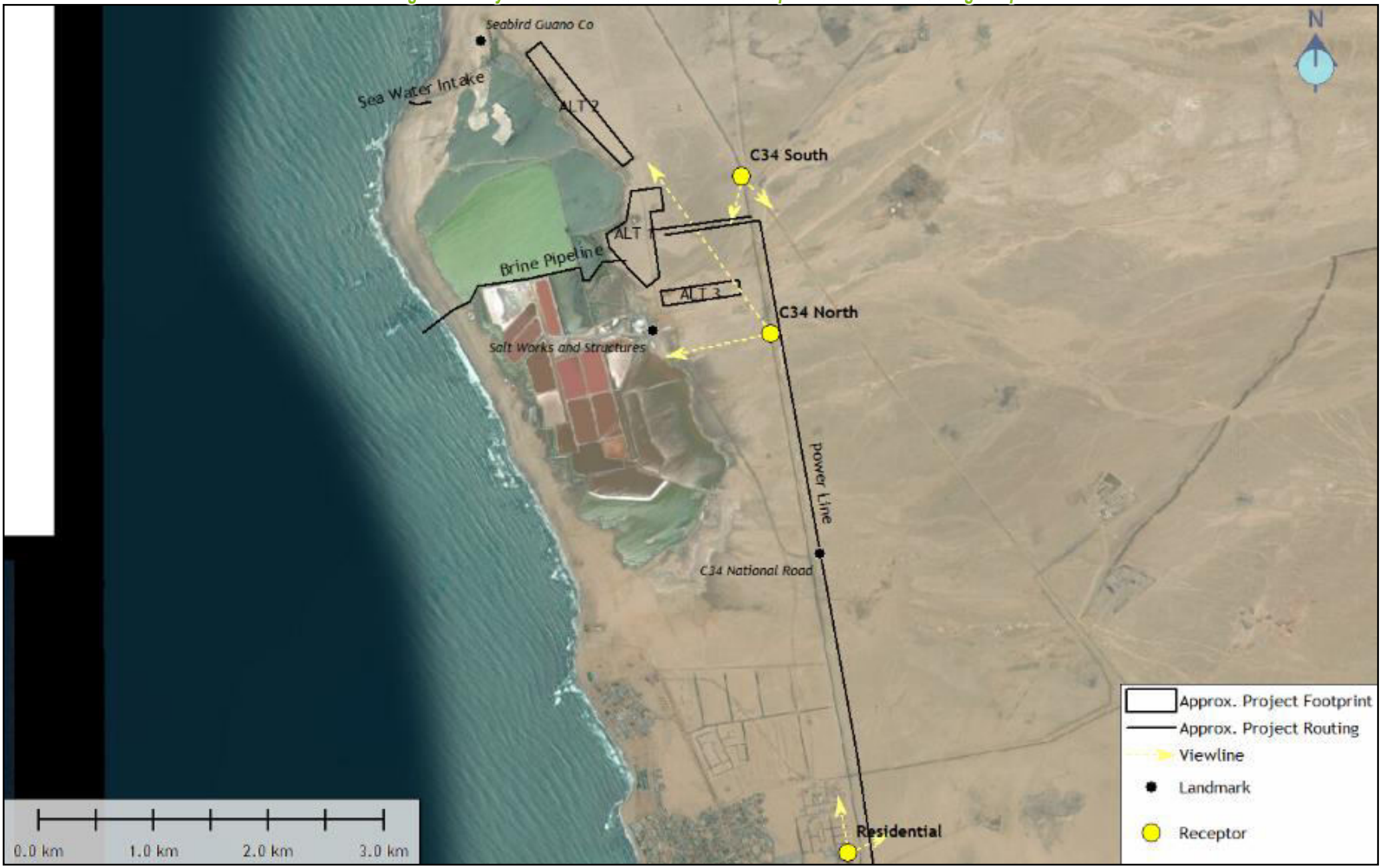


Figure 83: Viewshed of proposed plant and substation structures with a 6m height offset overlay onto Open Source Satellite Imagery Map

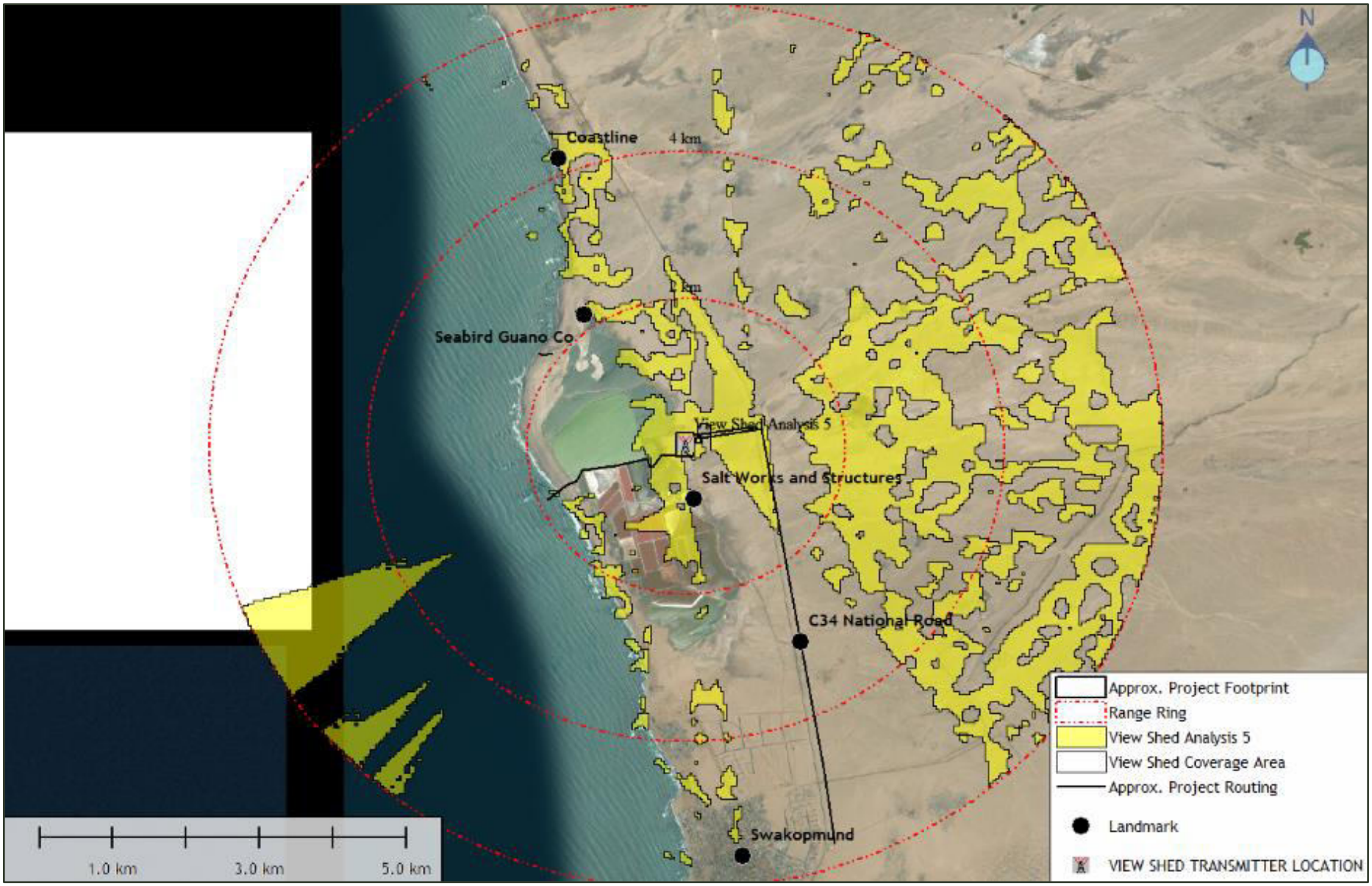


Figure 84: Existing and probable landscape change of plant Base Case as seen from travelling north on the Henties Bay Road

Initial view travelling north on the Henties Bay Road

Probable view of Plant Base Case ***(FOR ILLUSTRATIVE PURPOSES ONLY)***

Figure 85: Existing and probable landscape change of Plant Alternative 1 as seen from travelling north on the Henties Bay Road

Initial view travelling north on the Henties Bay Road

Probable view of Plant Alternative 1 ***(FOR ILLUSTRATIVE PURPOSES ONLY)***

Figure 86: Existing and probable landscape change of Plant Alternative 2 as seen from travelling north on the Henties Bay Road

Initial view travelling north on the Henties Bay Road

Probable view of Plant Alternative 2 ***(FOR ILLUSTRATIVE PURPOSES ONLY)***

Figure 87: Probable routings of the powerline as seen from Swakopmund north and the Henties Bay Road (Alternative 3)

View of probable above ground routing as seen from the Henties Bay Road with Swakopmund in the background

View of probable above ground routing as seen from Swakopmund northern residential

Views from Swakopmund residents are mainly restricted to those located in the outer north-eastern extents of the town. They would have moderate to low exposure views of the proposed plant and substation, but high exposure views of the proposed transmission line (if constructed above ground). Due to the existing structures visible in the landscape it is likely that their sensitivities to landscape modification would be moderate to low.

The C34 is a gravel road which links the town of Swakopmund with the small fishing and tourist town of Henties Bay. The road follows the coastline northwards and in certain areas, the contrasting views of Atlantic Ocean to the west and flat desert landscapes to the east create higher levels of scenic quality which add to the experience of the Namibian coastline sense of place. This route is utilised for tourism activities which radiate out from Swakopmund and as such it is likely that local and tourist viewers utilising the road would have higher sensitivities to landscape change, but seen with medium exposure. It is also important to note that the area is an important birding destination due to birdlife being attracted to the large evaporation pans required to obtain the salt. It is likely that tourist receptors participating in birding activities at the pans would have high exposure and higher sensitivities to landscape change.

With mitigation, it is unlikely that the existing visual resources would be significantly degraded by the proposed plant alternatives and associated infrastructure, as there is a strong precedent for isolated structures and a jetty in the region set by the Salt Works and the Guano Company. The preference from a visual perspective is Site Alternative 1, followed by Site Alternative 3 (located on the western side of the site) as it is closer to the Salt Works which reduces visual intrusion. It is strongly recommended that the plant structure design and colour follow the suitable example set by the Salt Company most recent warehouse. The simple style of the architecture reduces form contrast created by shadow effects, and the light grey-brown colour significantly reduces the colour contrast. It is recommended that overhead flood lighting is not utilised in order to minimise light spillage at night. Once the final footprint of the plant is defined, a qualified landscape architect should be contracted to assist in the design of the screening berm to ensure that it appears to tie into the natural landscape as seen from the pans. The preferred powerline alternative is the underground option as this would generate the least amount of visual intrusion.

To minimise the potential of cumulative visual impacts associated with ribbon development along the coast, effective planning should also be implemented to ensure that the development does not set a similar coastal development scenario as found between Walvis Bay and Swakopmund which is visually intrusive if not effectively planned.

7.6.1 Construction phase

7.6.1.1 Construction phase visual impacts

IMPACT DESCRIPTION:

Refer to the overview of impacts at the start of the visual impacts subsection.

IMPACT ASSESSMENT: VISUAL IMPACT OF INTAKE JETTY (ONLY)

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	~
Extent	Local	Local	Local	Local	Local	~
Magnitude	High	Medium	Medium	Medium	Medium	~
Duration	Short term	Short term	Short term	Short term	Short term	~
SIGNIFICANCE	High (-)	Medium (-)	Medium (-)	Medium (-)	Medium (-)	Neutral
Probability	Probable	Probable	Probable	Probable	Probable	Definite
Confidence	Unsure	Unsure	Unsure	Unsure	Unsure	Certain
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	~

It should be noted that the visual impact associated with the construction of the intake jetty was rated as being High (-) before mitigation and Medium (-) after mitigation, as shown hereunder. The intake jetty is a fixed component and is the same for all alternatives assessed above and so this has not been factored into the impact assessment rating for the main alternatives that follows.

IMPACT ASSESSMENT: VISUAL IMPACT OF RO PLANT

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	~
Extent	Local	Local	Local	Local	Local	~
Magnitude	Medium	Low	Low	Medium	Medium	~
Duration	Short term	Short term	Short term	Short term	Short term	~
SIGNIFICANCE	Medium (-)	Low (-)	Low (-)	Medium (-)	Medium (-)	Neutral
Probability	Probable	Probable	Probable	Probable	Probable	Definite
Confidence	Sure	Sure	Sure	Sure	Sure	Certain
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	~

Base Case: Construction phase impacts without mitigation are likely to be Medium to High. The landscape modification as seen from the Henties Bay road viewers would be medium by the distance to the site, and the lower elevation of the site in relation to the road which offers some base levels topographic screening. The site is also in the vicinity of the existing Salt Works which increases the regional Visual Absorption Capacity levels. Higher visual intrusion would be experienced by bird watchers due to the closer proximity of the proposed site to the pans. With mitigation, the construction phase impacts could be reduced to Medium to Low.

Alternative 1: Construction phase impacts without mitigation have the potential to be High (-). Due to the location of this Alternative in visual isolation from the existing structures (two kilometres north of the existing Salt Works and one kilometre from the Guano Company), the Visual Absorption Capacity levels are low. Higher visual intrusion would be experienced by bird watchers due to the close proximity of the proposed site to the pans. With mitigation, the construction phase impacts could be reduced to Moderate.

Alternative 2: Construction phase impacts without mitigation are likely to be high due to the high exposure of the eastern section of the site to the Henties Bay road. Moderate visual intrusion would be experienced by bird watchers due to greater distance of the proposed site from the pans.

Alternative 3: Construction phase impacts associated with an above ground transmission line have the potential to be High (-) if the powerline is routed directly adjacent the existing cathodic corrosion protection pole route as this will result in strong crowding effects along the road and is not recommended. With mitigation, the visual impacts can be reduced to Medium (-).

No go Alternative: If the project were to not proceed it would not have any visual impacts and these have been rated as Neutral in all instances.

Proposed mitigation measures:

- Access control (use same access point along route) and erosion control.
- Create screening berm around the west and north perimeter to screen off base levels views of construction site.
- Create screening berm around the west and north perimeter to screen off base levels views of construction site.
- Disturbed ground shaping to allow for natural run-off, rehabilitation and restoration.
- Effect regional planning to ensure that the proposed development does not set a precedent for ribbon development along the coast.
- Fence off laydown to prevent wind-blown litter.
- If overhead powerline alternative is pursued then hang cable on existing dis-used structures, or replace existing dis-used structures with new powerline structures, or place routing with a 20m buffer to the east of the existing routing of the cathodic corrosion protection poles.
- Alternative 2: Locate site closer to Salt Works (west side of site).
- Locate the construction camp in closer proximity to the Salt Works and camp away from the coastline out of the main views of the coastal receptors (i.e. Recreational anglers driving along the coast).
- No overhead flood lighting.
- Setting a plant construction precedent which maintains the existing tourism appeal for birders utilising the area through the implementation of the foregoing mitigations.

7.6.2 Operations phase

7.6.2.1 Operations phase visual impact

IMPACT DESCRIPTION:

Refer to the overview of impacts at the start of the visual impacts subsection; however the following impact assessment relates to the overall visual impact assessment with the RO plant and all associated infrastructure.

IMPACT ASSESSMENT: VISUAL IMPACT DURING OPERATIONS PHASE

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	~
Extent	Regional	Local	Local	Local	Local	~
Magnitude	Medium	Low	Medium	Medium	Medium	~
Duration	Long term	Long term	Long term	Long term	Long term	~
SIGNIFICANCE	High (-)	Low (-)	Medium (-)	Medium (-)	Medium (-)	Neutral
Probability	Definite	Probable	Probable	Probable	Probable	Definite
Confidence	Sure	Sure	Sure	Sure	Sure	Certain
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	~

Base Case layout: Operation phase impacts without mitigation would be High (-) if bright colours were utilised for the walls which would generate strong colour contrast as seen from the Henties Bay road as well as the birders. With mitigation in terms of colour and simple, lower profile design of the structures (similar to the Salt Works warehouse design), the operation phase impacts can be reduced to Low (-).

Desalinisation Plant Alternative 1: Operation phase impacts without mitigation would be High (-) if bright colours were utilised for the walls which would generate strong colour contrast as seen from

the Henties Bay road as well as the birders. With mitigation in terms of colour and simple, lower profile design of the structures (similar to the Salt Works warehouse design), the operation phase impacts can be reduced to Medium (-).

Desalinisation Plant Alternative 2: Operation phase impacts without mitigation would be High (-) if bright colours were utilised for the walls which would generate strong colour contrast as seen from the Henties Bay road as well as the birders. With mitigation in terms of colour and simple, lower profile design of the structures (similar to the Salt Works warehouse design), the operation phase impacts can be reduced to Medium (-).

Intake Jetty (same for all alternatives): Specific design plans for the proposed jetty were not available at the time of assessment so confidence levels for impacts were rated as Unsure. Due to the close proximity of the existing Salt Work intake, it is likely that the construction phase impacts would be moderated unless the scale of the proposed intake is larger than that of the exiting jetty, in which case the construction phase impacts could be high. Should the jetty be located in close proximity to the exiting jetty and be of a similar scale, it is likely that they would be viewed as a single entity where-by operation phase impacts would be Medium **(-)**. Closure phase would require that the structure be removed, unless it can be incorporated into another landuse activity where continued maintenance would reduce the landscape decay effect. It is recommended that overhead flood lighting is not utilised.

Transmission Lines above Ground (Alternative 3): Construction and Operation phase impacts have the potential to be High **(-)** if the powerline is routed directly adjacent the existing cathodic corrosion protection pole route as this will result in strong crowding effects along the road and is not recommended. With mitigation, the visual impacts can be reduced to Medium (-). Mitigation would require that the proposed cable be hung on the existing dis-used structures, or that the existing disused poles are replaced by new powerline structures, or by placing the routing 20m to the east of the existing cathodic corrosion protection pole routing to create a visual buffer if permission cannot be granted for removal of the disused poles.

Proposed mitigation measures:

- The intake jetty and associated structures to be painted desert-grey (refer to the Salt Works' new structure).
- Colour and building style to replicate colour and style of the new Salt Works building.
- Design the new intake structure as close to the existing jetty as possible so that the two structures read as a single entity as seen by the casual observer.
- Erosion control.
- No overhead flood lighting is to be used.
- No signage should be erected at the intake jetty.
- Retain earth screening berm to reduce light spillage and screen movement around the plant.
- Access control should be implemented during construction phase to reduce vehicle tracks as seen from the Henties Bay road followed up with on-going erosion control (if required).

7.6.3 Decommissioning phase

7.6.3.1 Decommissioning phase visual impacts

IMPACT DESCRIPTION:

Refer to the overview of impacts at the start of the visual impacts subsection.

IMPACT ASSESSMENT: VISUAL IMPACT DURING DECOMMISIONING

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	~
Extent	Regional	Local	Local	Local	Local	~
Magnitude	High	Very low	Very low	Very low	Very low	~
Duration	Short term	Short term	Short term	Short term	Short term	~
SIGNIFICANCE	High (-)	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
Probability	Probable	Probable	Probable	Probable	Probable	Definite
Confidence	Sure	Sure	Sure	Sure	Sure	Certain
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	~

It should be noted that the assessment related to decommissioning activities, which are similar in nature to construction phase activities, and the potential short term visual impacts associated with these activities. The removal of the plant and associated infrastructure would logically result in a positive long term impact.

Proposed mitigation measures:

- Deconstruction of all structures, ground shaping to reflect natural terrain, rehabilitation and restoration.

7.6.4 Cumulative visual impacts

Due to the closer proximity of the proposed Base Case and alternative 2 sites to the existing Salt Works which is already seen as a localised development node, cumulative visual impacts can be reduced to Medium (-) to Low (-) if colour and structure design mitigations are effectively implemented. The use of bright colours would not blend with the muted grey-browns of the surrounding desert and would set a negative precedent for development in the vicinity and is not recommended. Due to the locality of the Alternative 1 further to north away from any existing development nodes, the potential for cumulative impacts increases in terms of setting a precedent for isolated structures in low Visual Absorption Capacity levels environments. This effect could be reduced if effective mitigation was implemented which would reduce the contrast generated by the proposed structure. Effective planning should also be implemented to ensure that the development does not set a precedent for *ad hoc* development in the area which would lead to a similar 'ribbon development' scenario as found between Walvis Bay and Swakopmund which is visually intrusive if not effectively planned.

MITIGATION MEASURES

- Setting a plant development precedent which does not detract from the tourism appeal for birders utilising the area. Setting a low intrusive precedent for powerline routing along tourist view corridors. Effect regional planning to ensure that the proposed development does not set a precedent for ribbon development along the coast.

7.7 NOISE IMPACTS

The following subsection is a modified summary compiled using the noise impact assessment undertaken by Airshed Planning Professionals. The original report is attached here as Annexure D4 and can be referred to for added detail. A short overview to contextualise noise impacts follows.

7.7.1 IFC Guidelines on Environmental Noise

The International Finance Corporation (IFC) General Environmental, Health and Safety Guidelines on noise address impacts of noise beyond the property boundary of the facility under consideration and provides noise level guidelines.

The IFC states that noise impacts should not exceed the levels presented in Table 34, or result in a maximum increase above background levels of 3 dBA at the nearest receptor location off-site (IFC, 2007). For a person with average hearing acuity an increase of less than 3 dBA in the general ambient noise level is not detectable. Δ = 3 dBA is, therefore, a useful significance indicator for a noise impact.

Table 34: IFC noise level guidelines

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

7.7.2 SANS 10103

The South African National Standards (SANS) 10103 (2008) successfully addresses the manner in which environmental noise is to be assessed in South Africa, and is fully aligned with the World Health Organisation guidelines of 1999. The values given in Table 35 are typical rating levels that should not be exceeded outdoors in the different districts specified. Outdoor ambient noise exceeding these levels will be considered annoying to the community.

Table 35: Typical rating levels for outdoor noise

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

Notes

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

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

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

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

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

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

7.7.3 Birds and Their Response to Noise

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

7.7.3.1 Avian Hearing

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

Generally, humans have better auditory sensitivity (lower auditory thresholds[49]) both in quiet and in noise than does the 'typical' bird. This is illustrated in the audiograms presented in Figure 88. Whereas the hearing of a young, healthy person ranges between 20Hz and 20kHz, the hearing of a bird (the median of data for 49 bird species) ranges between 100Hz and 10kHz. Birds hear best at frequencies between about 1 and 5kHz, with absolute (best) sensitivity often approaching 0 to 10dB at the most sensitive frequency, which is usually in the region of 2 to 4kHz. The typical bird therefore hears less well than humans and over a narrower bandwidth.

According to Dooling (2002), there are some exceptions to the above homogenous picture of avian hearing. Pigeons, for instance, may have an unusual auditory sensitivity to very low frequency sounds. By some estimates they may be almost 50 dB more sensitive than humans in the frequency region of 1 to 10 Hz. The auditory sensitivity of some nocturnal predators, such as barn owls, is another exception (See Figure 88 (b), strigiformes).

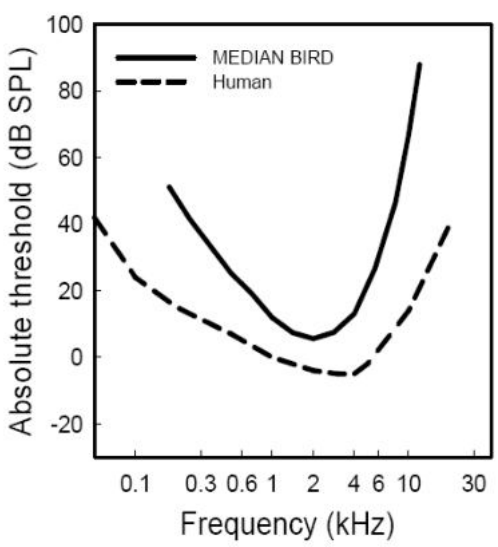
Birds are however unusual among vertebrates in the remarkable consistency of their auditory structures and in their basic hearing capabilities, such as absolute thresholds of hearing. Dooling (2002) reports that the centre frequency (the frequency at which hearing is most sensitive) and high-frequency cutoff are significantly and inversely correlated with a bird's size and weight. It is postulated that body size puts a constraint on the low-frequency sensitivity of small birds. Figure 88 (b) shows that the region of lowest thresholds for birds is between 1 and 5kHz, at which hearing thresholds range from –10 dB to about 20 dB. Hearing sensitivity falls off at the rate of about 15 dB/octave below 1kHz and about 35 to 40dB/octave above about 3kHz.

Almost all avian species rely heavily on acoustic communication for species and individual recognition, mate selection, territorial defence, and other social activities. Dooling (2002) states that it has long been recognized that there is a strong correlation between the range of hearing in birds and the frequency spectrum of bird vocalizations. That is, with the exception of some nocturnal predators, birds hear best in the spectral region of their species-specific vocalizations. This is an

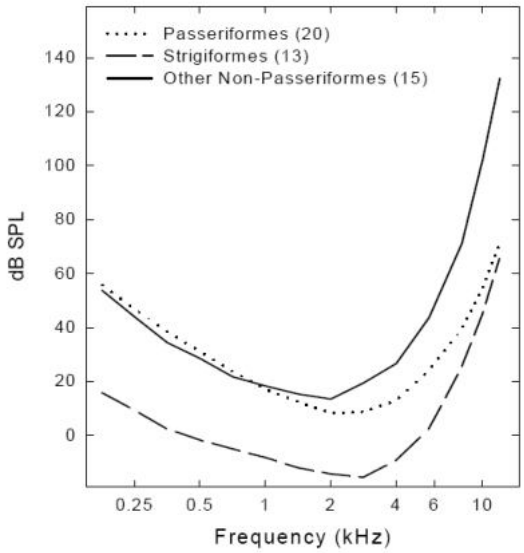
[49] *The hearing threshold is the minimum sound pressure level of a pure tone that an average ear with normal hearing can hear with no other sound present. The threshold relates to the sound that can just be heard by the organism.*

important observation since it highlights the fact that considerations of the masking or hearing damage effects of noise on acoustic communication in birds should focus attention on the critical frequency region of about 1 to 6kHz.

Figure 88: Hearing thresholds of several bird species in comparison with human hearing



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



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

7.7.3.2 Direct Effects of Noise on Hearing in Birds

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

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

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

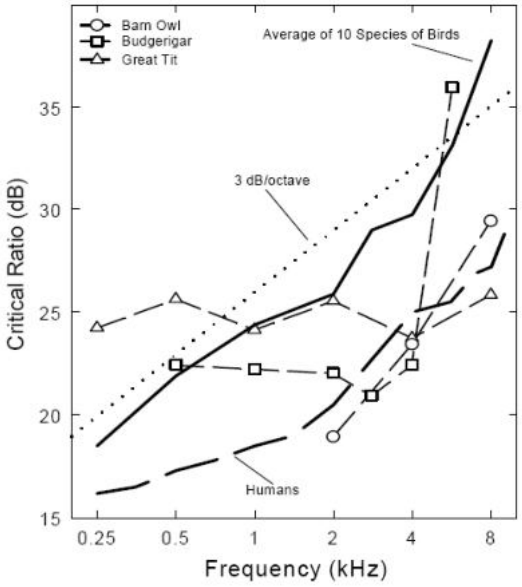
Of the potential effects on birds within the context of the current investigation, ***masking***, the interference with the detection one biologically relevant sound by another, is of most significance. It

refers to the increase in thresholds for detection or discrimination of sounds in the presence of another sound. Data from two kinds of masking experiments are described below.

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

Critical ratio data, obtained behaviourally, for 14 species of birds, including songbirds, non-songbirds, and nocturnal predators as reported by Dooling (2002) are presented in Figure 89. This figure describes the level in dB above the spectrum level of a background noise that a pure tone must be in order to be heard. For example, for the average bird a pure tone in the region of 3kHz must be at least 28dB above the spectrum level of the noise in order to be detected. For the human, the same pure tone need only be about 22dB above the spectrum level of noise to be heard. This difference in masked thresholds of 6dB is significant when considered in terms of the decrease in sound pressure with distance. Because of the inverse square law, this difference represents approximately a doubling of distance; a human can still detect a sound in noise at twice the distance the typical bird can. It is noted that the average critical ratio curve follows quite closely the typical pattern of approximately a 2 to 3dB/octave increase in signal-to-noise (S/N) ratio that is characteristic of these functions in mammals, including humans (the 3dB/octave slope is shown by a dotted line in Figure 89). Knowing the S/N ratio at threshold for a bird allows predictions about how far away a sound can be heard in a noisy background.

Figure 89: Masking functions (critical ratios) for 14 species of birds (Dooling R. , 2002)



Just as noise can mask a pure tone, it can also mask other noise. It can be determined how much a noise has to be increased in level in order to detect the increase. Another approach determines the level required of a second noise added to an original noise so that the second noise is just detectable. Experiments to determine how much the level of a noise needs to be increased to be detected has been done in humans, and the answer is about 0.5 to 1.0dB. Similar data are available in the form of modulation transfer functions for three species of birds: the budgerigar, the starling, and the barn owl. Dooling (2002) reports that all three species can hear about a 1.5dB change in level of flat, broadband noise. Again, it appears that human acoustic discrimination abilities are slightly better than those of birds.

Table 36: Critical ratio in dB to be exceeded for the detection of pure tones and broadband noise for average bird[50]

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

7.7.3.3 Recommended Thresholds

Dooling & Popper (2007) recommends, pending additional research, 'interim' guidelines for the protection of birds against potential effects from different industrial and commercial type noise sources (Table 37).

Table 37: Recommended interim guidelines for the protection of birds from industrial and commercial noise sources

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

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

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

7.7.4 Construction phase

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

- Earthworks, including site excavations and levelling;

[50] *Source: (Avian Hearing and the Avoidance of Wind Turbines, 2002)*

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

It is important to note that this study considers the potential impact that noise will have on humans and on birds, as the Mile 4 salt pans are an important bird area. The area is also known to serve as a breeding / nesting site for the endangered Damara Tern.

In the absence of information related to the extent of construction activities a general approach was adopted. Construction related noise was estimated over an area wide basis by applying the EC WG-AEN sound power level rating of 65dBA/m^2 for heavy industrial activities (EC WG-AEN, 2003). The footprint area of the proposed Rössing Uranium desalination plant was estimated at approximately 7,700m^2. Octave band sound power level's for activities during the construction phase is given in Table 38. It was assumed that construction activities would occur continually over 24 hours of the day.

Table 38: Sound power levels of activities during the construction phase

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

From simulations for the construction phase the following was found:

- The International Finance Corporation day-time guideline of 55dBA is exceeded only within the immediate vicinity (within 200m) of construction activities whereas exceedance of the International Finance Corporation night-time guideline of 45dBA is expected up to 1km downwind. The increase in noise levels above the baseline reduces to less than 3dBA within 300m during the day and 600m during the night.
- The Dooling and Popper interim guideline of 60dBA for birds adopted in this study is only exceeded within 100m from construction activities.
- From the assessment of 'worst case' impacts at community noise sensitive receptors at minimum distances from location alternatives considered the following was found:
  - Residents of the correctional services accomodation may be exposed to noise levels in excess of the night-time International Finance Corporation guideline should the Rössing Uranium desalination plant be located within site options (i.e. locations) 1 and 2 (refer to Figure 90 to Figure 93 below). The increase above the baseline at these houses is however expected to be slightly notable only when the facility is sited within location 2. According to SANS 10103 (2008) sporadic complaints with little community reaction can be expected.
  - The proposed Rössing Uranium desalination plant is not expected to have any effect on environmental noise levels at the Mile 4 Caravan Park or northern Suburbs of Swakopmund.

- From the assessment of 'worst case' impacts at the Damara Tern and Guano Platform areas, it was found that the Dooling and Popper interim guideline of 60dBA will not be exceeded during the day or night irrespective of the location alternative selected for the site of the Rössing Uranium desalination plant.

Total day- and night time noise levels associated with the Rössing Uranium desalination plant situated within the preferred area of Location 1 are presented in Figure 90 and Figure 92. The increase over the day- and night-time baseline of 49dBA and 44dBA respectively are presented in Figure 91 and Figure 93. It should be noted that these isopleths are representative of an hour during which the wind is from the north. Winds from the north occur 12 to 15% of the hours within a year.

Figure 90: Isopleths of day-time L_{Aeq} (1 hr) during the construction phase

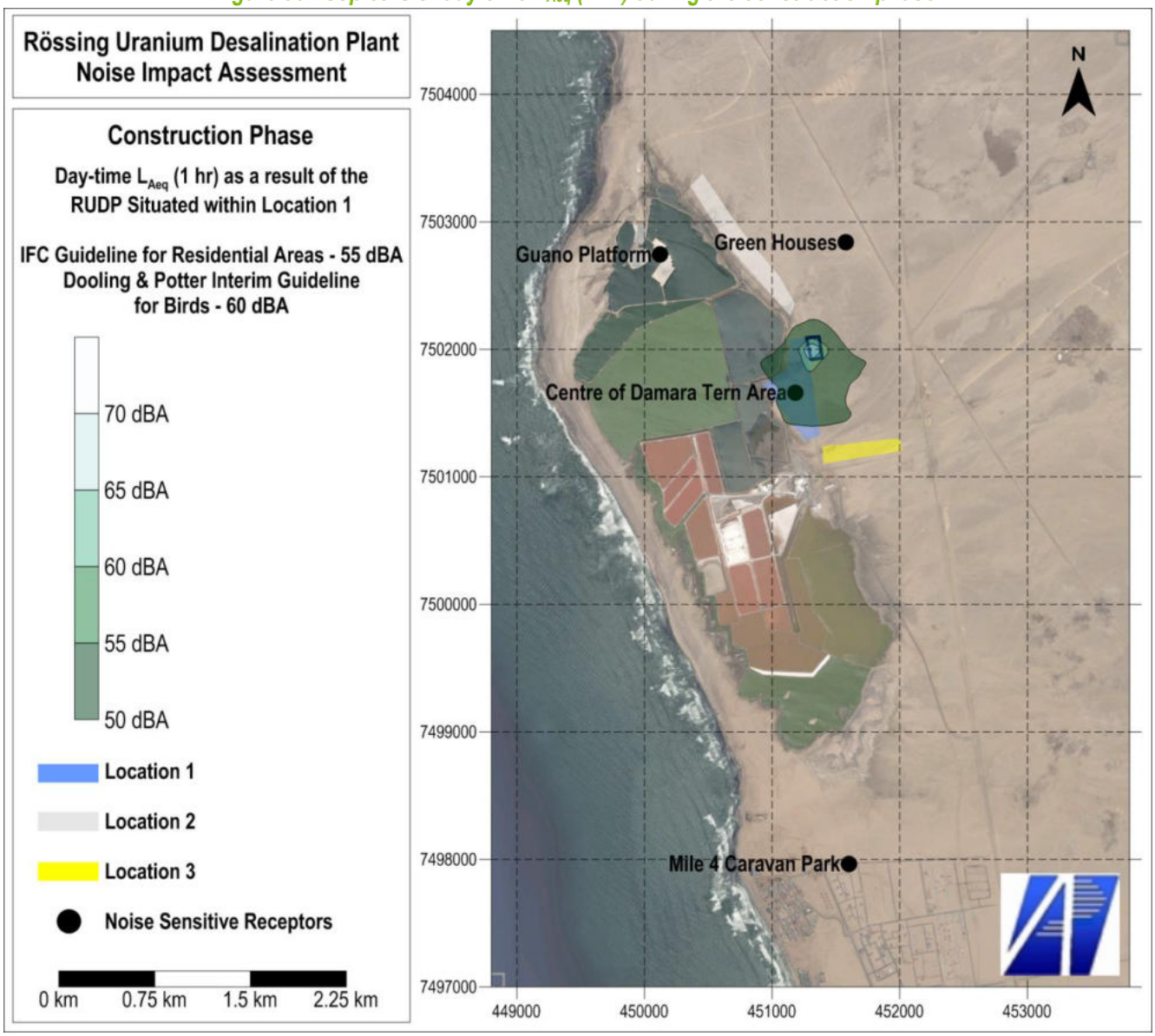


Figure 91: Isopleths of the increase in day-time L_{Aeq} (1 hr) during the construction phase

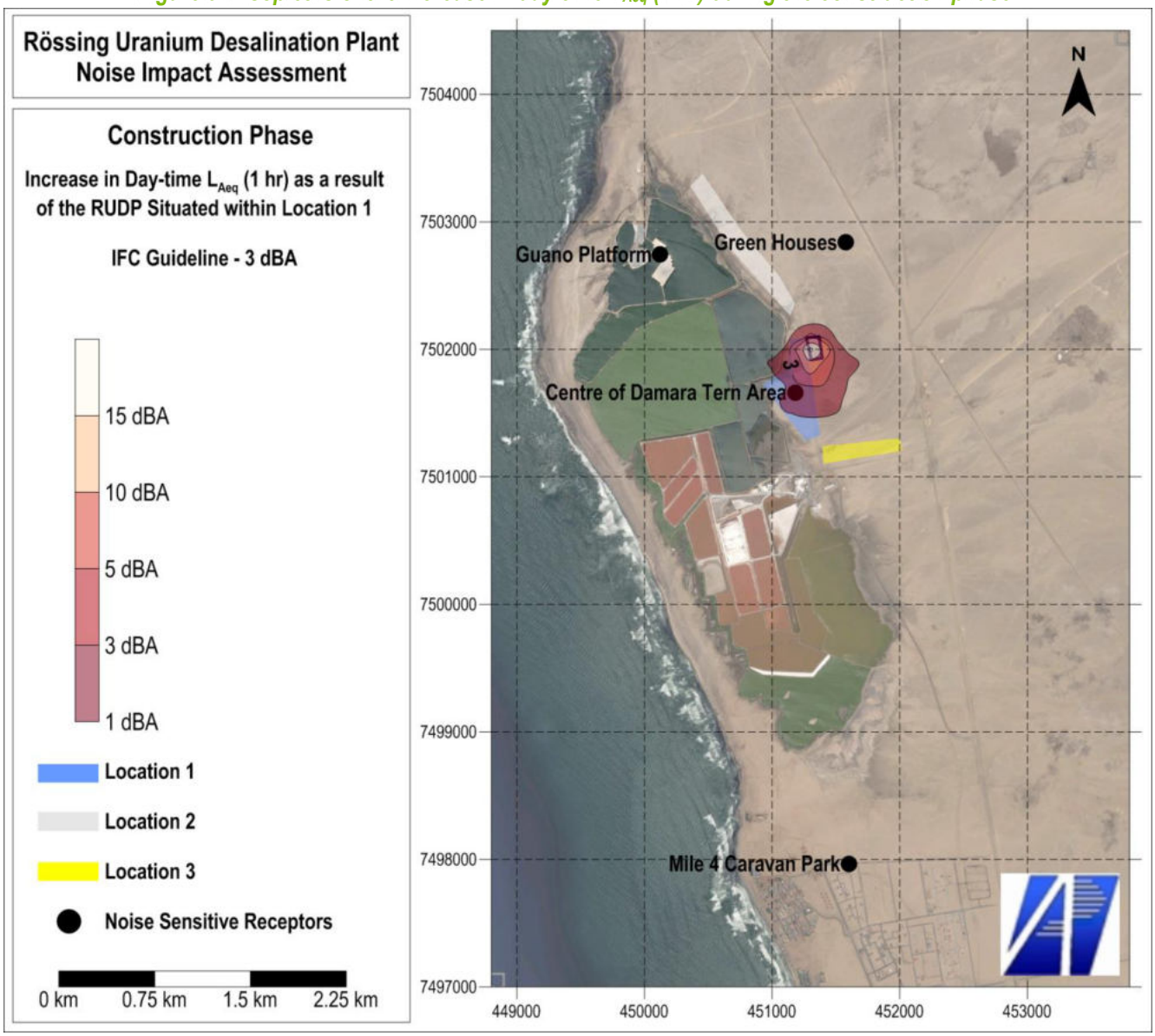


Figure 92: Isopleths of night-time L_{Aeq} (1 hr) during the construction phase

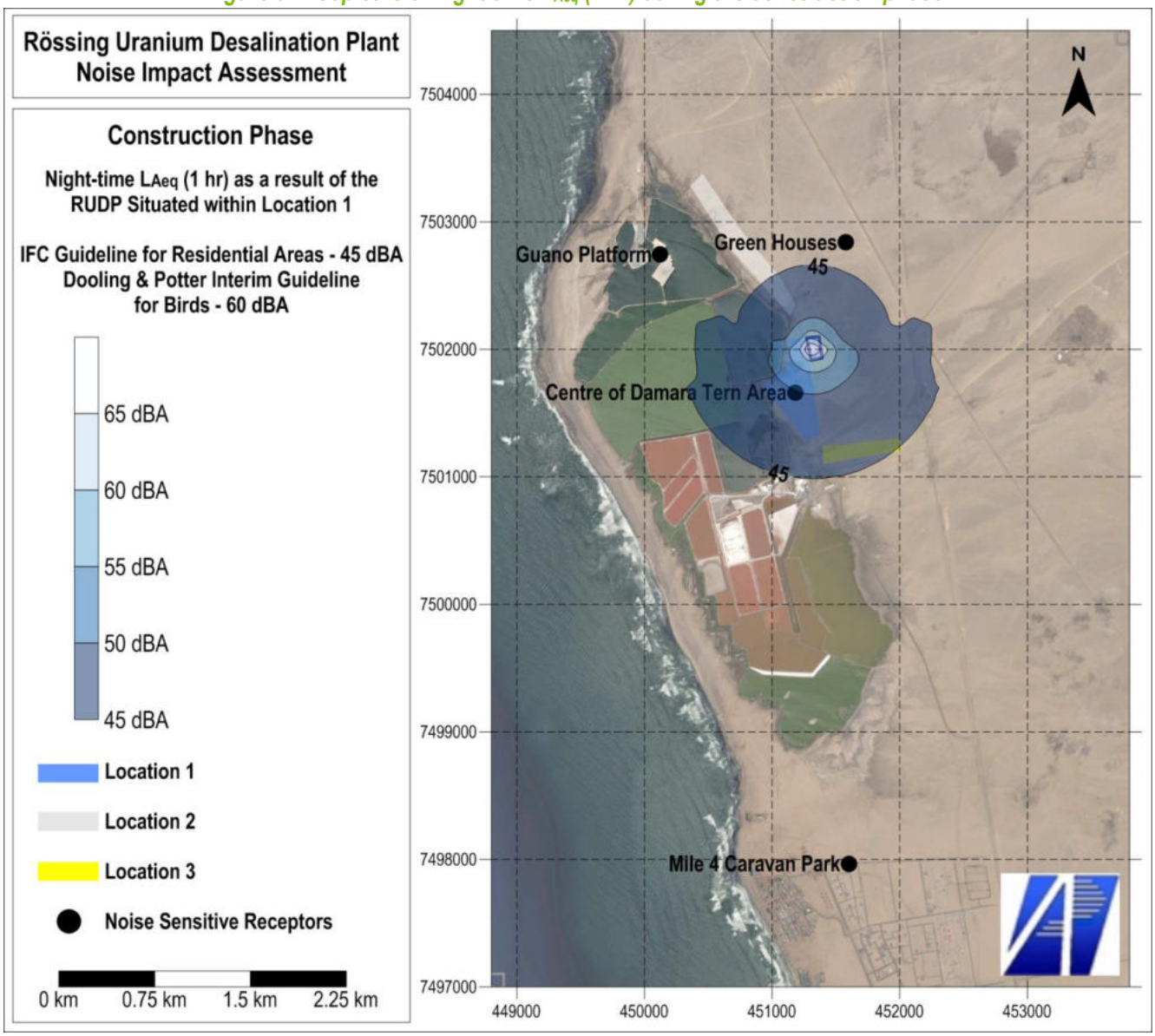
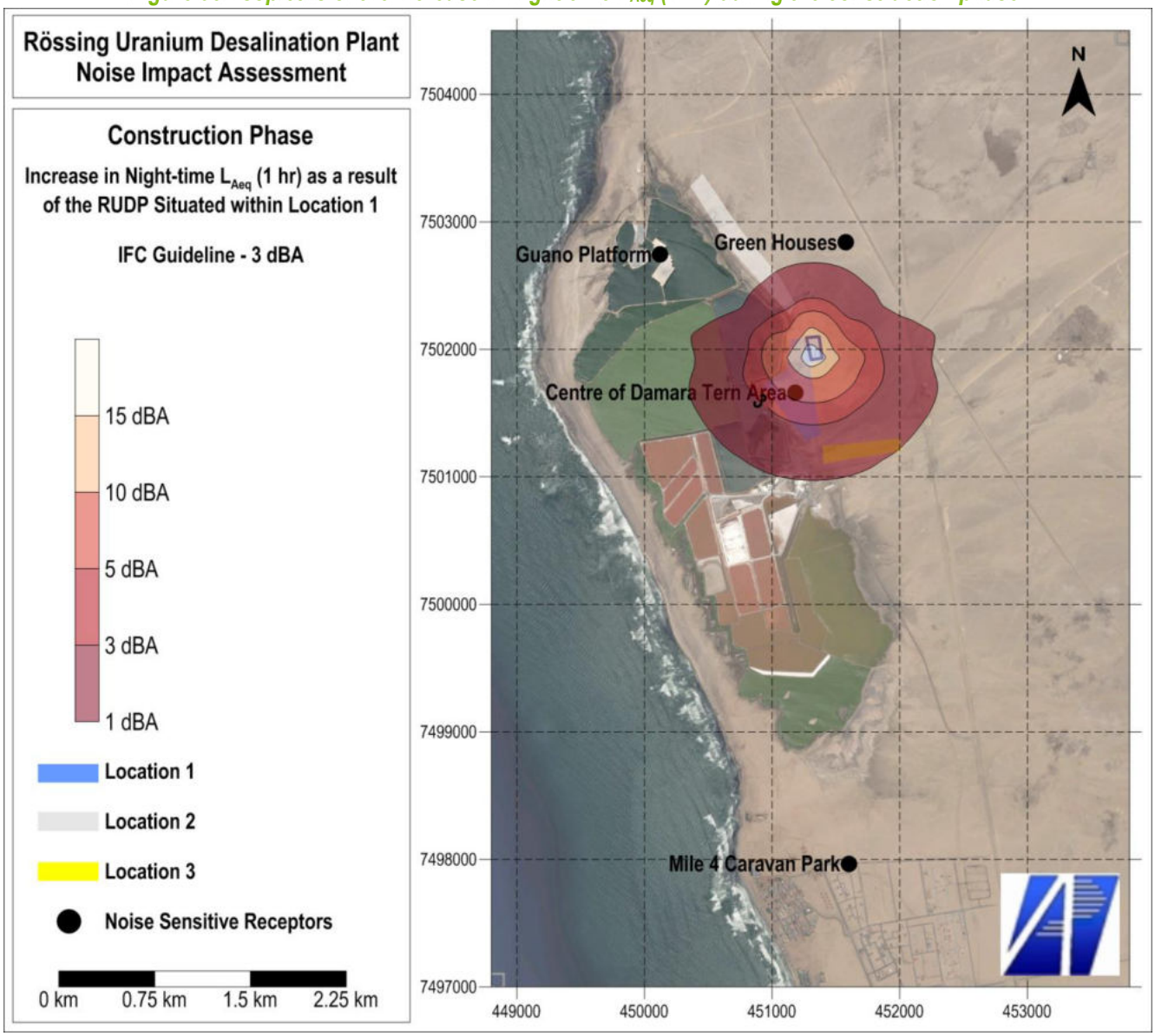


Figure 93: Isopleths of the increase in night-time L_{Aeq} (1 hr) during the construction phase



7.7.4.1 Construction phase noise impacts

IMPACT DESCRIPTION:

The potential for construction phase noise to cause annoyance of human activities or disrupt bird activities in and around the study area.

IMPACT ASSESSMENT: NOISE IMPACT ON BIRDS

Criteria \ Alternative	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	~
Extent	Local	Local	Local	Local	Local	~
Magnitude	Very low	Very low	Very low	Very low	Very low	~
Duration	Short term	Short term	Short term	Short term	Short term	~
SIGNIFICANCE	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
Probability	Probable	Probable	Probable	Probable	Probable	Definite
Confidence	Unsure	Unsure	Unsure	Unsure	Unsure	Certain
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	~

IMPACT ASSESSMENT: NOISE IMPACTS ON HUMANS

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	~
Extent	Local	Local	Local	Local	Local	~
Magnitude	Very low	Very low	Very low	Very low	Very low	~
Duration	Short term	Short term	Short term	Short term	Short term	~
SIGNIFICANCE	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
Probability	Probable	Probable	Probable	Probable	Probable	Definite
Confidence	Sure	Sure	Sure	Sure	Sure	Certain
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	~

Notes:

(a) Area of exceedance of assessment criteria on-site or within 1 km from site.
(b) Environmental noise is mainly assessed for its potential to cause annoyance to communities. The slight increase above baseline noise levels (3 dBA and lower) indicates that social functions will remain unaltered.
(c) According to interim guideline proposed by Dooling and Popper (2007) adopted for the assessment of impacts on birds, social and/or natural functions and/ or processes remain will unaltered at levels below 60 dBA.
(d) Construction phase, up to 3 years.
(e) Estimated 5% to 95% chance of the impact occurring.
(f) A reasonable amount of useful information on and relatively sound understanding of the environmental factors potentially influencing the impact on humans are available and have been applied in impact estimations.
(g) Limited information on and understanding of, the environmental factors potentially influencing the impact of noise on Damara Terns are available.
(h) The impact is reversible, within a period of 10 years.

In the interpretation of noise impact significance, the following should be noted:

- From a human perspective, environmental noise is assessed in terms of its potential to cause annoyance.
- In the assessment of impacts on birds, criteria protecting birds against the effects of masking and other behavioural/physiological changes have been adopted.
- There are no distinguishing elements in significance of impacts associated with the location alternatives considered in the study.
- During the construction phase, impacts on human receptors and birdlife are considered 'Very Low'.

Proposed mitigation measures:

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

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

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

- All diesel powered equipment and vehicles must be regularly maintained and kept at a high level of maintenance. This must particularly include the regular inspection and, if necessary, replacement of intake and exhaust silencers. Any change in the noise emission characteristics of equipment must serve as trigger for withdrawing it for maintenance.

- To minimise noise generation, vendors must be required to guarantee optimised equipment design noise levels.
- Acoustic attenuation devices should be installed on all ventilation outlet and high pressure gas or liquid should not be ventilated directly to the atmosphere, but through an attenuation chamber or device.
- Vibrating equipment must be on vibration isolation mountings.
- The site layout should be designed in such a manner that the noisiest sections of the plant are at the centre of the site, using surrounding buildings as noise attenuation shields.
- A mechanism to monitor noise levels, record and respond to complaints and mitigate impacts should be developed.
- It is recommended that, as far is as feasible, noise generating activities be limited to day-time hours (considered to be between 07:00 and 22:00) since noise impacts are most significant during the night. This includes:
  - Limiting all construction activities to day-time hours;
  - Limiting truck and other vehicle activity to and from the Rössing Uranium desalination plant during the operational phase to day-time hours.

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

  In addition to shielding provided by the building for sources located indoors, an acoustic barrier should be considered on the perimeter of the Rössing Uranium desalination plant. This will provide additional shielding to residents at the correctional services accomodation and the Damara Tern area from operational activities. The effects of such a barrier (a boundary wall 1.5m higher than noise sources) on noise levels have been presented in Annexure D4 and are considered in all post-mitigation impact significance ratings, for all alternatives, presented above. With the implementation of an earthen berm, total night-time noise levels at the correctional services accomodation will reduce to within the night-time International Finance Corporation guideline and the increase in noise level above the baseline can be reduced from less than 3dBA to less than 1dBA (i.e. virtually undetectable). Noise levels at the Damara Tern area can also be reduced to less than 60dBA (the interim guideline proposed by Dooling and Popper, 2007) with the installation of a boundary wall/earthen berm.

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

  In general, road traffic noise is the combination of noise from individual vehicles in a traffic stream and is considered as a line source if the density of the traffic is high enough to distinguish it from a point source. The following general factors are considered the most significant with respect to road traffic noise generation:
- Traffic volumes i.e. average daily traffic.
- Average speed of traffic.
- Traffic composition i.e. percentage heavy vehicles.
- Road gradient.
- Road surface type and condition.
- Individual vehicle noise including:
  - Engine noise.
  - Transmission noise.

- Contact noise (the interaction of tyres and the road surface).
- Body, tray and load vibration.
- Aerodynamic noise.

- In managing transport noise specifically related to trucks, efforts should be directed at:
  - Minimizing individual vehicle engine, transmission and body noise/vibration. This is achieved through the implementation of an equipment maintenance program.
  - Minimize slopes by managing and planning road gradients to avoid the need for excessive acceleration/deceleration.
  - Maintain road surface regularly to avoid corrugations, potholes etc.
  - Avoid unnecessary idling times.
  - Minimizing the need for trucks/equipment to reverse. This will reduce the frequency at which disturbing but necessary reverse warnings will occur. Alternatives to the traditional reverse 'beeper' alarm such as a 'self-adjusting' or 'smart' alarm could be considered. These alarms include a mechanism to detect the local noise level and automatically adjust the output of the alarm is so that it is 5 to 10dB above the noise level in the vicinity of the moving equipment. The promotional material for some smart alarms does state that the ability to adjust the level of the alarm is of advantage to those sites 'with low ambient noise level'.

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

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

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

7.7.5 Operations phase

The operational phase will include the following sources of noise:

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

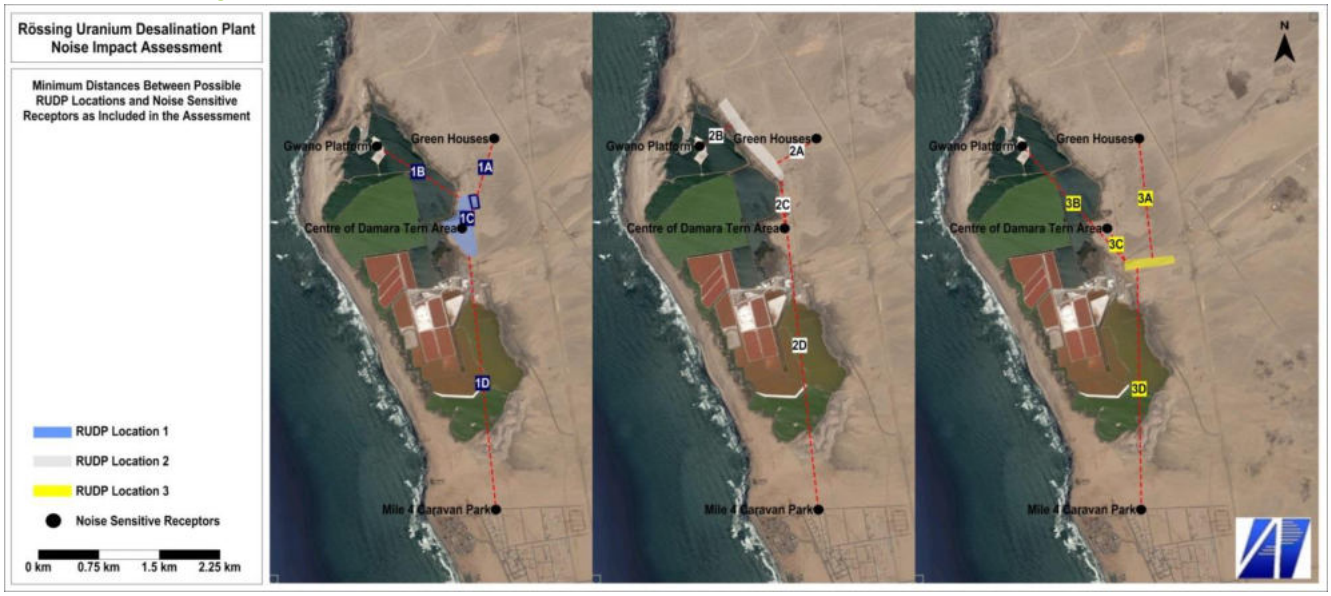
It was assumed that operational activities would occur continually over 24 hours of the day.

It is important to note that this study considers the potential impact that noise will have on humans and secondly on birds, as the salt pans are an important bird area. The noise sensitive receptors (NSR) are identified in Table 39 together with the distance, relative to the different project alternatives and shown in Figure 94 and include both the key human and bird sensitive receptors.

Table 39: Minimum distances between noise sensitive receptors and the RO Plant

Proposed Rössing Uranium desalination plant Situated Within:		Location 1 (Base Case)	Location 2 (Alternative 1)	Location 3 (Alternative 2)
Minimum Direct Distance to NSR	Correctional services accomodation	767 m (Figure 94, 1A)	593 m (Figure 94, 2A)	1 593 m (Figure 94, 3A)
	Guano Platform	1 187 m (Figure 94, 1B)	445 m (Figure 94, 2B)	1 849 m (Figure 94, 3B)
	Damara Tern Breeding Area (Centre)	271 m (Figure 94, 1C)	639 m (Figure 94, 2C)	515 m (Figure 94, 3C)
	Mile 4 Caravan Park/Northern Suburbs of Swakopmund	3 327 m (Figure 94, 1D)	4 334 m (Figure 94, 2D)	3 145 m (Figure 94, 3D)

Figure 94: Minimum distances between to noise sensitive receptors and RO Plant



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

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

In the equation, sound power levels (L_W) are the overall sound power level in dB and kW is the power rating of the vehicle's engine. In practice the sound power level will average about 4dB lower than the calculated level since engines are not always operated in the maximum power condition. Octave band sound power levels were obtained by applying adjustments recommended by Crocker (1998). Calculated sound power levels are given in Table 40.

Table 40: Sound power levels 's of diesel mobile equipment

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

Notes:

(a) Assumed

Plant Equipment: A list of plant equipment and sound pressure levels (L_P) at 1 m was supplied by the engineers (Table 41). The list also indicated which sources would be located within the plant

building. The octave band sound power level of plant equipment (estimated from adjustments recommended by Crocker (2008)) is also given in Table 41.

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

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

Table 41: Sound power levels 's for plant equipment

Operational Area[a]	Item Description[a]	Qty. [a]	Located inside or outside of building? [a]	L_P (dB) at 1 m[a]	Octave Band Sound Power Levels L_{Wi} (dB) [b]							L_{WA} (dBA) [b]
					63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	
Sea Water Intakes	Pumps	2	Out	75	74.0	75.0	77.0	77.0	80.0	77.0	73.0	83.5
	Feed Pump to Plant	2	Out	75	74.0	75.0	77.0	77.0	80.0	77.0	73.0	83.5
	Filter Pump	2	In	75	74.0	75.0	77.0	77.0	80.0	77.0	73.0	83.5
Pre-treatment	Aeration system / compressor	2	Out	95 - 100	96.7	99.0	99.5	99.1	101.5	105.2	102.2	109.3
	Recirculation pump	2	Out	75	74.0	75.0	77.0	77.0	80.0	77.0	73.0	83.5
	Mixers and scrapers	2	Out	50	48.8	51.6	52.9	55.0	53.3	50.8	45.0	57.7
Media Filters	Blower	2	In	90 – 95	93.8	96.6	97.9	100.0	98.3	95.8	90.0	102.7
	Backwash Pump	2	In	75	74.0	75.0	77.0	77.0	80.0	77.0	73.0	83.5
RO Trains	RO Units including HP Pump	4	In	85	87.0	88.0	90.0	90.0	93.0	90.0	86.0	96.5
	Energy Recovery Unit	4	In	90 - 95	96.8	99.6	100.9	103.0	101.3	98.8	93.1	105.7
	Compressor and ancillary equipment	2	In	95 - 100	96.7	99.0	99.5	99.1	101.5	105.2	102.2	109.3
RO and Chemical Dosing	CIP Pumps	3	In	65	65.8	66.8	68.8	68.8	71.8	68.8	64.8	75.3
	Dosing Pumps	6	In	65	68.8	69.8	71.8	71.8	74.8	71.8	67.8	78.3
Product Water System	Product Pump	2	In	85	84.0	85.0	87.0	87.0	90.0	87.0	83.0	93.5
Chemical Dosing and Effluent Handling	Dosing Pumps duty and standby	6	In	65	68.8	69.8	71.8	71.8	74.8	71.8	67.8	78.3
	Waste Pump	2	In	75	74.0	75.0	77.0	77.0	80.0	77.0	73.0	83.5
	Mixers	1	In	50	45.8	48.6	49.9	52.0	50.2	47.8	42.0	54.7
Media Filters	Ventilation Fan	2	In	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Reverse Osmosis Trains	Cartridge Filter	4	no data (n/d)	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Product Water System	Remineralisation units (Limestone columns)	3	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d

Operational Area[a]	Item Description[a]	Qty.[a]	Located inside or outside of building?[a]	L_P (dB) at 1 m[a]	Octave Band Sound Power Levels L_{Wi} (dB)[b]							L_{WA} (dBA)[b]
					63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	
Product Water System	Chlorine System	1	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d

Notes:

(a) Supplied by Royal HaskoningDHV

(b) Calculated

Other more general noise sources, not specifically identified or noted, were estimated over an area wide basis by applying the EC WG-AEN sound power levels rating of 60 dBA/m^2 for light industrial activities (EC WG-AEN, 2003). The footprint area of the proposed Rössing Uranium desalination plant was estimated at approximately 7,700m^2. Octave band sound power levels for general light industrial activities during the operational phase are provided in Table 42.

Table 42: Sound power levels of general light industrial activities during the operational phase

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

From simulations for the operational phase the following was found:

- The International Finance Corporation day-time guideline of 55dBA is exceeded over 400 m from the Rössing Uranium desalination plant whereas exceedance of the International Finance Corporation night-time guideline of 45dBA is expected up to 1.8km downwind.
- The increase in noise levels above the baseline reduces to less than 3dBA within 700m during the day and 1.2km during the night.
- The Dooling and Popper interim guideline of 60dBA for birds adopted in this study is exceeded 250m from the Rössing Uranium desalination plant during the day and 300m during the night.
- From the assessment of 'worst case' impacts at community noise sensitive receptors at minimum distances from location alternatives considered the following was found:
  - Residents of the correctional services accomodation may be exposed to noise levels in excess of only the night-time International Finance Corporation guideline should the Rössing Uranium desalination plant be located within Location 1, 2 or 3. The increase above the baseline at these houses is however expected to be notable when the facility is sited within Location 1 and 2. According to SANS 10103 (2008) sporadic complaints with little community reaction can be expected.
  - The proposed Rössing Uranium desalination plant is not expected to have any effect on environmental noise levels at the Mile 4 Caravan Park or northern Suburbs of Swakopmund.

- From the assessment of 'worst case' impacts at the Damara Tern and Guano Platform areas, it was found that the Dooling and Popper interim guideline of 60dBA will be exceeded at the Damara Tern area during the night when the Rössing Uranium desalination plant is situated within Location 1.
- Total day- and night time noise levels associated with the Rössing Uranium desalination plant situated within the preferred area of Location 1 are presented below. The increase over the day- and night-time baseline of 49dBA and 44dBA respectively are presented Figure 98. It should be noted that these isopleths are representative of an hour during which the wind is from the north. Winds from the north occur 12 to 15% of the hours within a year.

Figure 95: Isopleths of day-time LAeq (1 hr) during the operational phase

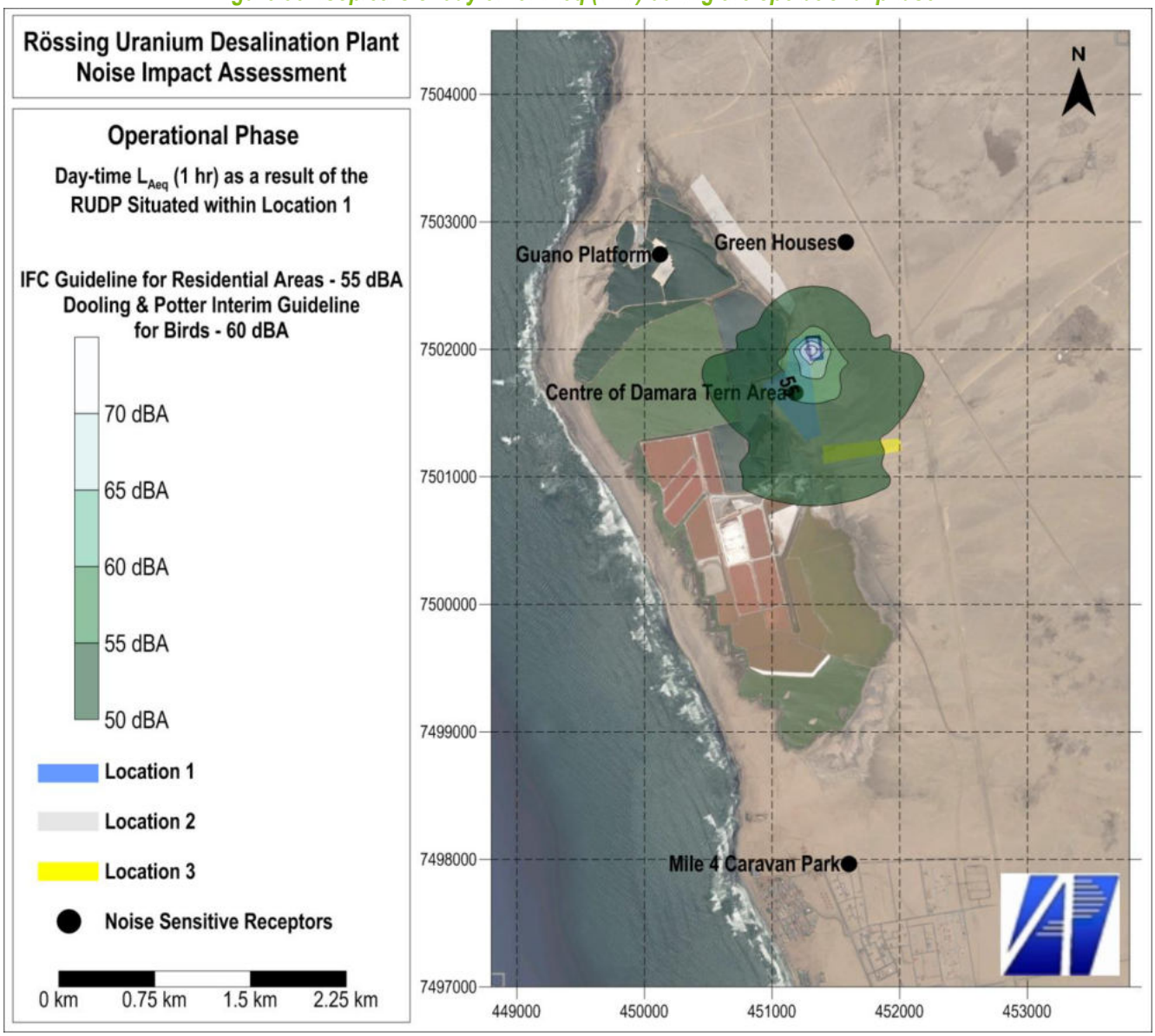


Figure 96: Isopleths of the increase in day-time LAeq (1 hr) during the operational phase

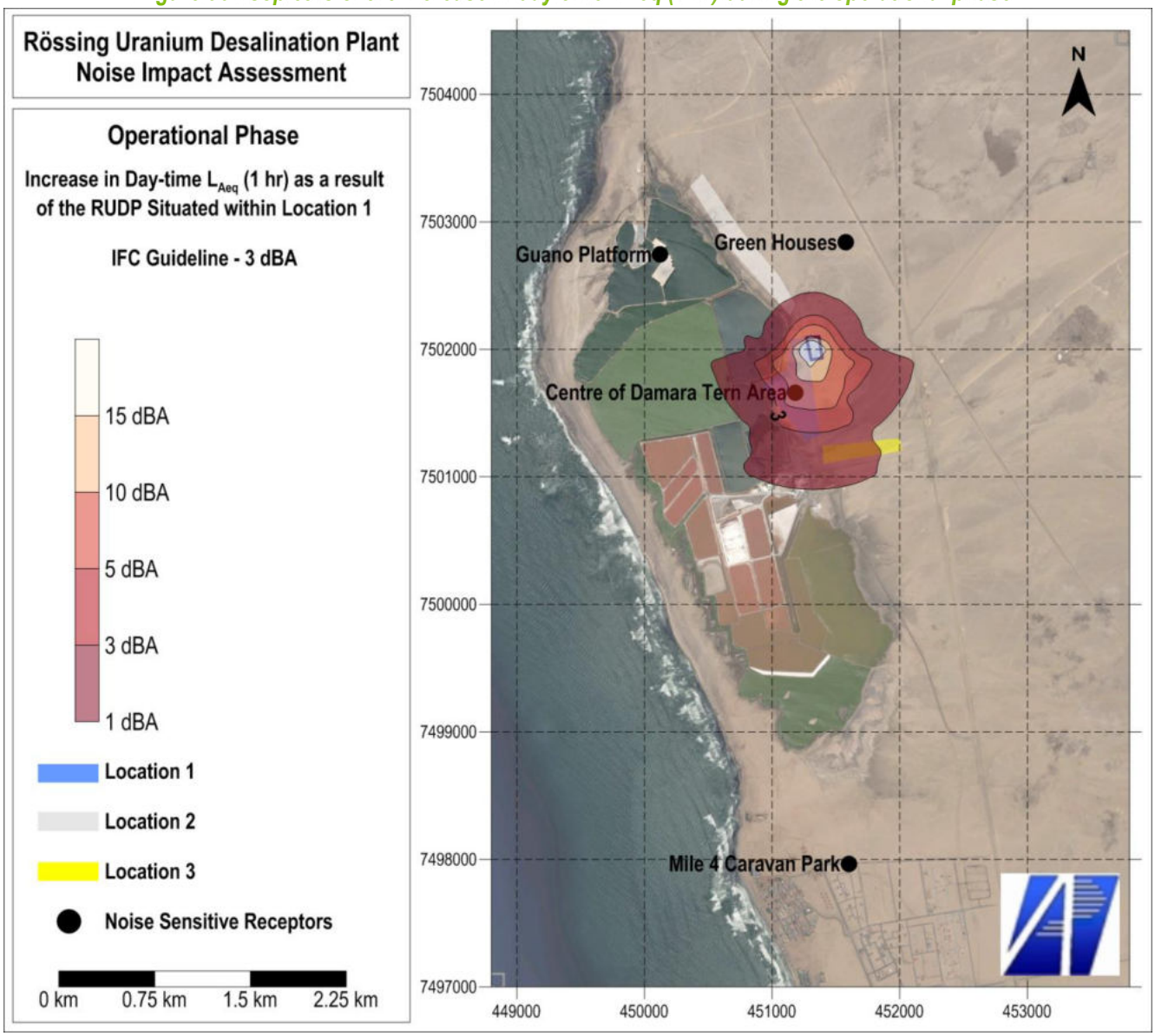


Figure 97: Isopleths of night-time L_{Aeq} (1 hr) during the operational phase

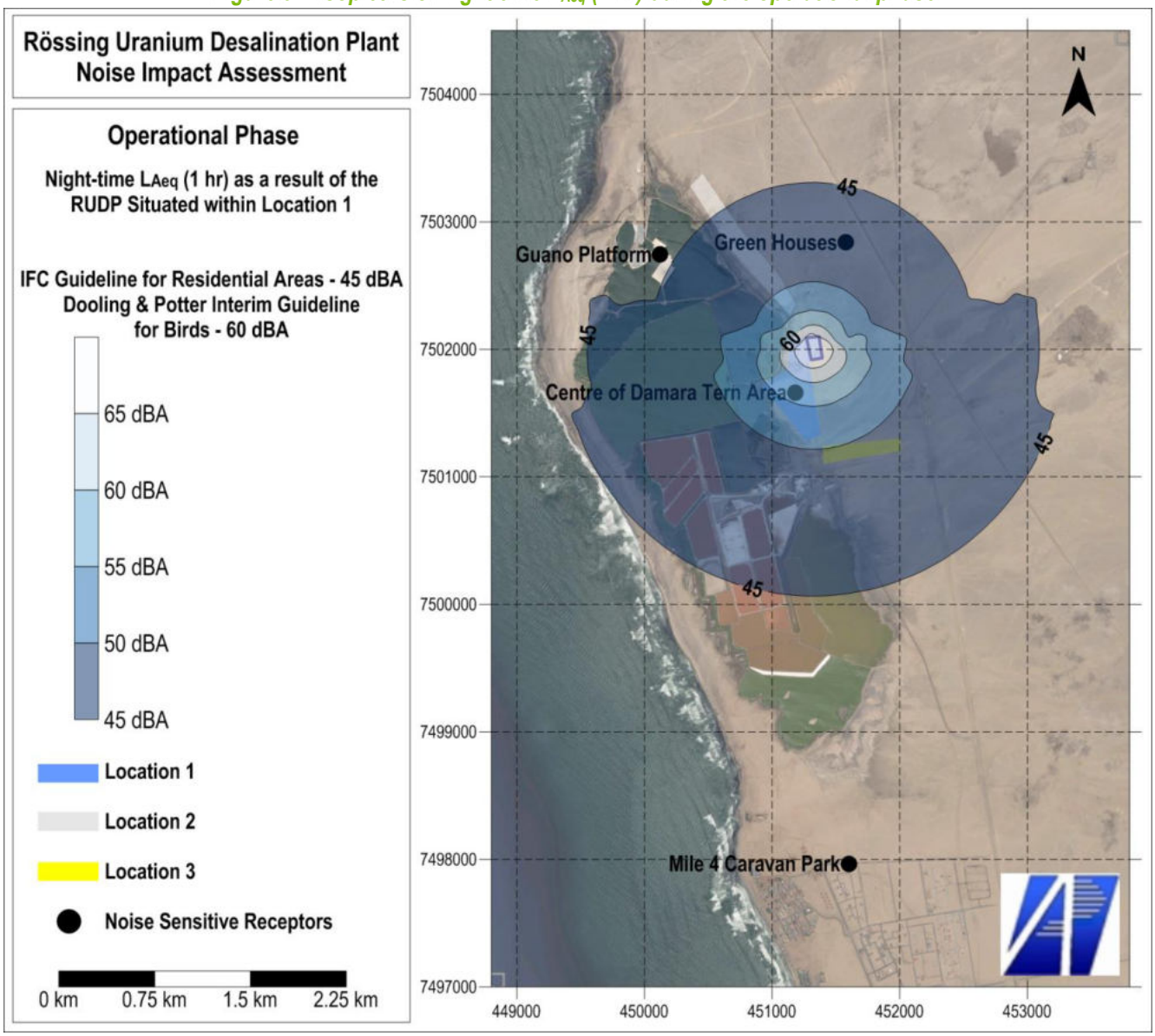
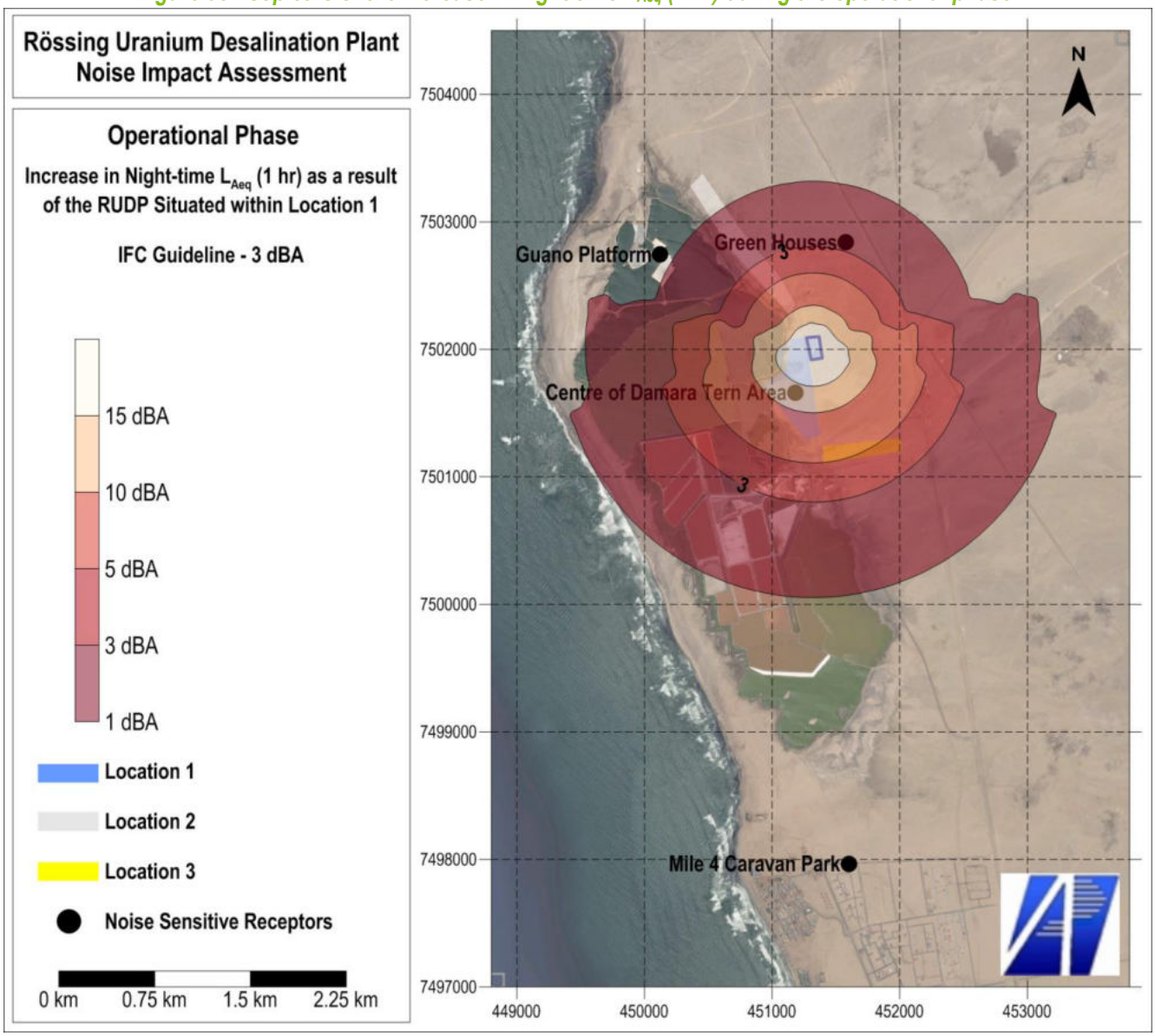


Figure 98: Isopleths of the increase in night-time L_{Aeq} (1 hr) during the operational phase



7.7.5.1 Operations phase noise impacts

IMPACT DESCRIPTION:

The potential for operations phase noise to cause annoyance or disturbance to human activities or disrupt bird in and around the study area.

IMPACT ASSESSMENT: NOISE IMPACTS ON BIRDS

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	~
Extent	Local	Local	Local	Local	Local	~
Magnitude	Very low	Very low	Very low	Very low	Very low	~
Duration	Short term	Short term	Short term	Short term	Short term	~
SIGNIFICANCE	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
Probability	Probable	Probable	Probable	Probable	Probable	Definite
Confidence	Unsure	Unsure	Unsure	Unsure	Unsure	Certain
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	~

IMPACT ASSESSMENT: NOISE IMPACTS ON HUMANS

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	~
Extent	Site specific	Site specific	Site specific	Site specific	Site specific	~
Magnitude	Low	Very low	Very low	Very low	Very low	~
Duration	Long term	Long term	Long term	Long term	Long term	~
SIGNIFICANCE	Low (-)	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
Probability	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Definite
Confidence	Sure	Sure	Sure	Sure	Sure	Certain
Reversibility	Irreversible	Irreversible	Irreversible	Irreversible	Irreversible	~

Notes:

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

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

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

(d) More than 10 years.

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

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

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

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

In the interpretation of noise impact significance, the following should be noted:

- From a human perspective, environmental noise is assessed in terms its potential to cause annoyance.
- In the assessment of impacts on birds, criteria protecting birds against the effects of masking and other behavioral/physiological changes have been adopted.
- There are no distinguishing elements in significance of impacts associated with the location alternatives considered in the study.
- With the installation of a boundary wall to act as an acoustic barrier, the significance of impacts on human receptors and birdlife during the operational phase will reduce from ‘Low’ to ‘Very Low’

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

Proposed mitigation measures:

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

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

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

- All diesel powered equipment and vehicles must be regularly maintained and kept at a high level of maintenance. This must particularly include the regular inspection and, if necessary, replacement of intake and exhaust silencers. Any change in the noise emission characteristics of equipment must serve as trigger for withdrawing it for maintenance.
- To minimise noise generation, vendors must be required to guarantee optimised equipment design noise levels.
- Acoustic attenuation devices should be installed on all ventilation outlet and high pressure gas or liquid should not be ventilated directly to the atmosphere, but through an attenuation chamber or device.
- Vibrating equipment must be on vibration isolation mountings.
- The site layout should be designed in such a manner that the noisiest sections of the plant are at the centre of the site, using surrounding buildings as noise attenuation shields.
- A mechanism to monitor noise levels, record and respond to complaints and mitigate impacts should be developed.
- It is recommended that, as far is as feasible, noise generating activities be limited to day-time hours (considered to be between 07:00 and 22:00) since noise impacts are most significant during the night. This includes:
  - Limiting all construction activities to day-time hours;
  - Limiting truck and other vehicle activity to and from the Rössing Uranium desalination plant during the operational phase to day-time hours.

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

  In addition to shielding provided by the building for sources located indoors, an acoustic barrier should be considered on the perimeter of the Rössing Uranium desalination plant. This will provide additional shielding to residents at the correctional services accomodation and the Damara Tern area from operational activities. The effects of such a barrier (a boundary wall 1.5m higher than noise sources) on noise levels are presented.

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

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

  In general, road traffic noise is the combination of noise from individual vehicles in a traffic stream and is considered as a line source if the density of the traffic is high enough to distinguish it from a point source. The following general factors are considered the most significant with respect to road traffic noise generation:
- Traffic volumes i.e. average daily traffic.
- Average speed of traffic.
- Traffic composition i.e. percentage heavy vehicles.
- Road gradient.
- Road surface type and condition.

- Individual vehicle noise including:
  - Engine noise.
  - Transmission noise.
  - Contact noise (the interaction of tyres and the road surface).
  - Body, tray and load vibration.
  - Aerodynamic noise

- In managing transport noise specifically related to trucks, efforts should be directed at:
  - Minimizing individual vehicle engine, transmission and body noise/vibration. This is achieved through the implementation of an equipment maintenance program.
  - Minimize slopes by managing and planning road gradients to avoid the need for excessive acceleration/deceleration.
  - Maintain road surface regularly to avoid corrugations, potholes etc.
  - Avoid unnecessary idling times.
  - Minimizing the need for trucks/equipment to reverse. This will reduce the frequency at which disturbing but necessary reverse warnings will occur. Alternatives to the traditional reverse 'beeper' alarm such as a 'self-adjusting' or 'smart' alarm could be considered. These alarms include a mechanism to detect the local noise level and automatically adjust the output of the alarm is so that it is 5 to 10dB above the noise level in the vicinity of the moving equipment. The promotional material for some smart alarms does state that the ability to adjust the level of the alarm is of advantage to those sites 'with low ambient noise level'.

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

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

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

7.7.6 Decommissioning phase

7.7.6.1 Decommissioning phase noise impact

IMPACT DESCRIPTION:

The following Noise impact associated with the decommissioning phase was not undertaken by the specialist. The EAP has provided these values based on the impact assessment notes provided by the specialist below. The impact assessment for decommissioning phase is assessed as being the same as for the construction phase as this will involve similar processes but may of shorter duration.

IMPACT ASSESSMENT: BIRDS AND HUMANS

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	~
Extent	Local	Local	Local	Local	Local	~
Magnitude	Very low	Very low	Very low	Very low	Very low	~
Duration	Short term	Short term	Short term	Short term	Short term	~
SIGNIFICANCE	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
Probability	Probable	Probable	Probable	Probable	Probable	Definite
Confidence	Sure	Sure	Sure	Sure	Sure	Certain
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	~

In the interpretation of noise impact significance, the following should be noted:

- From a human perspective, environmental noise is assessed in terms its potential to cause annoyance.
- In the assessment of impacts on birds, criteria protecting birds against the effects of masking and other behavioral/physiological changes have been adopted.
- There are no distinguishing elements in significance of impacts associated with the location alternatives considered in the study.
- The impact significance associated with the decommissioning phase will be similar or less than what was quantified for the construction phase, depending on potential changes to the ambient noise levels over the life of the project and the possible growth of residential areas closer to the facility.

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

Proposed mitigation measures:

- Refer to the mitigation measures contained under the construction phase.

7.7.7 Cumulative impacts

The findings from the noise impact assessment, presented in sections 7.7.4 and 7.7.5, were calculated both in terms of the ambient noise levels as a result of the proposed desalination plant incrementally, as well as the effective increase in ambient noise levels over the baseline i.e. cumulative assessment.

7.8 AVIFAUNA IMPACTS

The following subsection is a modified summary compiled using the impact assessment on birds undertaken by African Conservation Services CC. The original report is attached here as Annexure D5 and can be referred to for added detail in understanding the impacts on avifauna and the methodologies employed in assessing their significance.

Mile 4 Salt Works is registered as an Important Bird Area (IBA). Of the 233 bird species recorded for the broad study area, 11% are classed as Threatened in Namibia; 3% are also Globally Threatened. 18% species are endemic/near-endemic, with seven species classified as endemic or near-endemic to Namibia. 64% are resident, 34% are nomadic at times, and 31% are considered migrant at times.

Therefore, the Mile 4 Salt Works can thus be categorised as an area of high sensitivity of regional and global importance. Consequently, bird protection must form an important consideration for this proposed desalination project.

Although many of the bird species recorded in the study area could potentially be at risk from the proposed development, it is important to direct risk assessments and mitigation towards species that have high biological significance. These species fall mainly into the aquatic category and include the identified Red Data species, as well as endemic/near-endemic species and those that are nomadic or migrant at times.

Species identified as being at high risk from the proposed development include:

- Damara Tern (Near Threatened, Globally Near Threatened), threatened by disturbance in breeding habitat, destruction of breeding habitat;
- Lesser Flamingo (Vulnerable, Globally Threatened), threatened by power line collisions; and
- Greater Flamingo (Vulnerable), also threatened by power line collisions.

Species identified as being at moderate risk include:

- Cape Cormorant (Near Threatened, Globally Threatened), threatened by potential noise disturbance in breeding/ roosting habitat;
- Great White Pelican (Vulnerable), prone to power line collisions; and
- Black-necked Grebe (Near Threatened), prone to power line collisions.

The main predicted impacts that have to be assessed as a result of the proposed project are:

- Destruction/modification of bird habitat during the construction phase;
- Physical disturbance of (breeding) birds, including movement, noise and light disturbance during all project phases (i.e. construction, operations and decommissioning); and
- Collisions and electrocutions of birds on power line structures during operations.

7.8.1 Construction phase

7.8.1.1 Destruction/modification of Damara Tern breeding habitat

IMPACT DESCRIPTION:

With reference to section 5.3.2 of this SEIA report and the overview of impacts at the start of the avifauna impacts subsection, the Damara Tern is a breeding endemic seabird, globally Near Threatened and also Near Threatened in Namibia. Recent (conservative) estimate places the entire breeding population at a minimum of only 900 pairs.

Long term monitoring data indicate the regular use of the area proposed for the (Base Case pre-mitigation) desalination plant by 10-20 breeding pairs. This amounts to 0.4-2.0% of the global population of 1,001-2,685 breeding pairs.

The central portion of the Base Case site location (site option1) is regarded as highly sensitive by way of being a core, established breeding site for the Damara Tern (see Figure 31). The Base Case (pre-mitigation) layout has the desalination plant positioned centrally within this core breeding area. Habitat destruction could result in reduced breeding success or in the Damara Terns abandoning this breeding site, probably permanently. If they move to alternative breeding sites, their chances of breeding success would be reduced. Damara Tern breeding habitats are under threat elsewhere from development and human disturbance, and any further losses should be avoided.

The most important management approach for the population viability for seabirds such as the Damara Tern, which display high rates of site fidelity, may be long-term maintenance and protection of current colony sites.

Taking the above into consideration this impact assessment focusses on the potential significance of loss or modification of breeding habitat that may arise due to the activities associated with construction of the proposed desalination plant and associated infrastructure. This impact is driven primarily by location and the extent of the project footprint in relation to the known core Damara Tern breeding area and to other secondary Damara Tern breeding areas. This disturbance associated with the construction phase activities could impact on the Damara Tern breeding habitat, and the impact duration could extend beyond the construction term.

IMPACT ASSESSMENT: DESTRUCTION/MODIFICATION OF DAMARA TERN BREEDING HABITAT

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	
Extent	Local	Local	Local	Local	Local	~
Magnitude	High	Low	Very low	Low	Low	~
Duration	Long term	Long term	Long term	Long term	Long term	~
SIGNIFICANCE	High (-)	Low (-)	Very low (-)	Low (-)	Low (-)	Neutral
Probability	Definite	Probable	Probable	Probable	Probable	Definite
Confidence	Certain	Sure	Sure	Sure	Sure	Certain
Reversibility	Irreversible	Irreversible	Irreversible	Irreversible	Irreversible	~

Base Case: The significance of this impact is High (-) for the Base Case site (pre-mitigation) as this site coincides with an established core breeding site of the Damara Tern. The levels of physical disturbance and habitat destruction resulting from the selection of the central areas of this site for the proposed development are regarded as being incompatible with the breeding requirements for this species. The impact includes the habitat destruction caused by site levelling, burying of pipelines and of power cables (at least between the plant and the C34 road) and construction of intake/buffer ponds.

The significance of this impact is Low (-) for the mitigated Base Case site, as the site lies within or near secondary breeding areas for Damara Terns.

Alternative 1: The significance is Very Low (-) for site Alternative 1 as this is not known to be a Damara Tern breeding area.

Alternative 2: The significance is Low (-) for Alternative 2, as the still lies within or near secondary breeding areas for Damara Terns.

Alternative 3: The alternative of an overhead power line would have no effect, given that the section between the plant and the C34 would in any case be buried. This impact is therefore similar to the Base Case – post mitigation alternative.

No go Alternative: The No-Go alternative would have a neutral impact.

PROPOSED MITIGATION MEASURES:

- The Base Case site (i.e. centre of area No. 1) coincides with an established core breeding habitat for the Damara Terns, and should therefore be avoided and designated as a No-Go area at all times, with zero further habitat destruction;

- The plant should be shifted to a position as far as possible from the known breeding areas: in the case of the Base Case site (post-mitigation), the plant should be shifted to the furthest north / north-eastern extent of the area;
- To avoid disturbance of the Damara Tern breeding site it is also recommended that the alternative (northern) brine outfall be pursued, as this will reduce the disturbances to the core breeding area;
- Any construction activity located in or close to the Damara Tern breeding site should be scheduled to avoid taking place during the breeding months of October to April. This applies to the desalination plant and may apply to the upgrading of the intake channel, the construction of the intake/buffer pond and the intake pipeline from pond to plant;
- The plant and associated facilities (buffer pond; and pipelines, electrical cables and roads) should be designed and laid out to be compact and utilise the smallest possible footprint;
- Linear features (such as pipelines, electrical cables and roads) should share the same (existing) route wherever possible and should follow a route that avoids the known breeding areas as far as possible; and
- Construction staff should be made aware of the breeding area during awareness training and this area must be treated as a No-Go area during construction. Strict supervision and control must be exercised to keep people and plant out of this area, especially during the tern breeding months.

7.8.1.2 Destruction/modification of habitat of other birds

IMPACT DESCRIPTION:

With reference to section 5.3.2 of this SEIA report and the overview of impacts at the start of the avifauna impacts subsection, other species of concern that might be impacted as a result of destruction/modification of their habitat due to the proposed construction activities, include the following:

- Chestnut-banded Plover (Near Threatened) and White-fronted Plover:
- Gray's Lark (a Namibian near-endemic); and
- Red-capped Lark.

The levelling of the plant site will cause irreversible habitat damage to a limited area (maximum 100 x 100m). Minor habitat disturbances will occur with the trenching and backfilling required for burying linear infrastructure, e.g. the power line cable in the section between the plant and the C34 road, but from then on the line will run along an existing, already disturbed servitude. The pipeline construction between the plant and the C34 road could likewise have a limited, temporary impact on the habitat of both aquatic and terrestrial bird species in the area. The construction of both the plant and the buffer pond may be designed to incorporate existing borrow pits, which would minimise the destruction of undisturbed habitat.

Changes to the existing surface water structures in the area (e.g. the use of buffer ponds next to the desalination plant) may also impact on local faunal residents and migrants. Birds may move away from these areas during construction/implementation, but if the habitat is suitable they could also move in afterwards. These impacts are considered of less importance, given that the salt pan habitat has already been modified and a variety of other habitats are nearby. Further impacts are associated with the construction of feed water intake and brine discharge structures into the marine environment, and desalination plant infrastructure extending into the sea.

IMPACT ASSESSMENT: DESTRUCTION/MODIFICATION OF HABITAT OF OTHER BIRDS

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	~
Extent	Local	Local	Local	Local	Local	~
Magnitude	High	Low	Low	Low	Low	~
Duration	Long term	Long term	Long term	Long term	Long term	~
SIGNIFICANCE	Low (-)	Low (-)	Low (-)	Low (-)	Low (-)	Neutral
Probability	Definite	Probable	Probable	Probable	Probable	Definite
Confidence	Certain	Sure	Sure	Sure	Sure	Certain
Reversibility	Irreversible	Irreversible	Irreversible	Irreversible	Irreversible	~

Base Case: The Chestnut-banded Plover uses mainly the saltpan area south of the Swakopmund Salt Works and is therefore not considered at risk by the proposed development. This species as well as the White-fronted Plover do however use both the pre- and post-mitigation Base Case sites. The significance of this impact is assessed as Low (-) for both the Base Case layout (pre-mitigation) and post-mitigation sites.

The Base Case (post mitigation site) will however see construction activities such as the preparation of the site for the plant and the burial of the electric cables and pipelines will cause limited local habitat destruction in an area that is relatively less important for birds. The buffer pond will most likely be sited in an existing borrow pit or within the existing oyster pond. The plant may also be constructed in an existing borrow pit.

Alternative 1: The significance is Low (-) for site Alternative 1; a new buffer pond will be constructed. The above construction activities will cause limited local habitat destruction in an area that is relatively less important for birds.

Alternative 2: The significance is also Low (-) for site Alternative 2; the buffer pond will be sited in an existing pond that will be modified. The above construction activities will cause limited local habitat destruction in an area that is relatively less important for birds.

Alternative 3: The alternative of an overhead power line would have no effect, given that the section between the plant and the C34 would in any case be buried. This impact is therefore similar to the Base Case – post mitigation alternative.

No go Alternative: The No-Go alternative would have a neutral impact.

PROPOSED MITIGATION MEASURES:

- Construction activities should be restricted to the demarcated footprint;
- Roads, pipelines, cables should share servitudes as far as possible, and be routed to avoid the core bird breeding areas;
- Approved access and service roads should be demarcated in collaboration with the owners to ensure that vehicles are kept on the designated routes, and no off-road driving should be permitted;
- All modified areas should be rehabilitated to an acceptable level after the disturbance; and
- Ongoing awareness training should be promoted amongst staff about the negative impacts and undesirability of habitat destruction, especially to breeding birds.

7.8.1.3 Physical disturbance to breeding birds, especially Damara Terns

IMPACT DESCRIPTION:

This impact assesses the potential significance of physical disturbance (including human-induced light and noise) on breeding birds, especially Damara Terns.

Physical disturbance: Increased activities involving people and vehicles/machinery in the area during the construction of both the desalination plant and the associated infrastructure may result in disturbance of breeding, foraging, and roosting birds.

In particular, the desalination plant (i.e. Base Case site – pre-mitigation) coincides with an established core breeding site for the Damara Terns. Some 10 to 20 pairs regularly breed in this area and are likely to move away, possibly permanently, should disturbance increase. Damara Terns are increasingly under pressure in other parts of the coast, due to recreational disturbance and development and any further loss of breeding effort should be avoided.

Other breeding birds in the area could also be affected by these construction disturbances, although to a lesser extent, e.g. cormorants, Chestnut-banded Plover, White-fronted Plover, Caspian Tern, and Swift Tern.

Light: The presence of artificial lights has the potential to affect birds in various ways, particularly if unshielded:

- by providing more feeding time by allowing nocturnal feeding;
- by causing disorientation or direct mortality; and
- by causing birds roosting or nesting on the ground to cast a shadow, making it easier for terrestrial predators to see them and thereby potentially increasing predation, although lighting also makes it easier for birds to see predators.

The impacts of light will be minimal during the construction phase, as most of the activity will take place by day, although emergency night-time construction activity may be required (e.g. a late concrete pouring); and security lights are likely to be used on the construction site.

The impacts of light on birds are discussed further under the operations section, as this is when the main impacts are expected to occur.

Noise: The impacts of noise on birds are dealt with under section 7.7.4.1(noise impacts).

IMPACT ASSESSMENT: PHYSICAL DISTURBANCE TO BREEDING BIRDS, ESPECIALLY DAMARA TERNS

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	~
Extent	Local	Local	Local	Local	Local	~
Magnitude	High	Low	Very low	Low	Low	~
Duration	Long term	Short term	Short term	Short term	Short term	~
SIGNIFICANCE	High (-)	Low (-)	Very low (-)	Low (-)	Low (-)	Neutral
Probability	Definite	Probable	Probable	Probable	Probable	Definite
Confidence	Certain	Sure	Sure	Sure	Sure	Certain
Reversibility	Irreversible	Irreversible	Irreversible	Irreversible	Irreversible	~

Base Case: The significance of this impact is High (-) for the Base Case site (pre-mitigation) as it coincides with an established core breeding site of the Damara Tern, a threatened species. The levels of physical disturbance resulting from the selection of this site for the proposed development

are regarded as being incompatible with the breeding requirements for this species. If the birds leave the site due to disturbance, it is not likely that they will return; nor would they be as successful if they were to move to another (established) breeding site. The site has already been threatened by some potential physical disturbance during the exploratory stages of the project, had the terns been nesting in the area. Any further physical disturbance in the core Damara Tern breeding sites would be viewed as an unacceptably high impact, hence the importance of site selection.

The significance is Low (-) for the Base Case site (post-mitigation) as it lies further than the core breeding site, but still within or near secondary breeding areas for Damara Terns.

Alternative 1: The significance is Very Low (-) for site Alternative 1 (Plant site 2) as this is not a Damara Tern breeding area.

Alternative 2: The significance is also Low (-) for site Alternative 2 (Plant site 3), as it lies near secondary breeding areas for Damara Terns.

Alternative 3: The alternative of an overhead power line would have no effect, given that the section between the plant and the C34 would in any case be buried. This impact is therefore similar to the Base Case – post mitigation alternative.

No go Alternative: The No-Go alternative would have a neutral impact.

Proposed mitigation measures:

Physical disturbance

- Construction activities such as earth-moving and the laying of pipelines and cable, and the construction of the buffer pond, should be zoned in time outside the main Damara Tern breeding season, which is October-April. Even outside these times, excessive and unnecessary noise disturbance should be avoided;
- The construction of an earth berm/wall of 1.8 - 2.0m high around the facility could be investigated, which would contribute to the reduction of physical disturbance associated with movement and construction activity;
- Only designated and demarcated access and service roads should be used, and strict control and supervision is required to prevent off-road driving; and
- Ongoing awareness training should be promoted amongst staff about the negative impacts and undesirability of disturbance, especially to breeding birds.

Noise

- Laying of pipe, road construction and other activities on ancillary infrastructures located in or near the Damara Tern breeding area should be programmed to occur outside the breeding period from October to April;
- Further recommendations regarding noise controls by the noise specialist study should be applied.

Light

- Construction activity should be restricted to daylight hours and where emergency night-time construction activity (i.e. a late concrete pour) is required, careful attention shall be given to ensuring that lighting is task specific and does not result in the excessive light spill or flood lighting of vast areas.

- Outside lighting of the facility (including security lighting) must be kept to the minimum. Where required, all overhead lighting should be shaded and pointed downwards onto the area where illumination is needed, rather than directed upwards or outwards, in order to avoid light pollution. The guidelines laid down by the International Dark-Sky Association for the quality of outdoor lighting (including light design, wattage and light colour [preferably amber]) should be followed for preserving and protecting the night-time environment, including its wildlife (www.darksky.org);
- Construction plant and equipment should avoid using the bright headlight setting on their vehicles whilst driving through the Damara Tern breeding area. Similarly, construction vehicles should avoid the use of bright roof-mounted flashing lights (as is typical for construction sites); this becomes more critical during breeding season, although construction activities should be scheduled outside this period if possible.

7.8.2 Operations phase

7.8.2.1 Physical disturbance to breeding birds, especially Damara Terns

IMPACT DESCRIPTION:

This impact assesses the potential significance of physical disturbance (including human-induced light and noise) on breeding birds, especially Damara Terns during the operations phase.

Physical disturbance: Operations activities involving people and vehicles/machinery in the area may result in disturbance of breeding, foraging, and roosting birds.

Similarly to the construction phase, activities associated with the operations phase associated with the Base Case site (pre-mitigation) for the desalination plant would likely result in Damara Terns moving away, possibly permanently, from this core breeding site.

Physical disturbance (in association with light and/or noise) also has the potential to result in nest abandonment by cormorants (Near Threatened, Globally Threatened), and a consequent increase in the risk of predation. Other breeding birds in the area could be affected, although to a lesser extent, e.g. Chestnut-banded Plover, White-fronted Plover, Caspian Tern, and Swift Tern.

Light: Concerns about the impacts of artificial light on birds are discussed under section 7.8.1.3.

Sources of artificial light are likely to increase with the new development at Swakopmund Salt Works. During the operations phases the site will be illuminated at night, both for work and security reasons.

Disorientation in night-flying birds, especially migrants, due to artificial light may result in erroneous navigation and enhancing the potential for (mass) collisions with overhead structures.

Artificial light can disturb breeding birds, and increase susceptibility to predation (e.g. by jackals), particularly when the birds are of the ground-nesting variety, such as the Damara Terns and their eggs and chicks.

Lights that point outward or upward could result in the above-mentioned impacts by spreading their effect more widely than required. It appears that intermittent (flashing) lighting may be less attractive to birds than continuous lighting, and that possibly red/amber light is less attractive than white light.

Noise: The impacts of noise on birds are dealt with under section 8.5 (noise impacts).

Habitat modification: Other issues and potential impacts in terms of marine pollution and ecology include altered flows at the intake and discharge resulting in ecological impacts; and potential for habitat health impacts/losses resulting from elevated salinity in the vicinity of the brine discharge.

Brine discharge could impact on marine habitats and their organisms, and indirectly on feeding marine birds, including oystercatchers and other coastal waders, flamingos, cormorants and penguins, as the salinity is higher than that of normal sea water. However, the effects of brine discharge on birds, or (indirectly) on their food items, are not considered a key issue as only a limited amount of the sea water area would be affected by the brine.

IMPACT ASSESSMENT: PHYSICAL DISTURBANCE TO BREEDING BIRDS, ESPECIALLY DAMARA TERNS

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	~
Extent	Local	Local	Local	Local	Local	~
Magnitude	High	Low	Very low	Low	Low	~
Duration	Long term	Short term	Short term	Short term	Short term	~
SIGNIFICANCE	High (-)	Low (-)	Very low (-)	Low (-)	Low (-)	Neutral
Probability	Definite	Probable	Probable	Probable	Probable	Definite
Confidence	Certain	Sure	Sure	Sure	Sure	Certain
Reversibility	Irreversible	Irreversible	Irreversible	Irreversible	Irreversible	~

The assessment findings are similar to the construction phase (refer to subsection 7.8.1.3).

Proposed mitigation measures:

Physical disturbance

- As far as possible, planned (annual) maintenance activities should be zoned in time outside the main Damara Tern breeding season, which is October to April. Even then, unnecessary noise disturbance should be avoided;
- Approved access and service roads should be demarcated in collaboration with the owners to ensure that vehicles are kept on the designated routes, and no off-road driving should be permitted;
- The construction of an earth berm/wall of 1.8 - 2.0m high around the facility could be investigated, which would contribute to the reduction of physical disturbance associated with movement; and
- Ongoing awareness training should be promoted amongst staff about the negative impacts and undesirability of disturbance, especially to breeding birds.

Noise

- Service doors should be kept closed at night to prevent the escape of noise into adjoining areas;
- The construction of an earth berm/wall of 1.8 - 2.0m high around the facility could be investigated, which would contribute to the reduction of noise pollution;
- Regular audits of operations noise levels should be conducted on an ongoing basis, according to the recommendations of the noise specialist study. If nest abandonment by the terns is observed that can be related to noise, measures should be taken to reduce that level of disturbance; and
- Further recommendations regarding noise controls by the noise specialist study should be applied.

Light

- Outside lighting of the facility must be kept to the minimum. Where required, all overhead lighting should be shaded and pointed downwards onto the area where illumination is needed, rather than directed upwards or outwards. The guidelines laid down by the International Dark-Sky Association for the quality of outdoor lighting (including light design, wattage and light colour [preferably amber]) should be followed for preserving and protecting the night-time environment, including its wildlife;
- Service doors, parking bays and windows in the facility should be designed to face away from the breeding and bird areas;
- The construction of an earth berm/wall of 1.8 - 2.0m high around the facility could be investigated, which would contribute to the reduction of light pollution;
- Plant operations and equipment should avoid using the bright headlight setting on their vehicles whilst driving through the Damara Tern breeding area. Similarly, construction vehicles should avoid the use of bright roof mounted flashing lights (as is typical for construction sites) at night. This becomes more critical during breeding season; and
- Regular audits of outside lighting fixtures should be undertaken in order to ensure that the guidelines laid down by the International Dark-Sky Association.

7.8.2.2 Physical disturbance to roosting/breeding cormorants

IMPACT DESCRIPTION:

This impact assesses the potential significance of physical disturbance (including human-induced light and noise) on breeding Cape Cormorants (refer to section 7.8.2.1 for more details on impacts from physical disturbance to breeding birds as well as section 7.7 for noise impacts on birds).

The guano platform at Mile 4 has supported up to 700,000 Cape Cormorants in the past. The effects of ongoing noise, etc. resulting from the operation of the desalination plant close to breeding cormorants could cause desertion of nests, resulting in increased predation and eventually a reduction in breeding success. Additionally, any reduction in the production of the existing guano industry would have negative economic implications (refer to subsection 7.4.1.2).

Although the cormorants have probably become accustomed to the vehicle and construction-type noises already on site, they are also out feeding for much of the day. A new source of ongoing operational noise at night in close proximity (when the cormorants come in to roost) could become disruptive to breeding activity or have other indirect ecological effects.

IMPACT ASSESSMENT: PHYSICAL DISTURBANCE TO ROOSTING/BREEDING CORMORANTS

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	~
Extent	Local	Local	Local	Local	Local	~
Magnitude	Very low	Very low	Low	Very low	Very low	~
Duration	Long term	Long term	Long term	Long term	Long term	~
SIGNIFICANCE	Very low (-)	Very low (-)	Low (-)	Very low (-)	Very low (-)	Neutral
Probability	Probable	Probable	Probable	Definite	Probable	Definite
Confidence	Sure	Sure	Sure	Certain	Sure	Certain
Reversibility	Irreversible	Irreversible	Irreversible	Irreversible	Irreversible	~

Base Case: The significance of this impact is Very Low (-) for the Base Case site (pre-mitigation) as it is some distance (minimum 1.3km) from the guano platforms.

The significance is still Very Low (-) for the Base Case site (post-mitigation) although it is slightly closer to the guano platforms.

Alternative 1: The significance is Low (-) for site Alternative 1 as it is relatively closer to the guano platforms (0.5km), and some disturbance is possible.

Alternative 2: The significance is also Very Low (-) for site Alternative 2, as it is the furthest (2km) from the guano platforms.

Alternative 3: The alternative of an overhead power line would have no effect, given that the section between the plant and the C34 would in any case be buried. This impact is therefore similar to the Base Case – post mitigation alternative.

Proposed mitigation measures:

Refer to 7.8.2.1 for recommended mitigation measures.

7.8.2.3 Collision of birds with power line structures

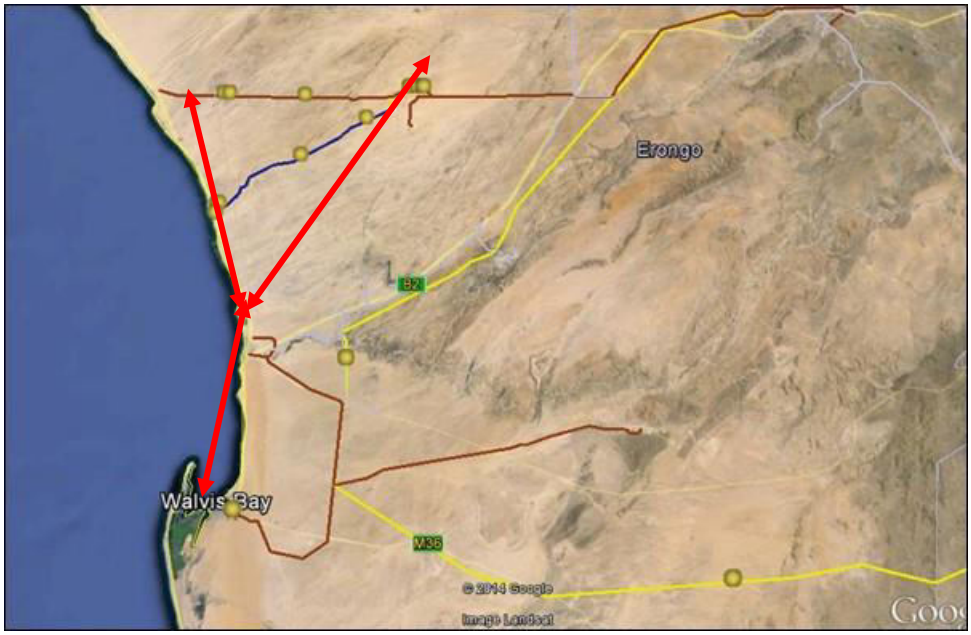
IMPACT DESCRIPTION:

A bird collision occurs when a bird in mid-flight does not see the overhead cables until it is too late to take evasive action. These impacts could take place on any parts of the power line, but are more likely in sections where the line crosses flight corridors such as drainage lines. Collisions may also take place on stay wires (e.g. on poles at bend points), for instance when a bird is flushed from its position on the ground.

Red Data bird species in the study area at risk from power line collisions include the Greater Flamingo, Lesser Flamingo, Black-necked Grebe, and Great White Pelican.

Flamingos are prone to collisions with overhead structures. This is in part due to their habit of flying low at times, in groups, and usually at night. The collision problem appears to be exacerbated by adverse weather conditions, including strong winds and fog, and by confusion caused by artificial light. Flamingo flight paths in the area are indicated by both satellite tracking (see Figure 99 below) and by collisions of the species on power lines in the area. The risk of further power line collisions with the construction of a new above-ground power line that intersects some of these flight paths is therefore considered high.

Figure 99: Recent flamingo collision incidents



The power line will cross flamingo flight paths, which greatly increases the risk of placing a new power line above ground in the vicinity of Mile 4. The continued life of the power line after the project is also a concern, in view of recorded impacts in terms of bird collisions and cumulative effects.

IMPACT ASSESSMENT: COLLISION OF BIRDS WITH POWER LINE STRUCTURES

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	~	~	~	~	Negative	~
Extent	~	~	~	~	Regional	~
Magnitude	~	~	~	~	Low	~
Duration	~	~	~	~	Long term	~
SIGNIFICANCE	Neutral	Neutral	Neutral	Neutral	Medium (-)	Neutral
Probability	Definite	Definite	Definite	Definite	Probable	Definite
Confidence	Certain	Certain	Certain	Certain	Sure	Certain
Reversibility	~	~	~	~	Irreversible	~

The significance of this impact will be High (-) for the alternative of an overhead power line (in the pre-mitigated scenario) in view of the high collision threat it would present in close proximity to a wetland area and its bird populations, although the section between the plant and the C34 road would be buried in both cases. Even though the significance of the impact would be reduced from High (-) to Medium (-) with mitigation (marking of the line), there is no truly effective way of preventing collisions other than burying the cable.

The impact is reversible if the line is removed at the end of the project duration; however, the long-term lifespan of the line beyond this period is a potential concern.

Where the underground cable is pursued there will be no impact and no need for mitigation. The No-Go alternative would also have a neutral impact.

Proposed mitigation measures associated with an overhead power line:

- The subsection linking the plant to the C34 road will be a buried cable and then the first 3.5 km of above-ground power line south of this intersection should be marked with bird flight diverters (BFDs; see below). Note that it is difficult to predict exactly where collision incidents would take place; and a truly effective method of marking power lines to mitigate for collisions is still being sought. NamPower should be consulted in terms of expertise with regard to the final design and fitting of mitigation devices. The following marking methods are currently available and could be used in combination:
  - Solar-powered light emitting diode (LED) bird flight diverter (BFD), an illuminated device incorporating a flashing light on the top and a moving flapper, that may assist in mitigating collisions of night-flying species such as flamingos;
  - Standard (double loop) bird flight diverters or a similar, smaller design have been shown to reduce collisions to some extent for diurnal species, and could be used in combination with the above device to reduce costs; and

- Ongoing monitoring is necessary (see below) to identify problem sites in terms of power line collisions; any incidents should be reported to the NamPower/NNF Strategic Partnership, which can offer advice and support. Should collisions start to occur repeatedly in any one unmarked area on the line, the relevant section(s) should be fitted with appropriate mitigation measures and should collisions still take place after mitigation, the marking methods would need to be re-assessed.

7.8.2.4 Bird electrocutions on power supply structures

IMPACT DESCRIPTION:

A bird electrocution occurs when a bird is perched or attempts to perch on an electrical structure and causes an electrical short circuit by physically bridging the air gap between live components and/or live and earthed components.

Electrocutions may take place when birds attempt to perch or nest on power line poles, transformers and substation structures (e.g. transformers, switchgears), and the risk is increased if birds are attracted to an open source of water nearby for bathing or drinking.

Bird species in the study area at risk from power line electrocutions include raptors such as owls; and Peregrine Falcon, African Fish-eagle and Lappet-faced Vulture in the general area; however, the likelihood is considered to be very low. Species such as cormorants may also perch on power line structures and become electrocuted.

Some birds, e.g. Pied Crow, have the potential to disrupt the power supply through their nesting activities. Crows may incorporate pieces of wire into their nesting material, which could result in short circuits. The potential of this impact is also considered very low in the study area.

IMPACT ASSESSMENT: BIRD ELECTROCUTIONS ON POWER SUPPLY STRUCTURES

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	~	~	~	~	Negative	~
Extent	~	~	~	~	Regional	~
Magnitude	~	~	~	~	Low	~
Duration	~	~	~	~	Long term	~
SIGNIFICANCE	Neutral	Neutral	Neutral	Neutral	Medium (-)	Neutral
Probability	Definite	Definite	Definite	Definite	Probable	Definite
Confidence	Certain	Certain	Certain	Certain	Sure	Certain
Reversibility	~	~	~	~	Irreversible	~

The presence of an overhead power line in the area would have a Medium (-) impact as it would increase the potential for electrocutions. There is little to be done in terms of mitigating this impact, until problem sites can be identified by means of monitoring. The long term lifespan of the power line is a potential concern.

RECOMMENDED MITIGATION MEASURES FOR THE ABOVE GROUND POWER LINE:

- Roof structures (e.g. substation roofing) should be of a sloping design in order to deter the perching/ roosting of birds such as cormorants and pelicans; and
- Ongoing monitoring of all power line and substation structures (including transformers) is necessary to identify problem sites in terms of electrocution; any incidents should be reported to the NamPower/NNF Strategic Partnership, and additional mitigation measures then considered.

7.8.3 Decommissioning phase

7.8.3.1 Physical disturbance to breeding birds, especially Damara Terns

IMPACT DESCRIPTION:

The impacts associated with the decommission phase relates to the physical disturbance (including human-induced light and noise) on breeding birds, especially Damara Terns and is similar to the construction related disturbances. (At a conceptual level, decommissioning can be considered a reverse of the construction phase with the demolition and removal of the majority of infrastructure and activities very similar to those in the construction phase).

Therefore, the assessment findings associated with the physical disturbance to breeding birds, especially Damara Terns during the decommissioning phase is the same as for the construction phase.

IMPACT ASSESSEMENT: PHYSICAL DISTURBANCE TO BREEDING BIRDS, ESPECIALLY DAMARA TERNS

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	~
Extent	Local	Local	Local	Local	Local	~
Magnitude	High	Low	Very low	Low	Low	~
Duration	Long term	Short term	Short term	Short term	Short term	~
SIGNIFICANCE	High (-)	Low (-)	Very low (-)	Low (-)	Low (-)	Neutral
Probability	Definite	Probable	Probable	Probable	Probable	Definite
Confidence	Certain	Sure	Sure	Sure	Sure	Certain
Reversibility	Irreversible	Irreversible	Irreversible	Irreversible	Irreversible	~

Proposed recommendations:

Refer to section 7.8.1.3 for the assessment findings and recommended mitigation measures.

7.8.4 Cumulative impacts

Some potentially cumulative effects (as described in the Strategic Environmental Assessment for the Uranium Rush in the Erongo Region (U-SEA)) have already been identified in the above assessment. These include:

- Activities relevant to the present study that are responsible for loss, degradation and fragmentation of habitats, e.g. construction activities and illegal off-road driving;
- Disturbance of birds at their nests, even if unintentional; this includes Damara Terns and large numbers of Cape Cormorants; and
- The cumulative impacts of the growing network of power lines both in the area and throughout Namibia, and the impact in terms of bird mortalities, especially from collisions.

Other cumulative impacts identified are the following:

- Mile 4 Salt Works is an Important Bird Area (IBA) and as such serves as a stopover for more than 70 migratory bird species (31% of those recorded at the site). A deterioration of this habitat could have far-reaching impacts on regional and international bird populations. The potential impacts of lighting, if unshielded, together with other (increasing) ambient artificial lighting on the navigation of flying birds are likely to increase, and this could impact on the large numbers of migrant bird species using the Swakopmund Salt Works and surrounding coastal areas, particularly in terms of night-flying species, e.g. terns. The ambient light in the Mile 4 area has increased markedly over the years, indicating a cumulative effect; and
- Some 71 Damara Tern breeding areas have been identified globally, many of which are under pressure elsewhere on the Namibian and South African coastline as a result of human strip development along coastal areas and the tendency for humans to use river mouths and estuaries for their endeavors. The species is also under hunting pressure during its migrations northwards over Angola. Accelerated growth and development on the coast has secondary impacts on species such as Damara Terns that have lost breeding areas and suffer increased mortalities at nests as a result of the expansion of Walvis Bay and Swakopmund, and this species serves as a flagship for the negative impacts of unsustainable development on coastal species and their habitats.

The objective of the U-SEA with respect to biodiversity is that the ecological integrity and diversity of fauna and flora of the central Namib are not compromised by the Uranium Rush. Integrity in this case means that key habitats are protected; rare, endangered, and endemic species are not threatened; ecological processes are maintained; and areas of high biodiversity value are conserved.

7.9 MARINE ECOLOGY IMPACTS

The following subsection is a modified summary compiled using the marine ecology impact assessment undertaken by Pisces Environmental Services. The marine ecology impact assessment builds on the brine diffusion study undertaken by WSP. WSP did not undertake an impact assessment, therefore the brine diffusion study is not reported on in the SEIA as a separate assessment. Thus, it has been summarised as part of the marine ecology study, which follows here. The original reports for the marine ecology impact assessment and the brine diffusion modelling study are attached here as Annexure D6 and Annexure D7 respectively and can be referred to for added detail.

7.9.1 Marine ecology

During the course of the environmental scoping process for the proposed Rössing Uranium desalination plant, key issues were identified relating to potential impacts on the marine environment. These are identified below in terms of the construction, commissioning, operation and decommissioning phases for the proposed plant.

The potential impacts associated with the construction of feedwater intake and brine discharge structures into the marine environment are related to:

- Onshore construction (human activity, air, noise and vibration pollution, dust, blasting and piling driving, disturbance of coastal flora and fauna) (to be dealt with by others); and
- Construction and installation of pipeline intakes and discharge (construction site, pipe lay-down areas, and trenching in the marine environment, vehicular traffic on the beach and consequent disturbance of intertidal and subtidal biota).

The desalination plant will be constructed a set-back distance from the existing shoreline. Consequently, issues associated with the location of the plant, and the associated pipelines leading to and from these constructions are not deemed to be of relevance to the marine environment, and were dealt with by other specialist studies. However, infrastructure extending into the sea will potentially impact on intertidal and shallow subtidal biota during the construction phase in the following ways:

- Temporary loss of benthic habitat and associated communities due to preparation of seabed for buried pipeline laying and associated activities (e.g. jetties);
- Temporary loss of supratidal habitat as a result of vehicular traffic and earth moving equipment on the shore, and associated spoils dumping, backfilling and stockpiling activities;
- Possible temporary short-term impacts on habitat health due to turbidity generated during construction;
- Temporary disturbance of marine biota, particularly marine mammals and turtles, due to construction activities (blasting and piling driving, breakwater construction);
- Interruption of longshore sediment movement by sheet piling and jetty structure resulting in increased erosion and/or accretion around the construction site (refer to the Coastal Dynamics Specialist Study);
- Possible impacts to marine water quality and sediments through hydrocarbon pollution by marine construction infrastructure and plant; and
- Potential contamination of marine waters and sediments by inappropriate disposal of spoil and/or surplus rock from construction activities or backfilling used lubricating oils from marine machinery maintenance and human wastes, which could in turn lead to impacts upon marine flora, fauna and habitat.

Once construction has been completed, it will take about three months to commission the new desalination plant. During the commissioning phase, seawater will be pumped into the plant at up to peak production rates. However, any fresh water produced will be combined with the brine and discharged. As the discharge will have a salinity equivalent to that of normal seawater, it will not have an environmental impact during the commissioning phase.

It may be necessary to discard the membrane storage solution and rinse the membranes before plant start-up. If the storage solution contains a biocide or other chemicals which may be harmful to marine life and this solution is discharged to the sea, local biota and water quality may be affected.

The key issues and major potential impacts are mostly associated with the operational phase. The key issues related to the presence of pipeline infrastructure and brine discharges into the marine environment are:

- Altered flows at the intake and discharge resulting in ecological impacts (e.g. entrainment and impingement of biota at the intake, flow distortion/changes at the discharge, and effects on natural sediment dynamics);
- Potential for habitat health impacts/losses resulting from elevated salinity in the vicinity of the brine discharge;
- The effect of the discharged effluent potentially having a higher temperature than the receiving environment;
- Biocidal action of residual chlorine in the effluent;
- The effects of co-discharged constituents in the waste-water;
- The abstraction of large volumes of feedwater resulting in the removal of particulate matter from the water column where it is a significant food source, as well as changes in phytoplankton production due to changes in nutrients, reduction in light, water column structure and mixing processes; and
- Direct changes in dissolved oxygen content due to the difference between the ambient dissolved oxygen concentrations and those in the discharged effluent, and indirect changes in dissolved oxygen content of the water column and sediments due to changes in phytoplankton production as a result of nutrient input.

Additional engineering design considerations, not strictly constituting issues to be considered within this marine specialist study, include the following:

- Structural integrity of the intake and outfall pipelines (e.g. related to shoreline movement);
- Potential changes in shoreline dynamics due to the presence of intake structures and discharge pipelines;
- Potential re-circulation of brine effluent;
- Pipeline maintenance and replacement requirements; and
- Water quality of feed-waters that should include consideration of possible deteriorating water quality (particularly algal blooms, sediments that may be stirred up during storms, or large-scale hypoxia or sulphur eruptions in bottom waters), that may require specific mitigation measures or planned flexibility in the operations of the desalination plant.

The minimum anticipated life of the desalination plant is approximately 10 years. The individual RO modules will be replaced as and when required during this period. No decommissioning procedures or restoration plans have been compiled at this stage. Being a modular plant, decommissioning should not involve extensive demolition of the plant area. In the case of decommissioning the pipeline will most likely be left in place. The potential impacts during the decommissioning phase are thus expected to be minimal in comparison to those occurring during the construction and operational phase, and no key issues related to the marine environment are identified at this stage, since

cessation in the operation of the plant will result in an immediate discontinuation of the majority of the identified marine impacts.

7.9.1.1 Conclusions and Impact Statement

The impact assessments, to follow, identified that the marine environment will be impacted to some degree during both the construction and operational phases of the proposed Rössing Uranium desalination plant. In summary:

Three negative impacts of medium significance (before mitigation) associated with the construction phase were identified:

- Disturbance and destruction of marine biota through alteration and disruption of the coastal zone during construction;
- Detrimental effects on marine biota through accidental hydrocarbon spills, concrete works and litter in the coastal zone during construction;
- Disturbance of and possible injury to shore birds and marine biota through blasting.

Two negative impacts of medium significance (before mitigation) associated with the operational phase were identified:

- Reduced physiological functioning of marine organisms due to elevated salinity;
- Detrimental effects on marine organisms due to residual chlorine levels in the mixing zone.

With few exceptions, recommended management actions and mitigation measures will reduce the above negative impacts of medium (-) significance to low (-) or very low (-).

If all environmental guidelines, and appropriate mitigation measures advanced in the specialist report, and the SEMP for the proposed project as a whole, are implemented, there is no reason why the proposed development of the Rössing Uranium desalination plant should not proceed. The impacts of operational discharges of brine (and potential co-pollutants) on marine water quality remains highly localised and confined to a <100m^2 area around the discharge. Furthermore, as the brine is discharged into the surf zone, rapid dilution, and mixing with the receiving water body is expected thereby ensuring that detectable effects on marine communities are unlikely to occur. The assessment of the individual impacts follows.

7.9.2 Construction phase

Construction activities as part of the proposed development will severely impact the rocky shore and nearshore habitats and their associated communities, but the impacts will be highly localised and confined to the immediate construction area. The installation of the intake and discharge structures will result in considerable disturbance of the high-shore, intertidal and shallow subtidal habitats at the construction site. The construction will involve substantial excavation activities on the intertidal beach, concreting of pipelines and installation of the jetty on the rocky intertidal and in the surf zone, as well as extensive traffic on the shore by heavy vehicles and machinery, and the potential for associated hydrocarbon spills.

Although the activities in the intertidal zone will be localised and confined to within a hundred metres of the construction site, the boulders and sediments will be completely turned over in the process and the associated macrofauna will almost certainly be entirely eliminated. Rock blasting may be necessary to remove existing bedrock to the required depth and pile driving may be required during jetty installation, resulting in disturbance of coastal and marine biota. The physical removal of sediments or bedrock in the trench will result in the total destruction of the associated sessile benthic

biota. Excavating operations will also result in increased suspended sediments in the water column and physical smothering of macrofauna by the discarded sediments. However, provided construction activities are not phased over an extended period, the shoreline is not repeatedly disturbed through persistent activities and suitable post-construction rehabilitation measures are adopted (e.g. track rehabilitation, removal of foreign construction materials which may hamper recovery of biota, backfilling excavations above mean sea level with the excavated material as trenching progresses, so as to maintain the original shore profile as far as possible), the macrofaunal communities are likely to recover in the short-to medium-term. The benthic communities of these shores are highly variable, on both spatial and temporal scales, and subject to dramatic natural fluctuations, particularly as a result of episodic disturbances such as unusual storms, and low oxygen events. As a consequence, the benthos is considered to be relatively resilient, being well-adapted to the dynamic environment, and capable of keeping pace with rapid biophysical changes (McLachlan and De Ruyck 1993). The highly localised, yet significant impacts over the short term thus need to be weighed up against the long-term benefits of the desalination plant.

7.9.2.1 Construction of the intake and discharge structures

IMPACT DESCRIPTION: DISTURBANCE OF THE COASTAL ZONE

The use of intake structures and discharge pipelines in the engineering designs for the desalination plant is unavoidable, but will involve considerable disturbance of the high-shore, intertidal and shallow subtidal habitats during the construction and installation process. The intake and outfall points of the pipelines will be located below the low water mark, in the surf zone.

Individual pipeline sections will be fabricated by the supplier and transported to site. This will require a sufficiently large and relatively flat onshore area (immediately inland of the final pipeline position) where the pipes can be stockpiled and prepared. Coastal vegetation and associated fauna at the jetty and pipeline construction sites will almost certainly be severely disturbed or removed. The pipe sections will subsequently be butt-welded together into long strings, and placed either on the jetty or in the excavated trench. Once trenched, the discharge pipeline will be covered with concrete and rock. Obviously, the physical removal of sediments or bedrock in the discharge pipeline trench, and disposal thereof into the surf zone will result in the total destruction of the associated benthic biota within the immediate area. Mobile organisms such as fish, shore birds and marine mammals, on the other hand, are capable of avoiding the construction area and although severely disturbed for the duration of construction activities, should not be significantly affected by the excavations.

Despite this unavoidable disturbance of the intertidal and shallow subtidal habitats, the activities would remain localised and impacts would generally become less intrusive with increasing distance from the construction disturbance and should not extend beyond a hundred metres of the construction site. Provided the construction activities are all conducted concurrently, the duration of the disturbance should also only be limited to a period of not more than 18 months. Active rehabilitation of intertidal communities is not possible, but rapid natural recovery of disturbed habitats in the turbulent intertidal and surf zone areas can be expected. Furthermore, the exposed pipeline, concrete foundations and concrete casing will serve as a new ‘hard-bottom’ substrate for colonisation by marine benthic communities. The ecological recovery of marine habitats is generally defined as the establishment of a successional community of species, which progresses towards a community that is similar in species composition, population density, and biomass to that previously present (Ellis 1996). In general, communities of short-lived species and/or species with a high reproduction rate (opportunists) may recover more rapidly than communities of slow growing, long-lived species. Opportunists are usually small, mobile, highly reproductive, and fast growing species and are the early colonisers. Habitats in the nearshore wave-base regime, which are subjected to frequent disturbances, are typically inhabited by these opportunistic species (Newell *et al.* 1998).

Recolonisation will start rapidly after cessation of trenching, and species numbers may recover within short periods (weeks) whereas biomass often remains reduced for several years (Kenny and Rees 1994, 1996).

Studies on the disturbance of beach macrofauna and rocky shore communities on the southern African West Coast by beach mining activities and shore-based diamond diving operations have ascertained that, provided physical changes to beach morphology and rocky intertidal zones are kept to a minimum, biological 'recovery' of disturbed areas will occur within 2-5 years (Nel *et al*. 2003; Pulfrich *et al*. 2003; Pulfrich *et al*. 2004). Disturbed subtidal communities within the wave base (<40 m water depth) might recover even faster (Newell *et al*. 1998; Pulfrich and Penney 2001).

IMPACT ASSESSMENT: DISTURBANCE AND DESTRUCTION OF MARINE BIOTA THROUGH ALTERATION AND DISRUPTION OF THE COASTAL ZONE DURING CONSTRUCTION

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	
Extent	Site specific	Site specific	Site specific	Site specific	Site specific	
Magnitude	High	Low	Low	Low	Low	
Duration	Medium term	Medium term	Medium term	Medium term	Medium term	
SIGNIFICANCE	Medium (-)	Low(-)	Low(-)	Low(-)	Low(-)	Neutral
Probability	Definite	Definite	Definite	Definite	Definite	
Confidence	Certain	Certain	Certain	Certain	Certain	
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	

Disturbance of the intertidal and subtidal rocky shore and/or beach during installation of the intake and discharge pipelines is consequently deemed of high magnitude within the immediate vicinity of the construction sites, with impacts persisting over the short- to medium-term and is considered to be of Medium (-) significance without mitigation. This rating is applicable to the construction of both the intake and the discharge pipelines, regardless of location. With the implementation of mitigation measures, the duration of the impacts may reduce to short-term thus reducing the significance to Low (-).

Proposed mitigation measures:

- Restrict disturbance of the intertidal and subtidal areas to the smallest area possible.
- Lay pipeline in such a way that required rock blasting is kept to a minimum.
- Restrict traffic on upper shore to minimum required.
- Restrict traffic to clearly demarcated access routes and construction areas only.
- Have good house-keeping practices in place during construction.

7.9.2.2 Pollution and Accidental Spills

IMPACT DESCRIPTION: POLLUTION AND ACCIDENTAL SPILLS

Construction activities in the intertidal and shallow subtidal zones will involve extensive traffic on the shore by heavy vehicles and machinery, as well as the potential for accidental spillage or leakage of fuel, chemicals, or lubricants. Any release of liquid hydrocarbons has the potential for direct, indirect, and cumulative effects on the marine environment through contamination of the water and/or sediments. These effects include physical oiling and toxicity impacts to marine fauna and flora, localised mortality of plankton, pelagic eggs and fish larvae, and habitat loss or contamination (CSIR, 1998; Perry, 2005). Many of the compounds in petroleum products have been known to smother organisms, lower fertility and cause disease in aquatic organisms. Hydrocarbons are incorporated

into sediments through attachment to fine dust particles, sinking and deposition in low turbulence areas. Due to differential uptake and elimination rates filter-feeders particularly mussels can bioaccumulate organic (hydrocarbons) contaminants (Birkeland *et al.*, 1976).

Concrete work will be required in the intertidal and shallow subtidal zones during construction and installation of the pipelines. As cement is highly alkaline, wet cement is strongly caustic, with the setting process being exothermic. Excessive spillage of cement in the intertidal area may thus potentially increase the alkalinity of the water column with potential sublethal or lethal effects on marine organisms.

During construction (and also during operation), litter can enter the marine environment. Inputs can be either direct by discarding garbage into the sea, or indirectly from the land when litter is blown into the water by wind. Marine litter is a cosmopolitan problem, with significant implications for the environment and human activity all over the world. Marine litter travels over long distances with ocean currents and winds. It originates from many sources and has a wide spectrum of environmental, economic, safety, health, and cultural impacts. It is not only unsightly, but can cause serious harm to marine organisms, such as turtles, birds, fish, and marine mammals. Considering the very slow rate of decomposition of most marine litter, a continuous input of large quantities will result in a gradual increase in litter in coastal and marine environment. Suitable waste management practices should thus be in place to ensure that littering is avoided.

IMPACT ASSESSMENT: DETRIMENTAL EFFECTS ON MARINE BIOTA THROUGH ACCIDENTAL HYDROCARBON SPILLS, CONCRETE WORKS AND LITTER IN THE COASTAL ZONE DURING CONSTRUCTION

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	
Extent	Site specific	Site specific	Site specific	Site specific	Site specific	
Magnitude	Medium	Low	Low	Low	Low	
Duration	Medium term	Medium term	Medium term	Medium term	Medium term	
SIGNIFICANCE	Medium (-)	Low(-)	Low(-)	Low(-)	Low(-)	Neutral
Probability	Definite	Definite	Definite	Definite	Definite	
Confidence	Certain	Certain	Certain	Certain	Certain	
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	

Potential hydrocarbon spills and pollution in the intertidal zone during installation of the intake and discharge pipelines is thus deemed of medium intensity within the immediate vicinity of the construction sites, with impacts persisting over the short- to medium-term. The impact is therefore assessed to be of Medium (-)significance without mitigation. This rating is applicable to the construction of both the intake and the discharge pipelines, regardless of location. With the implementation of mitigation measures, impacts would become Low (-).

Proposed mitigation measures:

- Conduct a comprehensive environmental awareness programme amongst contracted construction personnel.
- Only equipment and vehicles actively involved in construction should be permitted on the beach and associated works areas. When not in use, and overnight, all equipment and plant must be withdrawn to higher ground;
- Refueling of equipment from a bowser should take place on higher ground away from the beach and wet works areas;
- For equipment maintained in the field, oils and lubricants to be contained and correctly disposed of off-site.

- Maintain vehicles and equipment to ensure that no oils, diesel, fuel or hydraulic fluids are spilled.
- Vehicles should have a spill kit (peatsorb/ drip trays) onboard in the event of a spill.
- No mixing of concrete in the intertidal zone and care taken to dispose of concrete wash water in a responsible manner that will not leach back to the ocean.
- Regularly clean up concrete spilled during construction.
- No dumping of excess concrete or mortar on the sea bed.
- Ensure regular collection and removal of refuse and litter from intertidal areas.
- Have good house-keeping practices in place during construction.

7.9.2.3 Increased Turbidity

IMPACT DESCRIPTION:

Excavations, disturbance, and turnover of sediments and boulders in the intertidal and/or surf zone will result in increased suspended sediments in the water column and physical smothering of biota by the discarded sediments. The effects of elevated levels of particulate inorganic matter and deposition thereof have been well studied, and are known to have marked, but relatively predictable effects in determining the composition and ecology of intertidal and shallow subtidal benthic communities (e.g. Engledow and Bolton, 1994; Iglesias *et al,.* 1996; Slattery and Bockus, 1997). Increased suspended sediments in the surf zone and nearshore can potentially affect light penetration and thus phytoplankton productivity and algal growth, load the water with inorganic suspended particles, which may affect the feeding and absorption efficiency of filter-feeders, and can cause scouring of biota (e.g. shells, kelp stipes).

Rapid deposition of material from the water column will have a smothering effect. Some mobile benthic animals inhabiting soft-sediments are capable of migrating vertically through more than 30 cm of deposited sediment (Newell *et al*., 1998). Sand inundation of reef habitats was found to directly affect species diversity whereby community structure and species richness appears to be controlled by the frequency, nature and scale of disturbance of the system by sedimentation (Seapy and Littler, 1982, Littler *et al*., 1983; Schiel and Foster, 1986; McQuaid and Dower, 1990; Santos, 1993; Airoldi and Cinelli, 1997 amongst others). For example, frequent sand inundation may lead to the removal of grazers thereby resulting in the proliferation of algae (Hawkins and Hartnoll, 1983; Littler *et al*., 1983; Marshall and McQuaid, 1989; Pulfrich *et al.,* 2003a, 2003b).

Construction activities required for the installation of the intake and discharge pipelines for the Rössing Uranium desalination plant will be highly localised. The impact of the resulting sediment plumes is likewise expected to be localised and of short duration (only for a couple of hours to a few days after cessation of excavation activities). As the biota of sandy and rocky intertidal and subtidal habitats in the wave-dominated nearshore areas of southern Africa are well adapted to high suspended sediment concentrations, periodic sand deposition and re-suspension, impacts are expected to occur at a sublethal level only.

IMPACT ASSESSMENT: REDUCED PHYSIOLOGICAL FUNCTIONING OF MARINE ORGANISMS DUE TO INCREASED TURBIDITY OF NEARSHORE WATERS DURING EXCAVATIONS

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	
Extent	Site specific	Site specific	Site specific	Site specific	Site specific	
Magnitude	Very low	Very low	Very low	Very low	Very low	
Duration	Short term	Short term	Short term	Short term	Short term	
SIGNIFICANCE	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
Probability	Definite	Definite	Definite	Definite	Definite	
Confidence	Certain	Certain	Certain	Certain	Certain	
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	

Elevated suspended sediment concentrations in nearshore waters due to construction activities is thus deemed of low magnitude within the immediate vicinity of the construction sites, with impacts persisting over the short-term only. The impact is therefore assessed to be of Very Low (-) significance both without and with mitigation. This rating is applicable to the construction of both the intake and the discharge pipelines, regardless of location. As elevated suspended sediment concentrations are an unavoidable consequence of construction activities in the intertidal zone, no direct mitigation measures, other than the No-Go alternative, are possible. Impacts can however be kept to a minimum through responsible construction practices.

PROPOSED MITIGATION MEASURES:

- No dumping of construction materials in the intertidal and subtidal zones.
- Have good house-keeping practices in place during construction.

IMPACT ASSESSMENT: SMOTHERING OF BENTHOS THROUGH REDEPOSITION OF SUSPENDED SEDIMENTS

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	
Extent	Site specific	Site specific	Site specific	Site specific	Site specific	
Magnitude	Very low	Very low	Very low	Very low	Very low	
Duration	Short term	Short term	Short term	Short term	Short term	
SIGNIFICANCE	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
Probability	Definite	Definite	Definite	Definite	Definite	
Confidence	Certain	Certain	Certain	Certain	Certain	
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	

Elevated suspended sediment concentrations in nearshore waters due to construction activities is thus deemed of low magnitude within the immediate vicinity of the construction sites, with impacts persisting over the short-term only. The impact is therefore assessed to be of Very Low (-) significance both without and with mitigation. This rating is applicable to the construction of both the intake and the discharge pipelines, regardless of location. As elevated suspended sediment concentrations are an unavoidable consequence of construction activities in the intertidal zone, no direct mitigation measures, other than the No-Go alternative, are possible. Impacts can however be kept to a minimum through responsible construction practices.

Proposed mitigation measures: Smothering of benthos through re-deposition of suspended sediments

- No dumping of construction materials in the intertidal and subtidal zones.

- Implement design measures to reduce the loss of materials from temporary earthen berms, construction platforms or access roads during the construction period. I.e. reduce the construction programme of wet works where possible, use geotextiles to reduce scouring of earthen berms, etc.
- Have good house-keeping practices in place during construction.

7.9.2.4 Construction noise and blasting

IMPACT DESCRIPTION:

During jetty installation and pipeline trenching operations, noise and vibrations from excavation machinery and pile drivers may have an impact on surf zone biota, marine mammals, and shore birds in the area. Noise levels during construction are generally at a frequency much lower than that used by marine mammals for communication (Findlay, 1996), and these are therefore unlikely to be significantly affected. Additionally, the maximum radius over which the noise may influence is very small compared to the population distribution ranges of surf zone fish species, resident cetacean species and the Cape fur seal. Both fish and marine mammals are highly mobile and should move out of the noise-affected area (Findlay, 1996). Similarly, shorebirds and terrestrial biota are typically highly mobile and would be able to move out of the noise-affected area.

Trenching of the discharge pipeline may require blasting to attain the required depths. As details of the probable blast levels, blasting practice and duration of the blasting required to ensure suitable burial of the pipeline have not yet been determined, the assessment that follows is generic only. Effects of underwater blasting and pile driving on marine organisms have received extensive coverage in the formal peer-reviewed scientific literature (see Lewis, 1996 and Keevin and Hempen, 1997), as well as in various assessments for seismic surveys, underwater construction and weapons testing. The following impact description is based on two reviews on the subject provided in Lewis (1996) and Keevin and Hempen (1997).

Explosives generate chemical energy, which is released as physical, thermal, and gaseous products. The most important of these for marine organisms is the physical component which, as a shock wave, passes into the surrounding medium. Depending on the blasting practice, some of the energy may escape into the water column, and it is this shock wave that is the primary cause of damage to aquatic life at, or some distance from the shot point. Thermal energy dissipation, in contrast, is generally limited to the immediate vicinity (<10 m) of the exploding material, and in shallow water gaseous products produce minor shock wave amplitudes.

The nature of the shock wave generated by the blast depends on the type of explosive used. Relatively low energy explosives such as black powder are slow burning and produce a shock wave with a shallow rise height. Dynamite and other high explosives have a rapid detonation velocity and produce a more abrupt shock wave. Consequently, high explosives have more dramatic effects on marine organisms.

Two damage zones are associated with an underwater explosion:

- An immediate kill zone of relatively limited extent, but within which all animals are susceptible to damage through disruption of their body tissues by the pressure wave generated by the explosion; and
- A more extensive remote damage zone in which damage is caused by negative pressure pulses, generated when the compression wave is reflected from an air-water interface. The negative pulses act on gas bodies within the organism inducing injuries such as hemorrhaging and contusions of the gastro-intestinal tract (mammals and birds) or rupture of swimbladders in fish.

Keevin and Hempen (1997) and Lewis (1996) provide information on blast-effects on a variety of shallow water (<10 m) organisms. Appendix A.1 to the marine ecology report, attached hereto as Annexure D6 provides a summary of these effects focussing on the marine macrophytic algae, major invertebrate macrofaunal taxa, fish, turtles, and marine mammals that may occur in the blast area off the desalination plant site.

From this summary, the following can be gleaned:

- Any effects on macrophytes through blasting would be limited to the immediate vicinity of the charges.
- Marine invertebrates appear to be relatively immune to blast effects in terms of obvious injury or mortalities, suggesting that any blast-effects are likely to remain confined to the immediate area of blasting.
- In fish, the swim bladder is the organ most frequently damaged through blasting, potentially leading to high mortality in the immediate area of blasting. In contrast, fish species that do not possess swim bladders seem to be largely immune to underwater explosions. Egg and fish larvae may also be affected by underwater explosions, but impact ranges seem to be restricted to the immediate vicinity of the blasting. Although injury or mortality of fish and/or their eggs and larvae in the immediate area of the blasting is likely to occur, the probability of the blasting programme having a measurable effect at the population level on fish in the study area is judged to be unlikely, as surf zone and nearshore species along the central Namibian coastline are widely distributed.
- The limited information available on blasting effects on swimming and diving birds suggests that mortality occurs primarily within the immediate vicinity (<10m) of the blast.
- Effects on sea turtles may occur up to a distance of 1km from the underwater explosion. Although occurring in the study area, turtles are infrequent visitors in the shallow nearshore regions.
- Similar to fish, injuries to marine mammals generated by underwater explosions are primarily trauma of various levels to organs containing gas, and mortality can occur in the immediate area around the blasting. Given the generally low numbers of seals in the study area relative to the overall population size any population level mortality effects, or injuries that may be caused are judged to be insignificant. Seals and scavenging birds may, however, be attracted to the blasting area by stunned and dead fish following a blast. Although occurring in the study area, whales and dolphins are infrequent visitors in the shallow nearshore regions, being more common further offshore. However, Heaviside's Dolphin and the Common Bottlenose Dolphin occur in shallow waters (<50m) and could be vulnerable to detonations.

IMPACT ASSESSMENT: DISTURBANCE OF SHORE BIRDS AND MARINE BIOTA THROUGH CONSTRUCTION NOISE

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	
Extent	Site specific	Site specific	Site specific	Site specific	Site specific	
Magnitude	Medium	Low	Low	Low	Low	
Duration	Short term	Short term	Short term	Short term	Short term	
SIGNIFICANCE	Low (-)	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
Probability	Probable	Probable	Probable	Probable	Probable	
Confidence	Sure	Sure	Sure	Sure	Sure	
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	

Disturbance and injury to marine biota due to construction noise is thus deemed of low magnitude within the immediate vicinity of the construction sites, with impacts persisting over the short-term only. In the case of blasting, however, the impact would be of high magnitude, but also persist over the short-term only. Without mitigation, the impacts of construction noise and blasting are therefore

assessed to be of Low (-) and Medium (-) significance, respectively. This rating is applicable to the construction of both intake and the discharge pipelines, regardless of location. The implementation of mitigation would reduce the magnitude of the impact of construction noise to low and thus the overall significance to Very Low (-). As the noise associated with construction is unavoidable, no direct mitigation measures, other than the No-Go alternative, are possible. Impacts can however be kept to a minimum through responsible construction practices and an accelerated wet works construction program.

Proposed mitigation measures:

- Restrict construction noise and vibration-generating activities to the absolute minimum required.
- Have good house-keeping practices in place during construction.

IMPACT ASSESSMENT: DISTURBANCE OF AND INJURY TO SHORE BIRDS AND MARINE BIOTA THROUGH BLASTING

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	
Extent	Local	Local	Local	Local	Local	
Magnitude	High	Low	Low	Low	Low	
Duration	Short term	Short term	Short term	Short term	Short term	
SIGNIFICANCE	Medium (-)	Low (-)	Low (-)	Low (-)	Low (-)	Neutral
Probability	Probable	Probable	Probable	Probable	Probable	
Confidence	Sure	Sure	Sure	Sure	Sure	
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	

In the case of blasting, the magnitude would reduce to medium and the extent to site specific with the implementation of mitigation measures, thereby reducing the overall significance to Low (-). As the noise associated with construction is unavoidable, no direct mitigation measures, other than the No-Go alternative, are possible. Impacts can however be kept to a minimum through responsible construction practices and an accelerated wet works construction program. As details of the probable blast levels, blasting practice and duration of the blasting required have not yet been finalised, confidence in the assessment of this impact is rated as medium.

Proposed mitigation measures:

- Restrict blasting to the absolute minimum required (one blast per day).
- Use blasting methods which minimise the environmental effects of shock waves through the use of smaller, quick succession blasts directed into the rock.
- Avoid onshore blasting during the breeding season of shore-birds.
- Undertake visual observation prior to blasting to ensure there are no marine mammals and turtles present in the immediate vicinity (approximately 2-km radius).
- Development of a responsible blasting schedule.

7.9.2.5 Installation of Structures

IMPACT DESCRIPTION:

Installation of the jetty and discharge pipeline will effectively eliminate any (sandy or rocky) biota in the structural footprint, and reduce the area of seabed available for colonisation by marine benthic communities. Although the loss of substratum as a result of the jetty and discharge pipeline constitutes a negative impact, it will be temporary only, as the structures will provide an alternative

substratum for colonising communities. Assuming that the hydrographical conditions around the structures will not be significantly different to those on the seabed, a similar community to the one previously present can be expected to develop, thereby constituting a positive impact.

The composition of the fouling community on artificial structures depends on the age (length of time immersed in water) and the composition of the substratum, and usually differs from the communities of nearby natural rocky reefs (Connell and Glasby, 1999; Connell 2001). Colonisation of hard substratum goes through successional stages (Connell and Slayter, 1977). Early successional communities are characterised by opportunistic algae (e.g. *Ulva* sp., *Enteromorpha* sp.). These are eventually displaced by slower growing, long-lived species such as mussels, sponges and/or coralline algae, and mobile organisms, such as urchins and lobsters, which feed on the fouling community. With time, a consistent increase in biomass, cover and number of species can usually be observed (Bombace *et al*., 1994; Relini *et al,* 1994; Connell and Glasby, 1999). Depending on the supply of larvae and the success of recruitment, the colonisation process can take up to several years. For example, a community colonising concrete blocks in the Mediterranean was found to still be changing after five years with large algae and sponges in particular increasing in abundance (Relini *et al*., 1994). Other artificial reef communities, on the other hand, were reported to reach similar numbers of species (but not densities and biomass) to those at nearby artificial reefs within eight months (Hueckel *et al*., 1989).

IMPACT ASSESSMENT: ELIMINATION OF BENTHIC COMMUNITIES THROUGH LOSS OF SUBSTRATUM IN STRUCTURAL FOOTPRINT

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	
Extent	Site specific	Site specific	Site specific	Site specific	Site specific	
Magnitude	Low	Low	Low	Low	Low	
Duration	Short term	Short term	Short term	Short term	Short term	
SIGNIFICANCE	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
Probability	Probable	Probable	Probable	Probable	Probable	
Confidence	Sure	Sure	Sure	Sure	Sure	
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	

The elimination of marine benthic communities in the structural footprint is an unavoidable consequence of the installation of intake and discharge structures, and no direct mitigation measures, other than the No-Go alternative, are possible. The initial negative impacts are, however, deemed of low magnitude within the immediate vicinity of the construction sites. Furthermore, the negative impacts persist over the short-term only as the new structures will offer a new settling ground for hard bottom species and will be rapidly colonised. The impact is therefore assessed to be of **VERY LOW** significance both without and with mitigation. This rating is applicable to the construction of both the intake jetty and the discharge pipeline, regardless of location.

Proposed mitigation measures:

- Mimimising wet works construction footprint and duration could marginally reduce this impact.
- No other direct mitigation is possible other than pursuing the No-Go alternative.
- Leave pipeline in place post closure to prevent unnecessary disturbance of the seabed and associated communities.

7.9.3 Operations phase

The key potential impacts on the marine environment of the proposed Rössing Uranium desalination plant are mostly associated with the operational phase. The impacts involve impingement and

entrainment of biota at the intake point, and impacts associated with water quality due to pre-treatment of feed-water and discharge of the brine effluent.

The seawater intake considered for this project will result in impingement and entrainment of biota. Careful design of the intake with appropriate screens can reduce impingement substantially and should be implemented. The entrainment of biological matter and suspended matter, however, cannot be eliminated but through transfer of the water along the channel and interim storage in an inland pond much of the abstracted organic material should settle out and extensive chemical pre-treatment of the feed-water can thus be avoided. Furthermore, if the proposed bio-flocculation process, as part of the ProGreen™ pre-treatment system, is implemented, this would have substantial positive consequences from both environmental and operational costs perspective.

Unless the ProGreen™ technology is implemented, the need for pre-treatment of the feed water will also result in the use of chlorination to prevent biofouling of the pipelines and screens, and the use of other cleaning materials, which will be co-discharged with the reject brine (refer to section 3.5.6). Under this scenario, the impacts associated with the brine discharge would include:

- the effect of elevated salinities in the discharged effluent;
- the effect of the effluent having a higher temperature than the receiving environment;
- biocidal action of residual chlorine in the effluent (residual chlorine will be neutralized with sodium metabisulfite before the feed-water reaches the RO membranes);
- the effects of co-discharged constituents in the brine;
- the removal of particulate matter from the water column where it is a significant food source, as well as changes in phytoplankton production due to changes in nutrients, water column structure and mixing processes; and
- direct changes in dissolved oxygen content due to the difference between the ambient dissolved oxygen concentrations and those in the discharged effluent (especially if sodium bisulfate is used to neutralize residual chlorine), and indirect changes in dissolved oxygen content of the water column and sediments due to changes in phytoplankton production as a result of nutrient input.

The assessments presented in this section of the report relates to the worst case scenario in terms of the expected composition of the brine effluent, i.e. Conventional RO technology using DAF Pre-treatment only (i.e. the impact assessments do not consider the potential effects of the ProGreen™ system).

It is particularly important that the development of a coherent density flow of brine along the seabed is avoided by ensuring complete mixing in the surf zone at the point of discharge. Consequently, the effluent must be discharged in an area of relatively high wave energy where regular mixing of the water column can be expected as a result of the exposed nature of the coastline. Careful consideration of available technologies and processes in the plant design for the proposed desalination plant is thus the key issue that will allow the selection of the least environmentally damaging option for feedwater treatment, cleaning of plant components and brine disposal, thereby reducing discharges of hazardous components into the environment and ensuring adequate and rapid dilution of the effluent in the receiving water.

The near-field modelling results indicate that under average sea conditions, the predicted plume footprint for the southern discharge site is limited in spatial extent to a maximum area of 25-30 m from the outfall diffuser in a cross-shore direction, and 35-45 m in the alongshore direction. For the northern discharge site, the area of influence amounted to 30-40 m from the outfall diffuser in a cross-shore direction, and 35-50 m in the alongshore direction. Salinity would thus return to ambient levels (34.2 psu) within this area, and co-pollutants in the brine would be sufficiently diluted to no longer pose a hazard to marine biota. The maximum predicted plume footprints would be transient only and are predicted to occur approximatly 1% of the time under extremely calm conditions.

7.9.3.1 Comparison of Alternatives

From a marine ecological perspective, there are no noteworthy reasons for preferring the one discharge site alternative over the other. The hydrodynamic modelling results, however, indicate that the plume footprints are slightly smaller at the southern site than at the northern site. The northern site is however already disturbed through the presence of the derelict Salt Works intake structure and pipeline.

The coastline is relatively uniform over the ~4km stretch under consideration, and is already heavily impacted by regular vehicular traffic and seasonally high visitor numbers who utilize the area primarily for rock- and surf-angling and coastal recreation. Neither of the proposed discharge sites can therefore be considered particularly "pristine". Macrofaunal communities inhabiting the beach are relatively species deficient and on some beaches in the adjacent area show signs of moderate disturbance. No unique or new species were found on any of the beaches sampled in the vicinity of the study area (Pulfrich 2007), and the species assemblages were typical of high-energy, exposed southern African West Coast beaches. None of the species encountered are currently classified as rare or endangered.

7.9.3.2 No-Go Alternative

The No-Go alternative would have a neutral impact.

IMPACT DESCRIPTION:

Intake of water directly from the ocean through a submerged intake structure located in the surf zone will result in loss of marine species as a result of impingement and entrainment. Impingement refers to injury or mortality of larger organisms (e.g. fish, jellyfish) that collide with and are trapped by intake screens, whereas entrainment refers to smaller organisms that slip through the screens and are taken into the desalination plant intake ponds with the feed water. Impingement mortality is typically due to suffocation, starvation, or exhaustion due to being pinned up against the intake screens or from the physical force of the rakes used to clear screens of debris. The significance of impingement is related primarily to the location of the intake structure and is a function of intake velocity. The reduction of the average intake velocity of the feedwater to ~0.1 to 0.15m/s, which is comparable to background currents in the ocean, will allow mobile organisms to swim away from the intake under these flow conditions (UNEP, 2008). The intake of large quantities of seawater may also affect water circulation, especially in areas such as gullies and rockpools that are characterised by weak natural currents and waves.

While using screens reduces impingement, entrainment effects are likely to remain, as most of the entrained organisms are too small to be screened out without significantly reducing the intake water volume. Entrained material includes holoplanktic organisms (permanent members of the plankton, such as copepods, diatoms, and bacteria) and meroplanktic organisms (temporary members of the plankton, such as juvenile shrimps and the planktonic eggs and larvae of invertebrates and fish). Mortality rates of organisms entering desalination plants in the feedwater are likely to be 100% since the seawater is forced, at high pressure, through filters or membranes to remove particles, including the small organisms that are taken in with the feed-water. Furthermore, the feed-water will be treated with a biocide specifically designed to eliminate and kill entrained biota.

Although the mortality caused by entrainment may affect the productivity of coastal ecosystems, the effects are difficult to quantify (UNEP, 2008; World Health Organisation, 2007). Planktic organisms show temporal and spatial variations in species abundance, diversity, and productivity, but it can be assumed that species common in the Benguela region will be prevalent in the surface waters of the

project area. Furthermore, plankton species have rapid reproductive cycles. Due to these circumstances it seems unlikely that the operation of a single desalination facility of the capacity proposed at the Swakopmund Salt Works will have a substantial negative effect on the ability of plankton organisms to sustain their populations. The entrainment of eggs and larvae from common invertebrate and fish species will also unlikely adversely affect the ability of these species to reproduce successfully. The reproduction strategy of these species is to produce a large number of eggs and larvae, of which only a small percentage reaches maturity due to natural mortality (such as starvation of larvae or failure to settle in a suitable location). For example, an entrainment study for a RO Pilot Plant in San Francisco Bay showed that the estimated effects of fish larvae entrainment were minimal and indicated little potential for population-level effects (Tenera Environmental, 2007). The significance of entrainment is related both to the location of the intake, as well as the overall volume of feed-water required. As the feed-water volumes required for the Rössing Uranium desalination plant are comparatively small, impingement and entrainment impacts are unlikely to be of significance.

A further issue of potential concern is the removal of particulate matter from the water column, where it is a significant source of food for surf zone and nearshore communities. For the comparatively small feed-water volumes required for the Rössing Uranium desalination plant this is unlikely to be of significance, as the surf zone in the study area is particularly productive, and particulate organic matter frequently accumulates on the shore as foam and scum.

Algal blooms, which typically develop during periods of unusually calm wind conditions when sea surface temperatures are high (February to April), can negatively impact source water quality and may result in elevated organics in the source water and accelerated biofouling of RO installations. Red tides may result in the release of algal toxins of small molecular weight, which may impact product water quality. These are, however, typically effectively removed during the reverse osmosis process. Abstraction of the feed-water at depth and a reduced intake velocity can minimise the entrance of algal material in open water intakes (UNEP, 2008). For the current project, the feed-water will be abstracted from the surf zone. As the coastline of the study area is characterised by high wave energy, algal wrack often accumulates in large quantities in intertidal gullies and may thus similarly accumulate around the feed-water intake. This algal material could clog the screens at the intake and negatively impact source water quality through elevated organics. Transport of the water along the overland channel and interim storage in an inland seawater pond system will, however, allow much of this material to settle out prior to the feedwater entering the plant.

IMPACT ASSESSMENT: LOSS OF MARINE SPECIES THROUGH IMPINGEMENT AND ENTRAINMENT

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	
Extent	Site specific	Site specific	Site specific	Site specific	Site specific	
Magnitude	Low	Very low	Very low	Very low	Very low	
Duration	Long term	Long term	Long term	Long term	Long term	
SIGNIFICANCE	Low (-)	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
Probability	Definite	Definite	Definite	Definite	Definite	
Confidence	Certain	Sure	Sure	Sure	Sure	
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	

Considering the comparatively low feed-water volumes required for this project and the fact that feed-water will be abstracted from the surf zone, the loss of marine species through impingement and entrainment is deemed of low magnitude, but with impacts persisting over the operational life time of the plant. The impact is therefore assessed to be of Low (-) significance without mitigation and reducing the Very Low (-) with the implementation of mitigation measures.

Proposed mitigation measures:

- Adjust peak intake velocities to <0.15m/s.
- Ensure installation of screens on the end of the intake pipes, or the use of a screen box or shroud.
- Although an entrainment and impingement study is typically recommended for large desalination plants, the comparatively low volumes of feed-water to be extracted from the surf zone for this project would not justify such a study.

7.9.3.3 Flow Distortion

IMPACT DESCRIPTION:

The potential of scouring of sediment around the discharge outlet is a serious design issue for an effluent system discharging high volumes into a shallow receiving water body (Carter and van Ballegooyen, 1998). For the current project, however, the comparatively low brine volumes (174 litres/second) and their discharge into the highly turbulent surf zone are such that the potential impacts on the limited bottom sediments present in the area are expected to be limited, and will unlikely be detectable above those resulting from natural wave action, or seasonal inshore-offshore movement of sand.

IMPACT ASSESSMENT: POTENTIAL FLOW DISTORTION AROUND THE DISCHARGE OUTLET

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	
Extent	Site specific	Site specific	Site specific	Site specific	Site specific	
Magnitude	Very low	Very low	Very low	Very low	Very low	
Duration	Long term	Long term	Long term	Long term	Long term	
SIGNIFICANCE	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
Probability	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	
Confidence	Sure	Sure	Sure	Sure	Sure	
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	

Should any impacts associated with flow distortion be detectable, they would be of low magnitude within the immediate vicinity of the discharge. Despite persisting over the operational life time of the plant, the impact is deemed to be of Very Low (-) significance when seen in context with the highly dynamic natural sediment movements typical of the coastline. This rating is applicable regardless of the location of the discharge pipeline.

Proposed mitigation measures:

- Design outlet velocities so as to minimise the potential for flow distortion but still achieve diffusion objectives.

7.9.3.4 Desalination Plant Effluents

During operation, the desalination plant will discharge high-salinity brine into the surf zone through a single outfall pipeline. Due to its increased salinity (at 66psu: or approximately 1.7 times that of natural seawater), the brine is denser (heavier) than the surrounding seawater and would sink towards the seabed and flow away from the discharge point in the near-bottom layers of the water column, flowing down-slope (*i.e.* offshore) into deeper water. For the proposed discharge, the jet stream from the pipe end would be utilised to accelerate the brine directly into the oncoming rolling waves, thereby ensuring rapid mixing with the surrounding seawater. Depending on the discharge

velocity, the volumes of brine being discharged, and the local environmental conditions, thorough mixing throughout the water column is expected, but depending on the degree of mixing, the diluted brine may again sink towards the seabed and continue to dilute due to natural mixing processes. The region where the brine settles to the seafloor is termed the "near field" or "sacrificial mixing zone" as it represents an area in which large changes in water quality, sediments or biota can be expected. In other words, contaminant concentrations will be such that they will result in changes beyond natural variation in the natural diversity of species and biological communities, rates of ecosystem processes and abundance/biomass of marine life. Although the surf zone carries a significant amount of turbulent energy, it has a limited capacity to transport the brine to the open ocean. If the mass of the saline discharge exceeds the threshold of the surf zone's salinity load transport capacity, the excess salinity would begin to accumulate in the surf zone and could ultimately result in a long-term salinity increment in this zone beyond the level of tolerance of the aquatic life (World Health Organisation, 2007). This salinity threshold mixing/transport capacity of the surf zone was determined using hydrodynamic modelling.

Under the design specifications for the Rössing Uranium desalination plant project, the feed-waters will be drawn from a seawater intake located below the mean low water mark in the surf zone and is expected to be well mixed (i.e. no thermocline expected). Although no specific heating of the intake water will be done, transport and storage of water prior to it entering the desalination plant may potentially result in an elevation in temperature. This potential increase is assumed to be 2-3°C above ambient water temperature. On discharge, the slightly heated, dense effluent would sink towards the seabed where the receiving water masses may potentially have lower temperatures than the brine. However, discharge into the oncoming waves will ensure rapid dispersal throughout the water column, and no changes in absolute or mean temperatures of the receiving water are expected. Only under conditions of extreme calm, when the receiving waters may be stratified, would a thermal footprint be expected. Depending on the RO technology ultimately implemented, the brine may also contain traces of chemical residuals from RO membrane cleaning processes.

IMPACT DESCRIPTION: SALINITY

All marine organisms have a range of tolerance to salinity, which is related to their ability to regulate the osmotic balance of their individual cells and organs to maintain positive turgor pressure. Aquatic organisms are commonly classified in relation to their range of tolerance 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.

Salinity changes can also cause changes to water column structure (e.g. stratification) and water chemistry (e.g. dissolved oxygen saturation and turbidity). For example, fluctuation in the salinity regime has the potential to influence dissolved oxygen concentrations, and changes in the stratification could result in changes in the distribution of organisms in the water column and sediments. Behavioural responses to changes in salinity regime can include avoidance by mobile animals, such as fish and macro-crustaceans, by moving away from adverse salinity and avoidance by sessile animals by reducing contact with the water by closing shells or by retreating deeper into sediments.

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), and most studies undertaken to date have investigated effects of a decline in salinity due to an influx of freshwater, or

salinity fluctuations in estuarine environments, where most of the fauna can be expected to be of the euryhaline type. As large-scale desalination plants have only been in operation for a short period of time, very little information exists on the long-term effects of hypersaline brine on organisms in coastal marine systems (Al-Agha and Mortaja, 2005). However, from the limited studies that have been published, it has been observed that salinity has a toxic effect on numerous organisms dependant on specific sensitivities (Mabrook, 1994; Eniev *et al*., 2002), and by upsetting the osmotic balance, can lead to the dehydration of cells (Kirst, 1989; Ruso *et al.,* 2007).

Sub-lethal effects of changed salinity regimes (or salinity stress) can include modification of metabolic rate, change in activity patterns, slowing of development and alteration of growth rates (McLusky, 1981; Moullac *et al*., 1998), lowering of immune function (Matozzo *el al*., 2007) and increased mortality rates (Fagundez and Robaina, 1992). The limited data available include a reported tolerance of adults of the mussel *Mytilus edulis* of up to 60psu (Barnabe 1989), and successful fertilization (Clarke, 1992) and development (Bayne, 1965) of its larvae at a salinity of up to 40psu. The alga *Gracilaria verrucosa* can tolerate salinity ranges from 9-45psu (Engledow and Bolton, 1992). The shrimp *Penaeus indicus* was capable of tolerating a salinity range of 1 to 75psu if allowed an acclimation time of around 48 hours (McClurg 1974), the oyster *Crassostrea gigas* tolerated salinities as high as 44psu (King, 1977), and the shrimp *Penaeus monodon* survived in 40psu saline water (Kungvankij *et al*., 1986a, b, cited in DWAF, 1995). Chen *et al*. (1992) reported a higher moulting frequency in juveniles of the prawn *Penaeus chinensis* at a salinity of 40psu. Lethal effects were reported for seagrass species: for example, salinities of 50psu caused 100% mortality of the Mediterranean seagrass *Posidonia oceanica*, 50% mortality at 45psu, and 27% at 40psu. Salinity concentrations above 40psu also stunted plant growth and no-growth occurred at levels exceeding 48psu (Latorre, 2005). The high saline concentration can also lead to an increase of water turbidity, which is likely to reduce light penetration, an effect that might disrupt photosynthetic processes (Miri and Chouikhi, 2005). The increased salt concentration can reduce the production of plankton, particularly of invertebrate and fish larvae (Miri and Chouikhi, 2005). 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 by marine organisms. In a review on the effects of multiple stressors on aquatic organisms, Heugens *et al*. (2001) summarise that in general metal toxicity increases with decreasing salinity, while the toxicity of organophosphate insecticides increases with increasing salinity. 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; Rainbow and Black, 2002).

Very few ecological studies have been undertaken to examine the effects of high salinity discharges from desalination plants on the receiving communities. One example is a study on the macrobenthic community inhabiting the sandy substratum off the coast of Blanes in Spain (Raventos *et al.,* 2006). The brine discharge from this plant was approximately 33,700m^3/d, more than double the effluent volume considered for the Rössing Uranium desalination plant. Visual census of the macrobenthic communities were carried out at two control points (away from the discharge outlet) and one impacted (at the discharge outlet) location several times before and after the plant began operating. No significant variations attributable to the brine discharges from the desalination plant were found. This was partly attributed to the high natural variability that is a characteristic feature of seabeds of this type, and also to the rapid dilution of the hypersaline brine upon leaving the discharge pipe. Other studies, however, indicated that brine discharges have led to reductions in fish populations, and to die-offs of plankton and coral in the Red Sea (Mabrook, 1994), and to mortalities in mangrove and marine angiosperms in the Ras Hanjurah lagoon in the United Arab Emirates (Vries *et al.,* 1997). Salinity increases near the outfall of a RO plant on Cyprus were reported to be responsible for a decline of macroalgae forests, and echinoderm species vanished from the discharge site (Argyrou, 1999 cited in UNEP, 2008).

Research conducted on abalone (*Haliotis diversicolor supertexta*) has shown that they experience significant mortality at salinities greater than 38psu (Cheng and Chen, 2000). Cheng *et al.* (2004) demonstrated that salinity stress affects the immune system of abalone, making them more vulnerable to bacterial infection. The immune capabilities in bivalve molluscs (e.g. the clam *Chamelea gallina*, Matozzo *et al.,* 2007) and crustaceans (e.g. the prawn *Allacrobrachium rosenbergii*, Chen and Chen, 2000) have also been shown to be compromised by changes in salinity. The Indian spider lobster *Panulirus homarus*, suffered from a depressed immune system when exposed to salinities over 45psu, subsequently resulting in 100% mortality (Verghese *et al*., 2007). Desalination plants therefore have the potential to impact on the viability of fishing industries, if the brine accumulates beyond the optimal range for commercially important species.

The South African Water Quality guidelines (DWAF 2005) set an upper target value for salinity of 36psu. This is 1.8psu above the median ambient salinity (34.2psu) for the area (WSP, 2014b). The paucity of information on the effects of increased salinity on marine organisms makes an assessment of the high salinity plume difficult. However, this guideline seems sufficiently conservative to suggest that no adverse effects should occur for salinity <36psu. At levels exceeding 40psu, however, significant effects are expected, including possible disruptions to molluscan bivalves (e.g. mussels/oysters/clams) and crustacean (and possibly fish) recruitment as salinities >40psu may affect larval survival (e.g. Bayne, 1965; Clarke, 1992). 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.

In the case of the proposed Rössing Uranium desalination plant, the brine, which will have a salinity of ~66psu, will be discharged through a single port diffuser into the turbulent surf zone where the effluent would be expected to be rapidly diluted. The southern site pipe discharges 70m into the surf zone (measured from the high water mark) while the northern site will discharge at approximately 90m into the surf zone. Toxic effects of elevated salinities are likely to be experienced only by a very limited range of sensitive species, which may consequently be excluded from the sacrificial zone and/or the discharge gully. Most intertidal and shallow subtidal species are likely to experience sub-lethal effects only, if at all, and these would be restricted to within the immediate vicinity (i.e. within the discharge gully) of the outfall. As benthic communities within this region are largely ubiquitous and naturally highly variable at temporal and spatial scales, the loss or exclusion of sensitive species within the highly localised area around the outfall can be considered insignificant in both a local and regional context.

The results from the near-field dilution modelling study are summarised below. For greater detail, the report has been attached hereto as Annexure D7. Assuming a discharge with an exit velocity of 6 m/s through a single port located directly above the seabed in water depths of 0.9m to 2.3m and directed horizontally offshore, the model identified that the 18 times dilution required to meet the water quality guidelines[51] would not be achieved within an area of 64 m^2 to 66m^2 around the

[51] For each litre of effluent brine discharged from the RO plant, 17.7 litres of seawater must be mixed with the brine in order to dilute the brine to within 1.8g/l of the ambient receiving water salinity. According to the South African Marine Water Quality Guidelines (Department of Water Affairs and Forestry, 1995), the target value for salinity should range between 33.0g/l and 36.0 g/l. For this study the value of 36g/l is assumed. Thus, the difference in concentration between the published guidelines (36g/l) and the ambient salinity (34.2g/l) is 1.8g/l. As such, it is assumed that a dilution of the effluent brine in the near field to a level of 1.8 g/l above ambient is acceptable.

discharge point for a wave induced longshore current of 0.25m/s (energetic condition) and 0.08m/s (calm condition) perpendicular to the jet discharge direction, respectively. These dilution predictions can be considered conservative, however, as the interaction of jet discharges with surface waves was not taken into account in the model. Under the typically rough conditions along the coastline of the study area it can be assumed that required dilutions would be achieved well within this area and the observed effluent footprints would be considerably reduced or undetectable for most of the year. Therefore, only under under 'worst-case' conditions during a very calm period for a very short time (1% of the time), would the required dilutions not be achieved. Under such calm conditions, the brine would not be sufficiently mixed and would remain close to the seabed due to its greater density. The plume may thus extend through the narrow surf zone, potentially pooling in seabed depressions, and thereby resulting in a more extensive footprint. Frequent strong wind or storm events that are typical for this coastline are, however, likely to prevent any long term cumulative build up of high–density saline pools at the seafloor. Any detrimental effects on marine organisms would thus be sub-lethal and transient, and unlikely to be detectable above natural environmental perturbations.

When oscillating tidal currents and local surf zone processes were considered by way of an intermediate dilution model, it was identified that at the southern discharge site (Option 5), the maximum area influenced by the brine was 25 to 30m from the outfall diffuser in a cross-shore direction, and 35m to 45m in the alongshore direction. For the northern discharge site (Option 1), the area of influence amounted to 30m to 40m from the outfall diffuser in a cross-shore direction, and 35 to 50m in the alongshore direction. Within 15m of the discharge point, the achievable dilutions are thus achieved for most of the time, with only isolated periods of <0.5 days, when dilutions were not achieved.

Figure 100: The diluted intermediate brine influence area (Option 5 or Base Case)

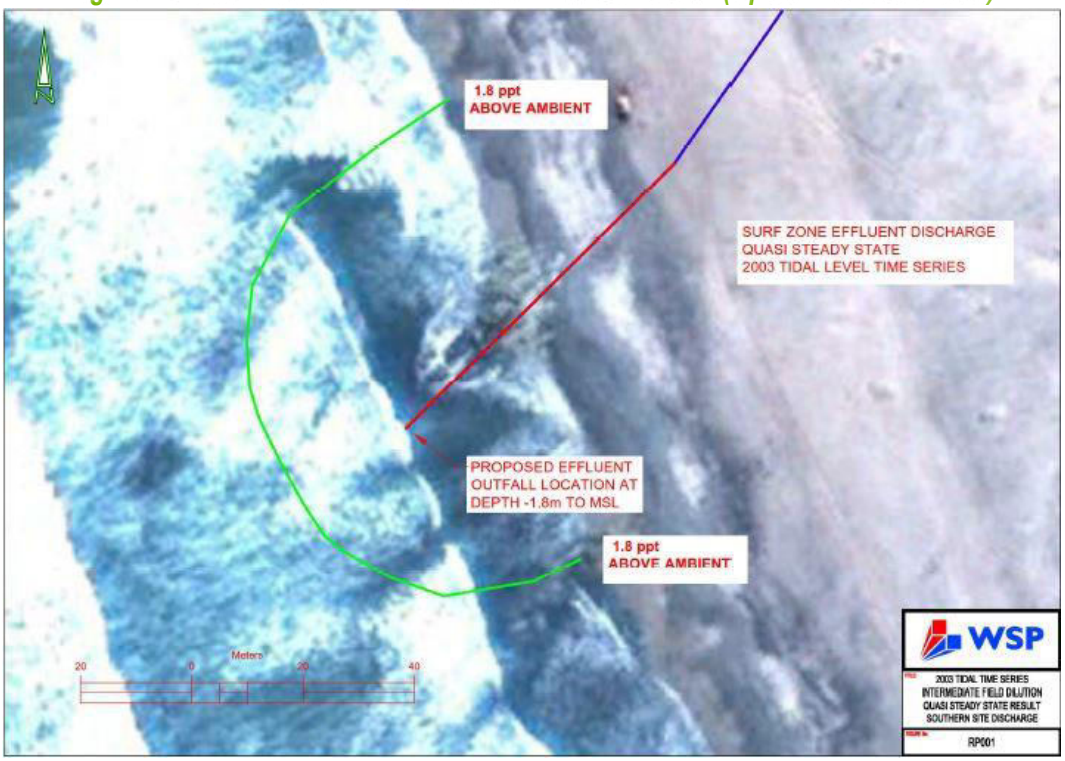


Figure 101: The diluted intermediate brine influence area (Alternative 1)

IMPACT ASSESSMENT: REDUCED PHYSIOLOGICAL FUNCTIONING OF MARINE ORGANISMS DUE TO ELEVATED SALINITY

Criteria \ Alternative	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	
Extent	Site specific	Site specific	Site specific	Site specific	Site specific	
Magnitude	Medium	Low	Low	Low	Low	
Duration	Long term	Long term	Long term	Long term	Long term	
SIGNIFICANCE	Medium (-)	Low (-)	Low (-)	Low (-)	Low (-)	Neutral
Probability	Probable	Probable	Probable	Probable	Probable	
Confidence	Sure	Sure	Sure	Sure	Sure	
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	

The effects of elevated salinities on the physiological functioning of marine organisms is considered to be of medium magnitude and dispersion modelling results indicate that should they occur, effects will remain localised (salinities return to ambient within a maximum radius of 22m from the diffuser port under transient, 'worst-case' conditions). Impacts will, however, persist over the operational life time of the plant. The impact is therefore assessed to be of Medium (-) significance without mitigation. Mitigation in the form of suitable engineering designs to ensure adequate dispersion and dilution of the brine in the receiving surf zone environment would reduce the significance to Low (-).

Proposed mitigation measures:

- Ensure engineering designs at the seaward end of the discharge pipe achieve the highest required dilution of brine (18 times), thereby limiting increased salinities to the minimum achievable mixing zone only.
- Implement a water quality monitoring programme to validate the predictions of the hydrodynamic modelling study and monitor constituents of the effluent to ensure compliance with water quality guidelines.

IMPACT ASSESSMENT: AVOIDANCE BEHAVIOUR BY INVERTEBRATES, FISH AND MARINE MAMMALS OF THE DISCHARGE AREA

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	
Extent	Site specific	Site specific	Site specific	Site specific	Site specific	
Magnitude	Low	Low	Low	Low	Low	
Duration	Long term	Long term	Long term	Long term	Long term	
SIGNIFICANCE	Low (-)	Low (-)	Low (-)	Low (-)	Low (-)	Neutral
Probability	Probable	Probable	Probable	Probable	Probable	
Confidence	Certain	Certain	Certain	Certain	Certain	
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	

Avoidance of the brine footprint by marine organisms is considered to be of low magnitude and would remain confined to the mixing zone. Impacts will, however, persist over the operational life time of the plant. The impact is therefore assessed to be of **Low (-)** significance without mitigation, reducing to Very Low (-) significance with the implementation of mitigation.

Proposed mitigation measures:

- Ensure engineering designs at the seaward end of the discharge pipe achieve the highest required dilution of brine (18times), thereby limiting increased salinities to the minimum achievable mixing zone only.
- Implement a water quality monitoring programme to validate the predictions of the hydrodynamic modelling study and monitor constituents of the effluent to ensure compliance with water quality guidelines.

IMPACT DESCRIPTION: TEMPERATURE

Generally, there is no heating process of the intake water in RO desalination plants. However, the temperature of the feed water may increase slightly during its passage along the inland channel and in the seawater holding pond due to increases exposure to solar radiation and other climatic drivers, i.e. wind. Such an increase is not expected to exceed 3°C.

Bamber (1995) defined four categories for direct effects of thermal discharges on marine organisms:

- Increases in mean temperature;
- Increases in absolute temperature;
- High short term fluctuations in temperature; and
- Thermal barriers.

Increased mean temperature

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); and
- Influences on ecosystem functioning (e.g. through altered oxygen solubility).

The impacts of increased temperature have been reviewed in a number of studies along the West Coast of South Africa (e.g. Luger *et al*., 1997; van Ballegooyen and Luger, 1999; van Ballegooyen *et al*. 2004, 2005). A synthesis of these findings is given below.

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 a reduction in respiration rate of adult *J. lalandii* at elevated temperatures.

Other reported effects include an increase in biomass of shallow water hake *Merluccious capensis* and West Coast sole *Austroglossus microlepis* at 18°C (MacPherson and Gordoa 1992) but no influence of temperatures of <17.5°C on chub-mackerel *Scomber japonicus* (Villacastin-Herroro *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 (van Ballegooyen *et al*., 2005). On a physiological level, however, some adverse effects were observed, mainly in the development of eggs and larvae (e.g. Cook, 1978; Sandstrom *et al*., 1997; Luksiene *et al*., 2000).

The South African Water Quality Guidelines recommend that the maximum acceptable variation in ambient temperature should not exceed 1°C (DWAF, 2005), which is an extremely conservative value in view of the negligible effects of thermal plumes on benthic assemblages reported elsewhere for a ΔT of +5°C or less.

All benthic species have preferred temperature ranges and it is reasonable to expect that those closest to their upper limits (*i.e.* boreal as opposed to temperate) would be negatively affected by an increase in mean temperature. The sessile biota in the Benguela region are, however, naturally exposed to wide temperature ranges due to surface heating and rapid vertical mixing of the water column and intrusions of cold bottom shelf water into the system. It can thus be assumed that the biota in these waters will be relatively robust and well-adapted to substantial natural variations in temperature.

The application of the ANZECC (2000) water quality guideline (that requires that the median temperature in the environment with an operational discharge should not lie outside the 20 and 80 percentile temperature values for a reference location or ambient temperatures observed prior to the construction and operation of the proposed discharge), may be more appropriate to the high temperature variability conditions in the study area. Conditions in the surf zone are, however, expected to be well mixed and thermoclines would not be expected.

Although not modelled for the current study, no discernible temperature footprint would be expected as temperature differences between the brine and receiving waters are expected to be <3°C. Although this would not be compliant with either the South African Water Quality Guidelines (DWAF, 2005) or the ANZECC (2000) guidelines, discharge into the turbulent surf zone would ensure rapid mixing of the thermal footprint with the receiving water. Furthermore, as seawater temperatures in the area vary between 10°C and 23°C, the biota are well adapted to temperature fluctuations and a localised increase in temperature of <3°C is not expected to have significant effects.

Increased absolute temperature

The maximum observed sea surface temperature in the region typically is <18°C. Strong wind events and wave action in the surf zone are likely to mix the water column to such an extent that the bottom waters will have similar water temperatures to the surface waters. The discharged brine will not be heated above this naturally occurring maximum temperature and therefore an increase in absolute temperature is not expected and is not further assessed here.

Short term fluctuations in temperature and thermal barriers

Temperature fluctuations are typically caused by variability in flow or circulation driven by frequently reversing winds or tidal streams. For example, Bamber (1995) described faunal impoverishment in a tidal canal receiving hot water effluent where the temperature variability was ~12°C over each tidal cycle. As noted above, although likely well mixed by surf zone turbulence, the receiving waters in the area may vary rapidly in temperature and the ecological effects of potential brine-induced changes of <3°C in temperature are therefore not further assessed.

For thermal barriers to be effective in limiting or altering marine organism migration paths they need to be persistent over time and cover a large cross-sectional area of the water body. The predictions for the brine plume distributions indicate that neither condition will be met in the study area. Although the migration pathways of various fish species (e.g. snoek, silver kob,dusky kob, white steenbras, Wes Coast steenbras) potentially pass through the impact area, the salinity footprint does not typically extend more than 100m offshore and 100m alongshore, and effects of the plume on the migratory behaviour of these species is thus considered highly unlikely.

IMPACT ASSESSMENT: REDUCED PHYSIOLOGICAL FUNCTIONING OF MARINE ORGANISMS DUE TO ELEVATED TEMPERATURE

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	
Extent	Site specific	Site specific	Site specific	Site specific	Site specific	
Magnitude	Very low	Very low	Very low	Very low	Very low	
Duration	Long term	Long term	Long term	Long term	Long term	
SIGNIFICANCE	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
Probability	Probable	Probable	Probable	Probable	Probable	
Confidence	Certain	Certain	Certain	Certain	Certain	
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	

The effects of elevated temperature on marine communities are considered to be of low magnitude. Impacts will, however, persist over the operational life time of the plant. The impact is therefore assessed to be of Very Low (-) significance without mitigation. Mitigation in the form of suitable engineering designs to ensure adequate dispersion and mixing of the effluent in the receiving surf zone environment would reduce the probability of the impact occurring but maintain the significance atVery Low (-).

Proposed mitigation measures:

- Ensure engineering designs at the seaward end of the discharge pipe achieve the highest required dilution of brine (18x), thereby limiting temperature elevations to the minimum achievable mixing zone only.
- Implement a water quality monitoring programme to validate the predictions of the hydrodynamic modelling study and monitor constituents of the effluent to ensure compliance with water quality guidelines.

IMPACT DESCRIPTION: DISSOLVED OXYGEN

Dissolved oxygen (DO) 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 owing to extremely high primary production and subsequent oxidative degeneration of organic matter. Along the southern African west coast, low-oxygen waters are a feature of the Benguela system.

Hypoxic water (<2,000m^3 O_2/ℓ) 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). Further anaerobic degradation of organic matter by sulphate-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. The temperature of the effluent is not significantly elevated in relation to the intake water temperature, and a reduction in dissolved oxygen is thus only expected as a result of the elevated salinity of the brine. For example, saturation levels of dissolved oxygen in seawater decrease with rising salinity from 5.69Mℓ/ℓ at 15˚C and 35psu, to 4.54Mℓ/ℓ at for example 67.5psu (DWAF 1995), not taking into account any biological use of oxygen due to respiration, oxidation and degradation. In summer months the surface water may reach temperatures of 23°C, and the saturation level of dissolved oxygen in the brine at this temperature would decline from 4.91Mℓ/ℓ at 35psu to 3.97Mℓ/ℓ at 67.5psu. These approximate calculations for example brine of 67.5psu translate into a 19% to 20% reduction of dissolved oxygen in the brine. The South African Water Quality Guidelines for Coastal Marine Waters (DWAF 2005) state that for the west coast, the dissolved oxygen should not fall below 10% of the established natural variation. A potential difference in dissolved oxygen concentration of 20% is within the natural variability range of the waters in the Benguela, and the potential for a reduction in dissolved oxygen levels will also drastically reduce within a few meters of the outlet as the receiving water body is very shallow and therefore likely to be well mixed.

Near-bottom waters on the southern African West Coast are often characterised by hypoxic conditions as a result of decomposition of organic matter and low-oxygen water generation processes. A decrease in dissolved oxygen levels in the discharged brine is thus not of great concern. Cumulative effects may occur though during such low oxygen events but compared to the potentially large footprint of the natural hypoxic water masses, the footprint of the effluent itself will be minimal.

As discussed above, the expected changes in dissolved oxygen are associated with both direct changes in dissolved oxygen content due to the difference between the ambient dissolved oxygen concentrations and those in the effluent being discharged. However, indirect changes in dissolved oxygen content of the water column and sediments due to changes in hydrodynamic and ecosystem functioning in the area are also possible. For example, oxygen concentrations may change (particularly in the bottom waters and in the sediments) due to changes in phytoplankton production as a result of changes in nutrient dynamics (both in terms of changes in nutrient inflows and vertical mixing of nutrients) and subsequent deposition of organic matter. Several of the scale control additives typically used in desalination plant operations has the potential to act as nutrients for plants (e.g. sodium tripolyphosphate and trisodium phosphate). In principle the phosphate can act as a plant nutrient and thus increase algal growth (Lattemann and Höpner, 2003), however, phosphate generally is not limiting in marine environments, unless there are significant inputs of nitrogen (nitrates, ammonia), which is the limiting nutrient in such systems.

A critical factor that also needs to be taken into account is that oxygen depletion in the brine might occur through the addition of sodium metabisulfite (SMBS), which is commonly used as a neutralizing agent for chlorine (Lattemann and Höpner, 2003) (see below). SMBS is an oxygen scavenger and if not properly dosed, can severely deplete the dissolved oxygen in the discharged water. In such cases, aeration of the effluent is recommended prior to discharge, in which case, the brine may in fact have a higher dissolved oxygen concentration than the receiving water body during natural low oxygen events.

IMPACT ASSESSMENT: REDUCED PHYSIOLOGICAL FUNCTIONING OF MARINE ORGANISMS DUE TO REDUCED DISSOLVED OXYGEN CONCENTRATIONS

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	
Extent	Site specific	Site specific	Site specific	Site specific	Site specific	
Magnitude	Medium	Medium	Medium	Medium	Medium	
Duration	Short term	Short term	Short term	Short term	Short term	
SIGNIFICANCE	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
Probability	Probable	Probable	Probable	Probable	Probable	
Confidence	Certain	Certain	Certain	Certain	Certain	
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	

The effects of reduced dissolved oxygen concentrations on marine communities are considered to be of medium magnitude and effects will likely remain localised. Impacts will, however, persist in the very short-term only, as 1) plankton blooms (should they occur) in response to elevated nutrients would be ephemeral only, and 2) accidental overdosing of SMBS would occur intermittently only, despite dechlorination being practiced over the life time of the plant. The impact is therefore assessed to be Insignificant.

Proposed mitigation measures:

- Avoid overdosing with SMBS or aerate effluent prior to discharge.
- Implement a water quality monitoring programme to monitor constituents of the effluent to ensure compliance with water quality guidelines.

IMPACT DESCRIPTION: PRE-TREATMENT OF INTAKE WATERS

Pre-treatment of the intake water and periodical cleaning of the RO membranes is essential in the effective operation of desalination plants. Pre-treatment and cleaning include treatment against biofouling, suspended solids, and scale deposits. The type of pre-treatment system used is

determined primarily by the intake type (e.g. pre-treatment for open water intake is generally more complex and comprehensive than that for sub-surface intakes) and the feed-water quality. Standard desalination technology typically involves chemical pre-treatment as well as chemical membrane cleaning. More recently, innovative environmentally friendly desalination technology has been developed, which involves effective filtration at the pre-treatment phase thereby minimising biofouling and eliminating the need for pre-treatment biocides and membrane cleaning chemicals (i.e. no coagulants or disinfectants required).

As both technologies are being considered for the Rössing Uranium desalination plant, for the sake of completeness, an assessment of potential pre-treatment chemicals and membrane cleaning additives is provided below.

The main components of a chemical pre-treatment system for the desalination plant are:

- Control of biofouling by addition of an oxidising (chlorine-based) or non-oxidising (e.g. Dibromonitrilopropionamide (DBNPA)) biocide, and dechlorination with sodium metabisulfite (in the case of chlorine-based products),
- Removal of suspended material by flocculation (possibly bioflocculation),
- Control of scaling by acid addition (lowering the pH of the incoming seawater) and/or dosing of special 'antiscalant' chemicals,
- Cartridge filters as a final protection barrier against suspended particles and microorganisms before the RO units.

Transport of the feedwater along the overland channel and interim storage in an inland seawater pond system will facilitate the settling out of any organic material abstracted with the seawater prior to the feedwater entering the plant, thereby reducing the need for excessive biocides and/or chemicals co-discharged with the brine.

Biocides

Chlorination of the intake water is undertaken to ensure that the pumping systems (e.g. intake pipe and membranes) are maintained free of biofouling organisms. For example, larvae of sessile organisms (e.g. mussels, barnacles) can grow in the intake pipe, and impede the intake flow of the feed-water. Biofouling of the membranes by algae, fungi and bacteria can rapidly lead to the formation and accumulation of slimes and biofilms, which can increase pumping costs and reduce the lifespan of the membranes.

There are two main groups of biocides: the oxidising biocides and the non-oxidising biocides. The classification is based on the mode of biocidal action against biological material. Oxidising biocides include chlorine and bromine-based compounds and are non-selective with respect to the organisms they kill. Non-oxidising biocides are more selective, in that they may be more effective against one type of micro-organisms than another. A large variety of active ingredients are used as non-oxidising biocides, including quaternary ammonium compounds, isothiazolones, halogenated bisphenols, thiocarbamates and others. In desalination plants, the non-oxidising Dibromonitrilopropionamide (DBNPA) is frequently used as an alternative to an oxidising biocide. DBNPA has extremely fast antimicrobial action and rapid degradation to relatively non-toxic end products. A summary of its environmental fate is included in Appendix A.3 to the marine ecology report, attached hereto as Annexure D6.

Should a biocide be required for the Rössing Uranium desalination plant, it is proposed that either sodium hypochlorite (NaOCl) or chlorine gas be used. The chlorine-based biocide should be added intermittently at the plant's intake structure as shock dosages of 10 minute duration every 4 hours. This would likely only be required in the case of a long pipeline running from the intake all the way to

the plant. If the plant uses the channel system then treatment with a biocide at the seawater intake cannot be permitted and dosing would occur at the plant intake. In this event the short seawater intake pipes will need to be mechanically cleaned by pigging.

Before the feed-water enters the RO units, residual chlorine needs to be neutralised with sodium metabisulfite (SMBS) to avoid membrane damage, as RO membranes are typically made from polyamide materials which are sensitive to oxidising chemicals such as chlorine. As a consequence, chlorine concentration will be very low to non-detectable in the brine effluent of the plant and is thus assumed to be below the 3µg/ℓ limit as permitted by ANZECC (2000), which provides the most conservative guideline value.

Compliance with the guidelines is thus expected, but for the sake of completeness a summary of chlorine chemistry and its potential effects on the receiving environment is provided as Appendix A.2 to the Marine ecology impact assessment (attached here as Annexure D6). This serves to highlight the importance of assuring that chlorine is at all times sufficiently neutralised before discharge of the brine.

IMPACT ASSESSMENT: DETRIMENTAL EFFECTS ON MARINE ORGANISMS DUE TO RESIDUAL CHLORINE LEVELS IN THE MIXING ZONE

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	
Extent	Site specific	Site specific	Site specific	Site specific	Site specific	
Magnitude	High	Very low	Very low	Very low	Very low	
Duration	Medium term	Medium term	Medium term	Medium term	Medium term	
SIGNIFICANCE	Medium (-)	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
Probability	Definite	Definite	Definite	Definite	Definite	
Confidence	Certain	Certain	Certain	Certain	Certain	
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	

The effects of residual chlorine on marine communities are considered to be of high magnitude, but effects will likely remain localised. Impacts will persist over the medium-term as impacted marine communities will recover within 2-5 years. The impact is therefore assessed to be of Medium (-) MEDIUM significance without mitigation, but would reduce to Very Low (-) with mitigation.

Proposed mitigation measures:

- Implement shock dosing of biocide in preference to continual dosing.
- Dechlorinate effluent prior to discharge with sodium metabisulphite (SMBS).
- Undertake ‘pigging’ of intake and discharge pipelines to reduce the need for and costs of biocides.
- Use a non-oxidising biocide (DBNPA) in preference to chlorine.
- Implement a water quality monitoring programme to monitor constituents of the effluent to ensure compliance with water quality guidelines.
- Give serious consideration to implementing the chemical –free ProGreen™ technology.

IMPACT DESCRIPTION: HALOGENATED BY-PRODUCTS

A major disadvantage of chlorination is the formation of organohalogen compounds (e.g. trihalomethanes, see Appendix A.2 of the marine ecology impact assessment which is attached here as Annexure D6). However, as only a few percent of the total added chlorine is recovered as halogenated by-products, and as by-product diversity is high, the environmental concentration of each substance can be expected to be relatively low. Dechlorination will further considerably reduce the potential for by-product formation. Nonetheless, there is some evidence that chlorinated-

dechlorinated seawater increased mortality of test species and chronic effects of dechlorinated seawater were observed, which were assumed to be due to the presence of halogenated organics formed during chlorination (see UNEP, 2008).

IMPACT ASSESSMENT: CHRONIC EFFECTS ON MARINE ORGANISMS DUE TO FORMATION OF HALOGENATED BY-PRODUCTS

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	
Extent	Site specific	Site specific	Site specific	Site specific	Site specific	
Magnitude	Medium	Medium	Medium	Medium	Medium	
Duration	Long term	Long term	Long term	Long term	Long term	
SIGNIFICANCE	Low (-)	Low (-)	Low (-)	Low (-)	Low (-)	Neutral
Probability	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	
Confidence	Certain	Certain	Certain	Certain	Certain	
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	

The effects of halogenated by-products on marine communities are considered to be of medium magnitude, but effects will be chronic and endure over the long-term. However, as only a very small percentage of the chlorine will transform into toxic by-products that cannot be eliminated by dechlorination and the likelihood of halogenated by-products reaching lethal concentrations is very low the impact would reduce to be of Low (-) significance both without and with mitigation.

Proposed mitigation measures:

- No direct mitigation is possible as chlorine chemistry is complex and type and concentrations of by-product formation cannot be predicted.
- Implement a water quality monitoring programme to monitor constituents of the effluent to ensure compliance with water quality guidelines.
- Give serious consideration to implementing the chemical –free ProGreen™ technology.

IMPACT DESCRIPTION: DE-CHLORINATION

SMBS is a powerful reducing agent that reduces hypobromous acid (HOBr) to hydrobromic acid (HBr) and is in turn oxidised to sulfate. Although the reaction products are non-hazardous, SMBS may cause oxygen depletion if dosing is not optimised. However, SMBS rapidly reacts with free chlorine but has a much slower reaction with naturally occurring dissolved oxygen. The reaction chemistry involved also means that SMBS can remove less oxygen from the seawater than the quantity of chlorine they are capable of removing. In case of overdosing with SMBS and resultant low oxygen levels, aeration of the effluent, prior to discharge may be necessary.

IMPACT ASSESSMENT: REDUCTION IN DISSOLVED OXYGEN CONCENTRATIONS AS A RESULT OF DECHLORINATION

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	~
Extent	Site specific	Site specific	Site specific	Site specific	Site specific	~
Magnitude	Low	Low	Low	Low	Low	~
Duration	Short term	Short term	Short term	Short term	Short term	~
SIGNIFICANCE	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
Probability	Probable	Probable	Probable	Probable	Probable	Definite
Confidence	Certain	Certain	Certain	Certain	Certain	Certain
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	~

As marine communities in the Benguela system are adapted to naturally occurring hypoxia, the effect is considered to be of low magnitude, of localised extent and persisting over the short-term only. The impact is therefore assessed to be of Very Low (-) significance without mitigation, and with mitigation.

Proposed mitigation measures:

- Implement shock dosing of biocide in preference to continual dosing.
- Avoid over-dosing of SMBS.
- Aerate the effluent prior to discharge.
- Implement a water quality monitoring programme to monitor constituents of the effluent to ensure compliance with water quality guidelines.
- Give serious consideration to implementing the chemical –free ProGreen™ technology.

IMPACT DESCRIPTION: BACTERIAL RE-GROWTH

Excessive bacterial re-growth in the brine after chlorination is a further concern. For example, this was reported for a RO desalination plant in Egypt (Diab, 2002), where bacterial counts in the brine were 7 to 10 times higher than those in the feed-water thereby posing potential health risks to marine biota as well as users of the marine environment (e.g. swimmers, surfers, divers). Besides inadequate maintenance of the plant and an ineffective cleaning in place (CIP) process, excessive bacterial after growth has also been attributed to the use of continuous chlorination. The reason for this ineffectiveness is that chlorination results in the breakdown of high molecular dissolved organics into nutrients, thus forming assimilable organic carbon (AOC). In addition, microorganisms subject to low levels of biocides often exude extracellular polysaccharides as a protective biofilm that increases their survival rate. Both, the availability of surplus nutrients and the survival of some microorganisms can cause a heavy re-growth in desalination systems following chlorination (UNEP, 2008). For most large RO facilities, continuous chlorination has proven ineffective and has been replaced by intermittent shock chlorination. Shock dosing is also proposed for this project. In severe cases of biological growth, additional shock treatment may become necessary to re-establish low bacterial numbers from time to time. Sodium metabisulfite is most commonly used for this purpose; with a typical application of 500 to 1,000mg/ℓ for 30 minutes (Redondo and Lomax, 1997). It has to be noted though that SMBS reduces bacterial numbers by oxygen depletion and is therefore only effective against aerobic microorganisms, while some other bacteria might survive in anaerobic conditions.

IMPACT ASSESSMENT: EXCESSIVE BACTERIAL RE-GROWTH IN THE BRINE AFTER CHLORINATION

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	~
Extent	Site specific	Site specific	Site specific	Site specific	Site specific	~
Magnitude	Low	Low	Low	Low	Low	~
Duration	Long term	Long term	Long term	Long term	Long term	~
SIGNIFICANCE	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
Probability	Probable	Probable	Probable	Probable	Probable	Definite
Confidence	Certain	Certain	Certain	Certain	Certain	Certain
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	~

The health risks associated with excessive bacterial re-growth following chlorination are considered to be of low magnitude, will likely remain localised, but may persist over the life time of the plant. The impact is therefore assessed to be of Very Low (-) significance without mitigation. The implementation of mitigation measures would ensure that should bacterial regrowth occur, this would only persist in the short-term, and significance would remain Very Low (-).

Proposed mitigation measures:

- Use intermittent shock dosing with a biocide to avoid bacterial resistance to the biocide.
- Monitor the brine for excessive bacterial re-growth and if necessary use SMBS shock dosing to reduce bacterial numbers (note that the brine will be oxygen depleted after this treatment and needs to be aerated before discharge).
- Ensure efficient CIP process and adequate maintenance of plant.
- Implement a water quality monitoring programme to monitor constituents of the effluent to ensure compliance with water quality guidelines.
- Give serious consideration to implementing the chemical –free ProGreen™ technology.

IMPACT DESCRIPTION: CO-DISCHARGED WASTE-WATER CONSTITUENTS

In addition to the biocide dosing, the pre-treatment of the feed-water includes the removal of suspended solids, the control of scaling, and the periodical cleaning in place of the RO membranes. Specifications and volume estimates of cleaning chemicals that may be used in the pre-treatment and CIP process, to be co-discharged with the brine effluent, have been provided in section 3.5.6 of this report. This section (below) thus describes the use and effects of cleaning chemicals that are used conventionally in desalination plants with an open water intake.

Ferric chloride ($FeCl_3$) will be used as primary coagulant or flocculent in the pre-treatment system. When added to water, a hydrolysis reaction produces an insoluble ferric hydroxide precipitate that binds non-reactive molecules and colloidal solids into larger aggregations that can then be more easily settled / floated or filtered from the water before it passes through to the RO membranes. Dosing of sulfuric acid to establish slightly acidic pH values and addition of coagulant aids such as polyelectrolytes can enhance the coagulation process. Polyelectrolytes are organic substances with high molecular masses (like polyacrylamide) that help to bridge particles together. The dosage of coagulants and coagulant aids is normally correlated with the amount of suspended material in the intake water. It can range between < 1 and 30mg/ℓ for coagulants and between 0.2 and 4mg/ℓ for polyelectrolytes. The resulting ferric hydroxide floc is retained when the seawater passes through the filter beds. The filters are backwashed on a periodic basis (few times every day), using filtered seawater or permeate water, to clean the particulate material off the filters. This produces a sludge that contains mainly sediments and organic matter, and filter coagulant chemicals. When co-discharged to the sea, ferric chloride may cause discoloration of the receiving water, and the sludge discharge may lead to increases in turbidity and suspended matter and could have benthos blanketing effects (Sotero-Santos *et al.,* 2007, Lattemann and Höpner, 2003).

For larger desalination plants it is considered best practice to collect the filter screenings and sludge (including those from the dissolved air floatation and ProGreen bio flocculation process, if used) and desiccate it before being disposed of via landfill, however in the case of the Rössing Uranium desalination plant, due to the small plant capacity, these solids may be co-discharged with the brine, and allowed to diffuse back to ambient concentrations. The impact to marine ecology associated with the release of these solids back to the ocean is assessed as being low. After passing through the filter beds, the feed-water is put through a Dissolved Air Flotation (DAF) tank. DAF is a water treatment process that clarifies waters by the removal of suspended matter such as oil or solids. The removal is achieved by dissolving air in the water under pressure and then releasing the air at atmospheric pressure in a flotation tank or basin. The released air forms tiny bubbles which adhere to the suspended matter causing the suspended matter to float to the surface of the water where it may then be removed by a skimming device. It should also be noted that ProGreen™ bio-flocculation process would also produce a sludge that would need to be co-discharged. However, this sludge would not contain chemical flocculant residues.

IMPACT ASSESSMENT: DETRIMENTAL EFFECTS ON MARINE ORGANISMS THROUGH DISCHARGE OF CO-POLLUTANTS IN BACKWASH WATERS

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	~
Extent	Site specific	Site specific	Site specific	Site specific	Site specific	~
Magnitude	Low	Low	Low	Low	Low	~
Duration	Long term	Long term	Long term	Long term	Long term	~
SIGNIFICANCE	Low (-)	Low (-)	Low (-)	Low (-)	Low (-)	Neutral
Probability	Probable	Probable	Probable	Probable	Probable	Definite
Confidence	Certain	Certain	Certain	Certain	Certain	Certain
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	~

It is expected that the footprints for typical dilutions and dispersion of co-pollutants in the brine will diffuse at a similar rate to the brine, although these tend to be found at lower concentrations than the salinity, which is likely to drive the zone of influence or footprint (this need to be verified through an impact verification monitoring program following plant commissioning, including Whole Effluent Toxicity testing, and should the residual concentrations of any co-discharge be found to be higher than the water quality guidelines or relevant standard, then additional measures may be needed to achieve the relevant standard). The effects on marine communities of discharging co-pollutants with the brine are considered to be of low magnitude, will remain localised (within a maximum of 22m under transient, 'worst-case' conditions), but would persist over the life time of the plant. The impact is therefore assessed to be of Low (-) significance without mitigation, and would remain Low (-) after mitigation.

Proposed mitigation measures:

- Use low-toxicity chemicals as far as practicable.
- Implement a water quality monitoring programme to monitor constituents of the effluent to ensure compliance with water quality guidelines.
- Give serious consideration to implementing the chemical –free ProGreen™ technology (the use of the ProGreen™ technology may lower the impact significance, which is currently not reflected in the above impact table).

IMPACT DESCRIPTION: ANTISCALANTS

Scaling on the inside of tubes or on RO membranes impairs plant performance and electrical efficiency. Antiscalants are commonly added to the feed-water in desalination plants to prevent scale formation. The main representatives of antiscalants are organic, carboxylic-rich polymers such as polyacrylic acid and polymaleic acid. Acids and polyphosphates are still in use to a limited degree but are generally on the retreat as they can cause eutrophication. Polyphosphate antiscalants are easily hydrolysed to orthophosphate, which is an essential nutrient for primary producers. Their use may cause a nutrient surplus and an increase in primary production at the discharge site, through formation of algal blooms and increased growth of macroalgae (DWAF, 2007). When the organic material decays, this in turn can lead to oxygen depletion.

In contrast, phosphonate and organic polymer antiscalants have a low toxicity to aquatic invertebrate and fish species, but some substances exhibit an increased toxicity to algae. The typical antiscalant dosing rate in desalination plants (1 to 2mg/ℓ), however, is a factor of 10 lower than the level at which a chronic effect was observed (20mg/ℓ), and it is 10 to 5,000 times lower than the concentrations at which acutely toxic effects were observed. It is recommended that phosphonate be used as the antiscalant for the Rössing Uranium desalination plant, with antiscalant concentration in the brine of 4 to 5mg/ℓ, which would be far below chronic effects level. Due to the antiscalants capability of binding

nutrients they may, however, interfere with the natural processes of dissolved metals in seawater following discharge (see UNEP, 2008). Some of these metals may be relevant micronutrients for marine algae.

IMPACT ASSESSMENT: DETRIMENTAL EFFECTS ON MARINE ORGANISMS THROUGH DISCHARGE OF ANTISCALANTS IN BACKWASH WATERS

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	
Extent	Site specific	Site specific	Site specific	Site specific	Site specific	
Magnitude	Low	Low	Low	Low	Low	
Duration	Long term	Long term	Long term	Long term	Long term	
SIGNIFICANCE	Low (-)	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
Probability	Probable	Probable	Probable	Probable	Probable	
Confidence	Certain	Certain	Certain	Certain	Certain	
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	

The effects on marine communities of discharging antiscalants with the brine are considered to be of low magnitude, will remain localised (within a maximum of 22m under transient, 'worst-case' conditions), but would persist over the life time of the plant. The impact is therefore assessed to be of Low (-) significance without mitigation, but would reduce to Very Low (-) with mitigation.

Proposed mitigation measures:

- Limit the use of scale-control additives to minimum practicable quantities.
- Avoid antiscalants that increase nutrient levels (e.g. polyphosphate antiscalants).
- Select an antiscalant that has relevant eco-toxicological testing.
- Conduct Whole Effluent Toxicity (WET) testing of the brine effluent.
- Implement a water quality monitoring programme to monitor constituents of the effluent to ensure compliance with water quality guidelines.
- Give serious consideration to implementing the chemical –free ProGreen™ technology.

IMPACT DESCRIPTION: CLEANING IN PLACE CHEMICALS

Despite feed-water pre-treatment, membranes may become fouled by biofilms, accumulation of suspended matter and scale deposits, necessitating periodic cleaning. In standard desalination technology plants, the cleaning intervals (CIP) of RO membranes are typically three to six months depending on the quality of the plant's feed-water (Einav *et al.*, 2002). The cleaning interval suggested for the proposed desalination plant is four times per year. The chemicals used are mainly weak acids and detergents. Alkaline cleaning solutions (pH 11-12) are used for removal of silt deposits and biofilms, whereas acidified solutions (pH 2-3) remove metal oxides and scales. Further chemicals such as detergents, oxidants, complexing agents and/or non-oxidising biocides for membrane disinfection, are often added to improve the cleaning process. These additional chemicals are usually generic types or special brands recommended by the membrane manufacturers. Common cleaning chemicals include Sulphuric acid, Ethylenediaminetetra-acetic acid (EDTA), Sodium tripolyphosphate (STPP), and Trisodium phosphate (TSP), and Dibromonitrilopropionamide (DBNPA) as the non-oxidising biocide.

After the cleaning process is complete and the cleaning agents have been circulated through the membranes, the membranes are rinsed with product water several times. For the Rössing Uranium desalination plant project, it is proposed that the residual membrane cleaning solution and rinse water will be blended with the other residual streams from the DAF and filtration systems, and drip-fed into the brine effluent. Generally, the toxicity of the various chemicals used in the pre-treatment

and CIP process (aside from biocides) is relatively low, and none of the products are listed as tainting substances (DWAF, 2005).

For assessment purposes, the near-field model used dilution target values of 18-times dilution. These are merely nominal conservative required dilutions that provide indicative results for potential co-discharges. The assumption here is that the respective water quality guidelines will be sufficiently stringent for required dilutions for co-discharges of at least 18times to be necessary. The model outputs, however, could be re-processed assuming any specified thresholds deemed to be representative of the pollutant of concern. In that sense the modelling approach utilised was entirely generic and scalable.

The area around the discharge point where the required dilution is not achieved occurs only during intermittent and short periods of extreme calm. It is unlikely that in such short time a surplus of nutrients will lead to a significant increase in algal production, or in the case of antiscalants, to a noticeable reduction in micronutrients. Mitigating measures include discharge of the brine through a diffuser, and the avoidance of polyphosphate antiscalants. A Whole Effluent Toxicity test of the discharged brine is recommended to more reliably assess the impact of any co-discharged constituents and to calculate the required dilution rate.

IMPACT ASSESSMENT: DETRIMENTAL EFFECTS ON MARINE ORGANISMS OR AMBIENT SEAWATER PH THROUGH DISCHARGE OF RESIDUAL CLEANING SOLUTIONS USED PERIODICALLY FOR CLEANING IN PLACE

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	
Extent	Site specific	Site specific	Site specific	Site specific	Site specific	
Magnitude	Very low	Very low	Very low	Very low	Very low	
Duration	Short term	Short term	Short term	Short term	Short term	
SIGNIFICANCE	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
Probability	Probable	Probable	Probable	Probable	Probable	
Confidence	Certain	Certain	Certain	Certain	Certain	
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	

The effects on marine communities of discharging CIP chemicals with the brine are considered to be of very low magnitude and will likely remain localised (within a maximum of 22 m under transient, 'worst-case' conditions). As discharge will be intermittent, effects are likely to persist over the short-term only. The impact is therefore assessed to be of Very Low (-) significance without mitigation, and with mitigation.

Proposed mitigation measures:

- Collect residual cleaning solutions and membrane filter washes and neutralize and remove solids before discharge.
- Use low-toxicity chemicals as far as practicable.
- Conduct Whole Effluent Toxicity (WET) testing of the brine effluent.
- Implement a water quality monitoring programme to monitor constituents of the effluent to ensure compliance with water quality guidelines.
- Give serious consideration to implementing the chemical –free ProGreen™ technology.

IMPACT DESCRIPTION: HEAVY METALS

The brine from a desalination plant often contains low amounts of heavy metals that pass into solution when the plant's interior surfaces corrode. In RO plants, non-metal equipment and stainless

steels are typically used. The RO brine may therefore contain traces of iron, nickel, chromium and molybdenum, but contamination levels are generally low (Hashim and Hajjaj, 2005; Lattemann and Höpner, 2003). Heavy metals tend to enrich in suspended material and finally in sediments, so that areas of restricted water exchange and soft bottom habitats impacted by the discharge could be affected by heavy metal accumulation. Many benthic invertebrates feed on this suspended or deposited material, with the risk that metals are enriched in their bodies and passed on to higher trophic levels. At this stage, no assessment of the potential concentration of heavy metals can be provided, as it is an incidental by-product of desalination plant processes. It is therefore recommended that limits are established for heavy metal concentrations in the brine discharges, and the brine regularly monitored to avoid exceedance of these limits.

IMPACT ASSESSMENT: DETRIMENTAL EFFECTS ON MARINE ORGANISMS OF HEAVY METALS FROM CORROSION PROCESSES

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	
Extent	Site specific	Site specific	Site specific	Site specific	Site specific	
Magnitude	Low	Very low	Very low	Very low	Very low	
Duration	Long term	Long term	Long term	Long term	Long term	
SIGNIFICANCE	Low (-)	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
Probability	Probable	Probable	Probable	Probable	Probable	
Confidence	Certain	Certain	Certain	Certain	Certain	
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	

The effects on marine communities of heavy metals in the brine from corrosion processes are considered to be of low magnitude, but will likely remain localised. As heavy metals can accumulate in the sediments, the effects would persist in the long-term. The impact is therefore assessed to be of Low (-) significance without mitigation, and would reduce to Very Low (-) with mitigation.

Proposed mitigation measures:

- Design the plant to reduce corrosion to a minimum by ensuring that dead spots and threaded connections are eliminated. Corrosion resistance is considered good when the corrosion rate is <0.1 mm/a (UNEP 2008).
- Implement a water quality monitoring programme to ensure compliance with water quality guidelines.

7.9.4 Decommissioning phase

The minimum anticipated life of the desalination plant is approximately 10 years. The individual RO modules will be replaced as and when required during this period. No decommissioning procedures or restoration plans have been compiled at this stage. Being a modular plant, decommissioning should not involve extensive demolition of the plant area. In the case of decommissioning the pipeline will most likely be left in place. The potential impacts during the decommissioning phase are thus expected to be minimal, i.e. Very low (-) in comparison to those occurring during the construction and operational phase, and no key issues related to the marine environment are identified at this stage, since cessation in the operation of the plant will result in an immediate discontinuation of the majority of the identified marine impacts.

7.9.5 Cumulative impacts

Anthropogenic activities in the coastal zone can result in complex immediate and indirect effects on the natural environment. Effects from disparate activities can combine and interact with each other in

time and space to cause incremental or cumulative effects. Cumulative effects can also be defined as the total impact that a series of developments, either present, past or future, will have on the environment within a specific region over a particular period of time (DEAT IEM Guideline 7, Cumulative effects assessment, 2004).

To define the level of cumulative impact in the intertidal and subtidal environment, it is therefore necessary to look beyond the environmental impacts of the current project and consider also the influence of other past or future developments in the area.

The coastline of the project area cannot be considered particularly “pristine” as it is already heavily impacted by regular vehicular traffic and seasonally high visitor numbers who utilize the area primarily for rock- and surf-angling and coastal recreation. The intake pipeline and supporting jetty and the northern discharge option would be located in close proximity to the current intake structure for the Salt Works and an old decommissioned, concrete encased intake pipeline, respectively. The southern discharge option would be situated immediately south of the current bitterns discharge location of the Salt Works. The bitterns are discharged intermittently onto the beach and do not contain co-pollutants. Cumulative effects of the proposed development with existing infrastructure and discharges from the Salt Works are thus anticipated. In contrast, potential cumulative effects of discharges from the Areva RO desalination plant, located some 23km to the north of the Salt Works near Wlotskasbaken, are unlikely.

Although it is difficult to quantify the potential cumulative impacts of the proposed desalination plant with existing infrastructure and discharges, the selection of technologies and processes proposed for the plant are state-of-the-art and every effort has been made in the planning phase to select the least environmentally damaging option for feed-water treatment and cleaning of plant components, thereby reducing discharges of hazardous components into the environment. Cumulative impacts are thus expected to remain of low intensity at the local scale, but persisting over the operational life of the plant (long-term), and are therefore rated as being of Low (-) significance.

7.10 SHORELINE DYNAMICS IMPACTS

The following subsection is a modified summary compiled using the Shoreline dynamics impact assessment undertaken by WSP. The original report is attached here as Annexure D8 and can be referred to for added detail.

The identified impacts have been categorised into construction, operations, decommissioning phase and cumulative impacts and are dealt with in that order, as follows.

7.10.1 Construction phase

7.10.1.1 Intake Jetty

IMPACT DESCRIPTION: DISRUPTION OF COASTAL PROCESSES BY MARINE WORKS

Temporary berms or bunds made of sand, rock or sand-filled geotextile bags, may be required to protect the working sites from wave action and allow dewatering. This is most likely to be required at the Outfall sites and less likely for the Intake Jetty. The bunds can temporarily interrupt the natural longshore transport of sand during the construction phase;

IMPACT ASSESSMENT: DISRUPTION OF COASTAL PROCESSES BY MARINE WORKS

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	~
Extent	Site specific	Site specific	Site specific	Site specific	Site specific	~
Magnitude	Low	Very low	Very low	Very low	Very low	~
Duration	Short term	Short term	Short term	Short term	Short term	~
SIGNIFICANCE	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
Probability	probable	probable	probable	probable	probable	Definite
Confidence	Sure	Sure	Sure	Sure	Sure	Certain
Reversibility	reversible	reversible	reversible	reversible	reversible	~

The intake jetty is located at the same position for all alternatives an so there is not variation between the impact significance between the Base Case and project alternatives (this explains why some text in the assessment table is in light text grey). These processes would only affect the immediate site (Site specific). The magnitude is considered "Low" as berms would be relatively small, extending into only part of surf zone, and thus natural process only slightly altered. This impact would have a short (construction period) duration. The Impact significance is therefore calculated as Very Low (-). This impact probability is rated as probable but depends on construction method. Impact rating confidence is rated as "Sure". This impact would be reversible, i.e. processes will naturally re-establish when berm is removed.

Proposed mitigation measures:

- Keep the marine works construction period short as is practical.
- The beach topography should be surveyed up- and downdrift of the intake and outfall location before construction commences, immediately after construction is complete, and after 1 year of operation, in order to confirm that the structures have had low impact on accretion or erosion of the beach.
- Avoid importing foreign fill materials for use in marine works. Use native beach material as far as practical.

IMPACT DESCRIPTION: ALTERATION OF BEACH COMPOSITION WITH ROCK SPOIL

The placement of rock on the beach to protect the construction area from waves in the inter-tidal zone from waves may be required. If these rocks not removed afterwards, this rock can alter the composition of the native beach material. This occurred during construction of a jetty at Coega, where rock was used and proved difficult to remove from the sandy beach afterwards.

IMPACT ASSESSMENT: ALTERATION OF BEACH COMPOSITION WITH ROCK SPOIL

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	~
Extent	Site specific	Site specific	Site specific	Site specific	Site specific	~
Magnitude	Low	Very low	Very low	Very low	Very low	~
Duration	Short term	Short term	Short term	Short term	Short term	~
SIGNIFICANCE	Low (-)	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
Probability	probable	probable	probable	probable	probable	Definite
Confidence	Sure	Sure	Sure	Sure	Sure	Certain
Reversibility	reversible	reversible	reversible	reversible	reversible	~

The intake jetty is located at the same position for all alternatives an so there is not variation between the impact significance between the Base Case and project alternatives. The alteration of beach composition if rock is used for berms will have a Local (site specific) extent. The Magnitude of the

impact is rated as Low as some rock is already present on the shore. The impact significance is rated as **Low (-)**. The probability of this impact occurring is rated as "Probable" but this depends on construction method employed. The confidence in the significance rating is rated as "Sure". The impact is considered "Reversible" as processes naturally re-establish if rock is removed.

Mitigation measures:

- Avoid importing foreign fill materials for use in marine works. Use only native beach material as far as practical.
- Remove all rock after construction.
- Due to the disturbances at Outfall 1 (derelict Salt Works intake), this outfall (associated with Alternative 2, would be preferable.

7.10.1.2 Brine outfall works

IMPACT DESCRIPTION: DISRUPTION OF COASTAL PROCESSES BY MARINE WORKS

Coastal processes may be disrupted by temporary berms used for wave protection and dewatering, leading to unusual erosion or accretion of sand and other materials, which could have temporary and small scale impacts on the local coastal profiles. These would however resolve them once the construction period ends, provided that the natural shoreline profile is re-established.

IMPACT ASSESSMENT: DISRUPTION OF COASTAL PROCESSES BY MARINE WORKS

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	~
Extent	Site specific	Site specific	Site specific	Site specific	Site specific	~
Magnitude	Low	Very low	Very low	Very low	Very low	~
Duration	Short term	Short term	Short term	Short term	Short term	~
SIGNIFICANCE	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
Probability	probable	probable	probable	probable	probable	Definite
Confidence	Sure	Sure	Sure	Sure	Sure	Certain
Reversibility	reversible	reversible	reversible	reversible	reversible	~

The impacts ratings for both outfall locations were found to be the same. It should however be noted that outfall 1, associated with Alternative 2, is situated at the derelict Salt Works intake structure and this site has already undergone modification and is deemed to be less sensitive than the Base Case outfall location. The coastal processes may be disrupted by temporary berms used for wave protection and dewatering which would have a "Local (site only)" extent. The magnitude of the impact is rated as "Low" as berms would be relatively small and thus natural process only slightly altered. The impact duration is rated as being of "Short (construction time)". As a result it is calculated that the impact significance would be **"Very Low (-)"**. The probability of this impact occurring is rated as "Probable" but depends on construction methods employed. The confidence in the impact rating is rated as "Sure" and the reversibility as "Reversible" as natural processes would naturally re-establish when berm is removed.

Proposed mitigation measures:

- Keep the marine works construction period short as is practical.
- Avoid importing foreign fill materials for use in marine works. Use native beach material as far as practical.

- The beach topography should be surveyed updrift and downdrift of the intake and outfall location before construction commences, immediately after construction is complete, and after 1 year of operation, in order to confirm that the structures have had low impact on accretion or erosion of the beach.
- Due to the disturbances at Outfall 1 (derelict Salt Works intake), this outfall (associated with Alternative 2), would be preferable.

IMPACT DESCRIPTION: ALTERATION OF BEACH COMPOSITION WITH ROCK SPOIL

Alteration of beach composition will occur if rock is used for berms remains or is unrecoverable after the completion of the construction which may affect shoreline dynamics (affecting local erosion and accretion processes small scale), depending on the volume and size of the rock materials used. This rock material would however eventually be recovered by the sea and converted into cobble stone as seen on this section of coastline.

IMPACT ASSESSMENT: ALTERATION OF BEACH COMPOSITION WITH ROCK SPOIL

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	~
Extent	Site specific	Site specific	Site specific	Site specific	Site specific	~
Magnitude	Low	Very low	Very low	Very low	Very low	~
Duration	Medium term	Medium term	Medium term	Medium term	Medium term	~
SIGNIFICANCE	Low (-)	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
Probability	probable	probable	probable	probable	probable	Definite
Confidence	Sure	Sure	Sure	Sure	Sure	Certain
Reversibility	reversible	reversible	reversible	reversible	reversible	~

The impacts ratings for both outfall locations were found to be the same. It should however be noted that outfall 1, associated with Alternative 2, is situated at the derelict Salt Works intake structure and this site has already undergone modification and is deemed to be less sensitive than the Base Case outfall location. Alteration of beach composition may occur if rock is used for berms and this would have a "Local (site only)" impact on shoreline dynamics. The magnitude of this impact is rated as being " Low" as some rock is already naturally present on the shoreline and the ocean should have the capacity to process this material in time. This impact is rated as have a "Medium duration" as the rock will remain there for some time unless removed. Therefore the impact significance is calculated as "**Low (-)"** before mitigation. The probability of this impact occurring as rated as "Probable" but depends on construction method employed. The confidence in the significance rating is rated as "Sure" and the impact is will be "Reversible" as natural shoreline processes will naturally re-establish if rock is removed.

Proposed mitigation measures:

- Use only native materials and avoid importing foreign materials and rock onto the beach.
- Alternatively, ensure that all imported rock and fill material is recovered and removed after construction.

IMPACT DESCRIPTION: EARTHWORKS RELATED FLOODING OR BEACH EROSION

Flooding or beach erosion may occur as a result of excavation of the beach. Excavation of the upper beach can change the natural beach profile, leading to erosion, or allowing waves to wash over the beach and flood low-lying areas.

IMPACT ASSESSMENT: EARTHWORKS RELATED FLOODING OR BEACH EROSION

Criteria \ Alternative	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	~
Extent	Site specific	Site specific	Site specific	Site specific	Site specific	~
Magnitude	Medium	Low	Low	Low	Low	~
Duration	Short term	Short term	Short term	Short term	Short term	~
SIGNIFICANCE	Low (-)	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
Probability	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Definite
Confidence	Sure	Sure	Sure	Sure	Sure	Certain
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	~

The impacts ratings for both outfall locations were found to be the same. It should however be noted that outfall 1, associated with Alternative 2, is situated at the derelict Salt Works intake structure and this site has already undergone modification and is deemed to be less sensitive than the Base Case outfall location. Flooding or beach erosion may occur as a result of excavations and earthworks on the beach, affecting shoreline dynamics processes on a "Local (site only)" extent. This may result in a "Medium" magnitude impact as flooding could affect the Salt Works operations at Outfall 5 the magnitude at Outfall 1 is deemed to be "Low" as there is little that could be impacted on through flooding. The impact duration is rated as "Short term". The impact significance is calculated as "**Low (-)".** The probability of the impact occurring is rated as "Probable". The confidence in the impact rating is rated as "Sure" and the impact is deemed to be "Reversible" as the process will cease if beach profile is restored

Proposed mitigation measures:

- Natural beach profile to be restored following the construction phase (pre-construction phots should be taken).
- Outfall 1 is considered less sensitive to this impact (although marginally) but notwithstanding other determining factors, is the preferred discharge location. Outfall site 1 has already been disturbed by Salt Works activities (derelict intake structure). Outfall 5 flooding and erosion may impact on the Salt Works operations which would be undesirable.

7.10.2 Operations phase

7.10.2.1 Intake jetty

IMPACT DESCRIPTION: THE COASTAL PROCESSES (WAVES, CURRENTS, SEDIMENT TRANSPORT) ARE AFFECTED BY THE JETTY STRUCTURE

The piles structures used to support the new intake jetty could impact the coastal dynamics, particularly the waves, currents, resulting in localised changes in sediment transport, accretion, and deposition.

IMPACT ASSESSMENT: THE COASTAL PROCESSES (WAVES, CURRENTS, SEDIMENT TRANSPORT) ARE AFFECTED BY THE JETTY STRUCTURE

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	~
Extent	Site specific	Site specific	Site specific	Site specific	Site specific	~
Magnitude	Very Low	Very Low	Very Low	Very Low	Very Low	~
Duration	Long term	Long term	Long term	Long term	Long term	~
SIGNIFICANCE	Low (-)	Low (-)	Low (-)	Low (-)	Low (-)	Neutral
Probability	Probable	Probable	Probable	Probable	Probable	Definite
Confidence	Certain	Certain	Certain	Certain	Certain	Certain
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	~

The extent of the impact is rated as Local (site only). The magnitude is rated as "Very Low" as the piles present only small obstructions to the coastal processes. The duration of the impact is rated as "Long Term" as the impact will persist for the lifetime of jetty. The Impact significance is therefore rated as "Low (-)" The probability of the impact occurring is rated as "Definite". The Confidence in the impact rating is considered "Certain" and the impact would be "Reversible" as natural processes would re-establish if jetty is removed.

Proposed mitigation measures:

- The beach topography should be surveyed up- and downdrift of the intake and outfall location before construction commences, immediately after construction is complete, and after 1 year of operation, in order to confirm that the structures have had low impact on accretion or erosion of the beach.

IMPACT DESCRIPTION: NATURAL SAND MOVEMENT IS IMPACTED BY THE JETTY ABUTMENT TO SHORE

The abutment, or embankment, where the intake jetty connects to the land can interfere with natural sand movement if it is located in the dynamic beach zone.

IMPACT ASSESSMENT: NATURAL SAND MOVEMENT IS IMPACTED BY THE JETTY ABUTMENT TO SHORE

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	~
Extent	Site specific	Site specific	Site specific	Site specific	Site specific	~
Magnitude	Low	~	~	~	~	~
Duration	Long term	Long term	Long term	Long term	Long term	~
SIGNIFICANCE	Medium (-)	Neutral	Neutral	Neutral	Neutral	Neutral
Probability	Definite	Definite	Definite	Definite	Definite	Definite
Confidence	Certain	Certain	Certain	Certain	Certain	Certain
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	~

The impact extent is rated as "Local (site only)". The Magnitude of the impact is rated as "Low" as the abutment presents only a small obstruction as compared to the width of the surfzone. The impact would occur over the "Long Term" or for the life of jetty. The impact significance is calculated as "Medium (-)". The probability of the impact occurring is considered "Definite", the confidence in the impact rating is rated as "Certain" and the impact would be "Reversible", as natural processes would re-establish if the jetty is removed. If the abutment of the jetty were moved above the high water mark then the impact would be avoided, magnitude would reduce to "zero" and the impact significance to "Neutral".

Proposed mitigation measures:

- Locate abutment above high water mark to avoid impacting sand movement.
- The beach topography should be surveyed updrift and downdrift of the intake and outfall location before construction commences, immediately after construction is complete, and after 1 year of operation, in order to confirm that the structures have had low impact on accretion or erosion of the beach.

IMPACT DESCRIPTION: WIND-BLOWN SAND PATHWAYS ARE IMPACTED BY THE INTAKE STRUCTURE AND PIPELINES

Pipelines and infrastructure located above ground can obstruct / alter natural wind-blown sand pathways leading the erosion or depositing.

IMPACT ASSESSMENT: WIND-BLOWN SAND PATHWAYS ARE IMPACTED BY THE INTAKE STRUCTURE AND PIPELINES

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	~
Extent	Site specific	Site specific	Site specific	Site specific	Site specific	~
Magnitude	Low	Very low	Very low	Very low	Very low	~
Duration	Long term	Long term	Long term	Long term	Long term	~
SIGNIFICANCE	Low (-)	Very low (-)	Very low (-)	Very low (-)	Very low (-)	Neutral
Probability	Probable	Probable	Probable	Probable	Probable	Definite
Confidence	Uncertain	Uncertain	Uncertain	Uncertain	Uncertain	Certain
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	~

The impact will be restricted to a “Local (site only)” extent. The magnitude of the impact is considered “Low” as wind-blown sand pathways are absent or indistinct on this section of coastline. The impact would occur over the “Long Term”, or for life of jetty. The impact significance is therefore “Low (-)”. The impact is considered “Probable” although the confidence in the impact significance rating is “Uncertain”. The impact is however “Reversible” as natural processes would re-establish if the infrastructure is removed.

Proposed mitigation measures:

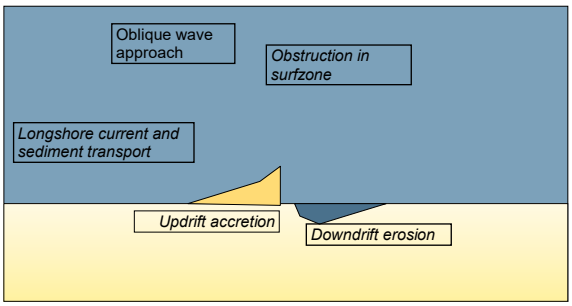
- Reduce height of pipelines and infrastructure above ground.
- The beach topography should be surveyed updrift and downdrift of the intake and outfall location before construction commences, immediately after construction is complete, and after 1 year of operation, in order to confirm that the structures have had low impact on accretion or erosion of the beach.

7.10.2.2 Brine outfall works

IMPACT DESCRIPTION: THE OUTFALL PIPELINE CAUSING UPDRIFT ACCRETION AND DOWNDRIFT EROSION OF THE BEACH

The outfall pipeline and its concrete encasement could lead to updrift accretion of sand and downdrift erosion of the beach (Figure 102). The magnitude of this effect will be determined by the height of the structure and the distance that it extends into the surfzone. The old concrete-encased pipe at the alternative location Outfall 1 appears to have little effect on sand movement and has been used as a proxy for the assessment of this impact.;

Figure 102: Sand accretion and erosion processes



Schematic map of accretion/erosion due to an obstruction such as a pipeline or bund in the surfzone;

Example of sand accretion adjacent to a concrete encased outfall pipe in the inter-tidal zone

IMPACT ASSESSMENT: THE OUTFALL PIPELINE CAUSING UPDRIFT ACCRETION AND DOWNDRIFT EROSION OF THE BEACH

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	~
Extent	Site specific	Site specific	Site specific	Site specific	Site specific	~
Magnitude	Low	Low	Low	Low	Low	~
Duration	Long term	Long term	Long term	Long term	Long term	~
SIGNIFICANCE	Low (-)	Low (-)	Low (-)	Low (-)	Low (-)	Neutral
Probability	Definite	Definite	Definite	Definite	Definite	Definite
Confidence	Sure	Sure	Sure	Sure	Sure	Certain
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	~

The impact has the same rating for both the outfall alternatives, although outfall 1 already has a concrete structure (derelict Salt Works intake pipeline) causing this impact and is therefore less sensitive to the impact and preferred from an environmental perspective. The extent of the impact is rated as “Local (site only)” the magnitude of the impact would be “Low” as the pipeline encasement forms only a small obstacle to longshore transport (i.e. only 1m high and terminates close to shore). The duration of the impact would be “Long Term” and would persist for the life of desalination plant. The impact significance is therefore “Low (-)”. The probability is “Definite”, the confidence in this rating is “Sure” and the impact is considered “Reversible” as processes naturally re-establish when pipeline is removed. The impact significance rating does not change after mitigation as the concrete encased pipeline is already low profile concept.

Proposed mitigation measures:

- Reduce height of pipeline encasement as much as is practical and consider trenching into rock below natural beach level (although this would have other environmental impacts which need to be weighed up).
- The beach topography should be surveyed updrift and downdrift of the intake and outfall location before construction commences, immediately after construction is complete, and after 1 year of operation, in order to confirm that the structures have had low impact on accretion or erosion of the beach.

IMPACT DESCRIPTION: WIND-BLOWN SAND PATHWAYS ON THE UPPER BEACH ARE IMPACTED BY THE BRINE OUTFALL PIPELINE

The brine pipelines and infrastructure located above ground can disturb / obstruct natural wind-blown sand pathways, affecting the movement, and deposition of sand as part of natural coastal processes.

IMPACT ASSESSMENT: WIND-BLOWN SAND PATHWAYS ON THE UPPER BEACH ARE IMPACTED BY THE BRINE OUTFALL PIPELINE

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	~
Extent	Site specific	Site specific	Site specific	Site specific	Site specific	~
Magnitude	~	~	~	~	~	~
Duration	Long term	Long term	Long term	Long term	Long term	~
SIGNIFICANCE	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
Probability	Definite	Definite	Definite	Definite	Definite	Definite
Confidence	Certain	Certain	Certain	Certain	Certain	Certain
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	~

The extent would be “Local (site only)”, the magnitude “Zero” as the design indicates that pipelines will be buried. The extent would be “ Long Term”, or for life of desalination plant. The impact significance is rated as “Neutral”. The likelihood of the impact occurring are “Probable” and the confidence in the impact rating is “Sure”. The impact is “Reversible” as processes naturally re-establish when pipeline is removed.

Proposed mitigation measures:

- Ensure that pipelines are adequately buried in relation to natural beach levels.
- The beach topography should be surveyed updrift and downdrift of the intake and outfall location before construction commences, immediately after construction is complete, and after 1 year of operation, in order to confirm that the structures have had low impact on accretion or erosion of the beach.

IMPACT DESCRIPTION: THE HIGH VELOCITY FLOW FROM THE OUTFALL CAUSES SCOURING OF THE SANDY SEABED.

High velocity brine flow exiting the outfall can cause scouring of the seabed.

IMPACT ASSESSMENT: THE HIGH VELOCITY FLOW FROM THE OUTFALL CAUSES SCOURING OF THE SANDY SEABED.

Alternative / Criteria	Base Case - Pre-mitigation	Base Case - Post-mitigation	Alternative 1 - Plant site 2	Alternative 2 - Plant site 3	Alternative 3 – Overhead powerline	Alternative 4 - No go
Type	Negative	Negative	Negative	Negative	Negative	~
Extent	Site specific	Site specific	Site specific	Site specific	Site specific	~
Magnitude	Low	Low	Low	Low	Low	~
Duration	Long term	Long term	Long term	Long term	Long term	~
SIGNIFICANCE	Low (-)	Low (-)	Low (-)	Low (-)	Low (-)	Neutral
Probability	Definite	Definite	Definite	Definite	Definite	Definite
Confidence	Sure	Sure	Sure	Sure	Sure	Certain
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	~

The impact extent is rated as “Local (site only)”. The impact magnitude is “Low” since the existing seabed is partly rocky with thin sand cover and is not sensitive to mass erosion. The impact would endure over the “Long Term” or for the life of desalination plant. The impact significance is therefore “Low (-)”. The likelihood of the impact occurring is “Definite” and the confidence in the impact rating is “Sure”. The impact would be “Reversible” as processes naturally re-establish when flow stops.

Proposed mitigation measures:

- None (high velocities must be maintained for good brine dilution).

7.10.3 Decommissioning phase

No additional impacts have been identified that would occur as a result of decommissioning of either the Intake Jetty, or either of the brine outfalls. It is foreseen that decommissioning would include the removal of the intake jetty and the brine outfall pipeline. Impacts to shoreline dynamics would be comparable with those experienced during the construction phase, although they will be of a lesser magnitude. The same mitigations proposed for the management of construction related impacts should therefore be implemented during any decommissioning activity.

7.10.4 Cumulative impacts

The impacts of the intake and outfall structures are limited to the immediate site. This, together with the generally low nature of the impacts, would result in a negligible effect on the regional beach and shoreline dynamics. Developments further south in Swakopmund, such as at Vineta, are likely to be the major driver of any cumulative impacts on shoreline dynamics in the region.

MET:DEA asked if the presence of the proposed Rössing Desalination plant and the associated brine discharges would impact on the water quality for the planned Mile 6 NamWater desalination plant. Based on the diffusion modelling, elevated salinity levels should fall back to undetectable levels (i.e. near ambient) within 50m of the diffuser (point discharge), therefore the potential for the Rössing's brine discharges to prejudice water quality for the planned Mile 6 desalination are considered negligible.

7.11 OTHER IMPACTS AND ASPECTS

The impacts identified and assessed in the foregoing sections and for which specialist investigations were undertaken are not an exhaustive list of potential impacts associated with the project, but rather those that are deemed to be potentially significant and key in informing a decision on the acceptability of the project. There is a number of lower significance, transient or generic impacts that associated with the construction and operation of the proposed project. None of these impacts were found to be of great significance and would not add or detract from the taking of an informed decision and include, *inter alia,* the following:

- Air quality impacts (most notably dust generation during the construction phase);
- Groundwater quality, as a result of construction and operation phase activities and pollution events;
- Hydrological impacts, including concentration and deviation of natural stormwater paths leading to erosion and sedimentation;
- Pollution prevention and waste management;
- Seawater quality impacts, restricting other uses, such as other desalination plants (i.e. NamWater's planned Mile 6) or possible future mariculture operations in the area;
- Soil impacts including compaction and erosion; and
- Terrestrial ecology impacts, including loss of vegetative cover and habitat area.

Best practice in environmental management encourages a responsible and holistic approach to impact management. As such, these second tier impacts (which are unlikely to inform a decision of acceptability), are included in the SEMP, where appropriate mitigations and management interventions have been proposed to ensure that these social and environmental aspects are responsibly managed throughout the project lifecycle.

7.12 SOCIAL AND ENVIRONMENTAL MANAGEMENT PLAN

Based on the findings of the SEIA Report, a SEMP has been compiled which incorporates the recommended mitigation measures and aims to ensure optimal environmental protection is achieved during the construction and operational phases of the proposed project. The SEMP is attached here as Annexure E. The SEIA Report together with the SEMP will be submitted to the MET:DEA for consideration and decision making. The SEMP aims to bridge the gap between the SEIA phase of the project and the implementation of the project. As such, the SEMP will be provided to the contractor / proponent to implement during the detailed design and construction phase.

The SEMP outlines all monitoring requirements to ensure that all aspects of the proposed project comply with the agreed environmental management objectives. The SEMP includes specific mitigation measures aimed at managing the key environmental impacts but also includes mitigations and management measures aimed at managing a variety of generic construction phase social and environmental aspects. The SEMP sets out a management framework and assigns responsibility for the various interventions as a measure to ensure accountability and ensures effective implementation and compliance. The SEMP also includes penalty clauses to be triggered in the event that the contractor fails to implement the environmental requirements successfully or respond to environmental issues with due diligence.

7.13 ASSUMPTIONS, UNCERTAINTIES AND GAPS IN KNOWLEDGE

7.13.1 Socio-economic

The methods used for the study included desk-top research, a site visit, and communications with Rössing Uranium, NamWater, and the Swakopmund Municipality. The data to compile the demographic section were sourced from the 2011 Population and Housing Census and the Namibia Household Income and Expenditure Survey 2009-2010 and 2003/04 (NSA, 2012 and CBS, 2006). Information for the water supply and demand sections was sourced from government, NamWater, the Swakopmund Municipality and research documents available on the Internet. The assessment methodology is detailed in the assessment section.

The following gaps in information are noted:

- Swakopmund Municipality is planning to extend its boundaries eastwards but the decision to extend northwards, beyond the Swakopmund Salt Works has not been taken.
- NamWater did not wish to provide any information or insights into the potential impact of the proposed project on water tariffs to domestic and industrial users. The assessment of this impact is therefore based on assumptions.

7.13.2 Archeology and heritage

A detailed inspection of the site was carried out on 6th August, 2014, covering the entire eastern margin of the Salt Works as far as the M0044 road reserve, and the entire seaward side of the Salt Works including the current and disused pump-station facilities. No trace of any archaeological or historical remains as relevant to the National Heritage Act 27 of 2004, were evident on the surface in this area. It is unclear what resources may be buried and unearthed during the construction.

7.13.3 Visual

- Information pertaining to the specific heights of activities proposed for the development was limited and, where required, generic heights were be used to define the visibility of the project.
- Although every effort to maintain accuracy was undertaken, as a result of the Digital Elevation Model (DEM) being generated from satellite imagery and not being a true representation of the earth's surface, the viewshed mapping is approximate and may not represent an exact visibility incidence.
- The use of open source satellite imagery was utilised for base maps in the report.
- Some of the mapping in this document was created using Bing Maps and powered by the Enterprise framework.
- The information for the terrain used in the 3D computer model on which the visibility analysis is based on is:
  - The Advanced Spaceborne Thermal Emission and Reflection (ASTER) Radiometer Data (ASTGTM_S2 3E014 and ASTGTM_S24E014 data set). ASTER GDEM is a product of Japan's Ministry of Economy, Trade and Industry (METI) and National Aeronautics and Space Administration (NASA) in USA. (ASTER GDEM. METI / NASA. 2011).

- Determining visual resources is a subjective process where absolute terms are not achievable. Evaluating a landscape's visual quality is complex, as assessment of the visual landscape applies mainly qualitative standards. Therefore, subjectivity cannot be excluded in the assessment procedure *(Lange, 1994)*. The project deliverables, including electronic copies of reports, maps, data, shape files and photographs are based on the author's professional knowledge, as well as available information. This study is based on assessment techniques and investigations that are limited by time and budgetary constraints applicable to the type and level of assessment undertaken. VRM Africa reserves the right to modify aspects of the project deliverables if and when new/additional information may become available from research or further work in the applicable field of practice, or pertaining to this study.

7.13.4 Noise

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

- Although noise measurements are considered sufficient in the determination of baseline noise levels for use during the impact assessment phase to estimate cumulative impacts, the reader is reminded that these measurements do not take into account:
  - Varying weather conditions associated with seasons;
  - Varying ocean conditions, most notably surf generated noise;
  - Varying traffic noise along the C34 over an entire day; and
  - The effect of variability activities at the Swakopmund Salt Works.

- 24 hour average wind speed and wind direction data for Swakopmund was supplied for use in the study. A distinction between the wind field during the day and night can however not be made from 24 hour average data. Hourly data recorded at Wlotzkasbaken were applied in calculations.
- No information on the nature and extent of construction activities were available at the time of the study. A generic approach for determining the impact of the construction phase, as recommended by the EC (EC WG-AEN, 2003), was adopted.
- All construction and operational phase activities were assumed to be continuous that is, 24 hours per day.

7.13.5 Avifauna

- The description of bird diversity is based primarily on the first Southern African Bird Atlas Project (SABAP1), when data were gathered during 1987-1992 (Harrison et al. 1997). Although reliable, these data are relatively dated. In order to address this limitation, the above information was supplemented by available data, although still limited, from the second bird atlas project (SABAP2), which was launched in Namibia in 2012;
- Only limited information is available on the potential negative effects of noise on breeding seabirds, especially on African - and colonial - species such as the Cape Cormorant (Near Threatened in Namibia, Globally Threatened [Endangered]) on the guano platforms in the study area. To address this, the growing literature on the effects of noise caused by wind turbines (which could have some similarities to noise caused by pumps used in the desalination process) was consulted, although this literature pertains mainly to the effects of noise on humans;
- A major limitation to the assessment of potential impacts from power line structures is the difficulty in obtaining confirmed records of bird flight paths. Available recent satellite tracking data for flamingos in Namibia were included to help address this limitation;
- Also limiting, is the lack of long term data on power line incidents in Namibia. Available data from the NamPower/NNF Strategic Partnership (EIS 2014) were consulted in this respect; and

- The impact significance ratings provided for the project alternatives assessed assume that the recommended or equivalent mitigation measures have been applied in an effort to manage these impacts responsibly.

For all of the above limitations, the precautionary principle should apply until such time as further data can be obtained.

7.13.6 Marine ecology

The following are the assumptions and limitations of the marine ecology study:

- The study is based on the project description made available to the specialist at the time of the commencement of the study (plant capacities, discharge locations, constituents, volumes, etc.). The impact assessment is restricted to only those constituents specified by Rössing Uranium as being contained within the effluents from the desalination plant and have been augmented through the project as more information has become available.
- The ecological assessment is limited to a “desktop” approach and thus relies on existing information only. However, site-specific descriptions for three sites spanning the coastline between the seawater intake and brine discharge locations were provided by divers, who swam transects through the surf zone perpendicular to the shoreline, photographically recording seabed type, notable features and representative marine biota.
- The modelling study comprises semi-empirical methods and an analytical near-field model. This approach was adopted because sophisticated numerical models typically used for modelling of brine discharges in deep water are incapable of numerically simulating discharges in the turbulent beach and nearshore zone. Some important conclusions and associated assessments and recommendations made in the marine ecology assessment are based on the modelling results. The predictions of these models, whilst considered to be robust in terms of the major discharge constituent, need to be validated by field observations and subsequent monitoring. If field observations and monitoring, however, fail to mirror predicted results, the forecasted impacts will need to be confirmed and /or reviewed through a post-commissioning monitoring programming.
- Potential changes in the marine environment such as sea level rise and/or increases in the severity and frequency of storms related to climate change are not explicitly considered here. Such scenarios are difficult to assess due to the uncertainties surrounding climate change. Should evidence or more certain predictions of such changes become available, Rössing Uranium should re-assess their development and management plans to include the impacts of these anticipated macroscale changes. However, it is not expected that these climate changes will affect the effluent plume behaviour to the extent that the conclusions of this study will be altered.

7.13.7 Brine diffusion

The salinity concentration of the reject brine was assumed to be 66.0g/l, for an ambient salinity of the intake seawater of 34.2g/l (communications with RH-DHV via email).

During the desalination process, the intake water would be retained in a series of retention ponds before being processed through the RO plant. This process will raise the temperature of the intake water. As a result, the brine will be discharged at an elevated temperature relative to the receiving waters. The RO process itself generally imparts only a small temperature increase to the water. For this study, a discharge temperature of 17.0ºC is assumed for the brine discharge (communications with RH-DHV via email), based on an ambient seawater temperature of 14ºC.

The density of the brine and ambient water affect the dilution. The density of water is dependent on the temperature of the water and the salinity. Table 43 shows the relevant densities calculated for the ambient seawater and the brine discharge.

Table 43: Salinity values assumed at the site

	Concentration	Density at 14°C	Density at 17°C	Density at 21°C
Median Ambient Salinity (TDS)	34.2 g/l	1,025.5 kg/m^3	1,024.8 kg/m^3	1,023.6 kg/m^3
Brine discharge Salinity	66.0 g/l	-	1,049.0 kg/m^3	1,047.8 kg/m^3
Recommended concentration (guideline – DWAF 1995)	36.0 g/l	1,026.9 kg/m^3	1,026.1 kg/m^3	

Information on other constituents of the brine, or co-discharges, such as filter backwashes and cleaning chemicals, was not available. The dilution values calculated in this study for the brine would also be applicable to such co-discharges, provided they do not undergo chemical transformation once discharged.

7.13.8 Shoreline dynamics

The scope of work did not include numerical modelling of waves, currents, or sediment transport and shoreline evolution. It was initially assumed that the physical scale of the proposed infrastructure would not justify such studies – coastal infrastructure, such as jetties or breakwaters that impact the coastline, are typically in the order of several hundred metres long. The comparatively small scale of the intake and outfall structures confirms that this assumption is not a limitation.

8 PUBLIC PARTICIPATION

In terms of Section 21 of the EIA Regulations a call for open consultation with all interested and affected parties (I&APs) at defined stages of the EIA process are required. This entails participatory consultation with members of the public by providing an opportunity to comment on the proposed project. Public participation in this project was undertaken to meet the specific requirements in accordance with the international best practice.

8.1 SEIA PROGRAMME

A summary of the SEIA process that was followed is provided below:

- Phase 1: Project initiation/application:
  - Internal screening (site visits / identify social and environmental issues) ~ **complete.**
- Phase 2: Scoping ~ **complete**:
  - Notification to IAPs ~ **complete**;
  - Place adverts (24 July and 31 July 2014) and sent out BIDs (24 July 2014) ~ **complete**;
  - Public meeting (31 July 2014 – Swakopmund Hotel) ~ **complete**;
  - Focus group meetings (31 July to 4 August 2014) **~ complete**;
  - Specialist input for Scoping – completed on 19 August 2014 ~ **complete**;
  - Prepare Draft Scoping Report ~**complete**;
  - I&APs review of Scoping Report (9 September to 7 October) ~ **complete**.
  - Submit final Scoping Report (including I&APS comments) to MET (10 October 2014) ~ **complete**.
- Phase 3: SEIA:
  - Specialist investigations (completed by 15 November) ~ **complete**;
  - Prepare Draft SEIA Report and SEMP for internal review ~ **complete**;
  - I&APs review SEIA Report and SEMP – 1 December 2014 to 20 January 2015 (extended review period due to the review period overlapping with the Christmas Holiday period **~ complete**.
  - Submit final Report to the MET **~ complete**; and
  - MET review and issuing of a record of decision

8.2 INITIATION OF THE PUBLIC PARTICIPATION PROCESS

The approach adopted for the initiation of the SEIA and associated public participation process was to identify and contact as many potential I&APs as possible through a number of activities which are listed in Table 44:

Table 44: Initiation of public participation process

DATE	DESCRIPTION
24 July – 5 August 2014	The existing Rössing Uranium I&AP database was updated prior to, and during, the project initiation phase (refer to Annexure C6). (This database was continuously updated though the SEIA process).
9 July 2014	Initial site visit. (Various sites visits were conducted thought the SEIA process).
17 July 2014	SLR and Ecoserve (Bird specialists) met with NACOMA to inform them about the proposed project and to discuss issues relating the Damara Tern breeding areas in the location of the Swakopmund Salt Works.
Early July 2014	A non-technical Background Information Document describing the project and SEIA process was compiled (refer to Annexure B1).
24 July and 1 August 2014	Rössing Uranium carried out an internal staff notification process regarding the project by issuing two different employee briefs (refer to Annexure B5).
24 July 2014	The Background Information Document was distributed electronically to all I&APs on the database. Hard copies of the Background Information Document were placed in the Swakopmund Library and the Namibian Uranium Institute (in Swakopmund).
24 July – 5 August 2014	Various key stakeholders were contacted telephonically during the course of the public participation process.
25 July 2014	Site notices were placed at the Seaside Hotel and Spar entrance at Mile 4 and on site (refer to Annexure B3).
24 and 31 July 2014 (National) 25 July and 1 August 2014 (Local)	Advertisements were placed in two (2) national newspapers (The Namibian and the Republikein) and one (1) local newspaper (Namib Times) (refer to Annexure B4). These advertisements were placed once a week for two consecutive weeks as per the regulatory requirement.
24 July – 5 August 2014	As part of the notification period all of the identified potential I&APs were invited to participate in the SEIA process via posting and/ or emailing their comments or filling in a comment sheet. I&APs were given 14 days within which to submit comment on the project. Comments received are included in a Comments and Response Report which is attached here as Annexure C9. (The Comments and Response Report are kept up to date throughout the process and more relevant responses as a result of the assessment findings are now presented in this document).
July 2014	Various newspapers published articles on the project based on the contents of the Background Information Document and the media briefing/meeting.

8.3 MEETINGS

The following stakeholder engagement meetings were held during the initial I&AP notification period:

Table 45: Details of stakeholder engagement meetings

DATE	TIME	VENUE	DESCRIPTION
31 July 2014	8:00 AM	Rössing Uranium Corporate Office.	Mineworkers' Union of Namibia (MUN).
31 July 2014	12:00 PM	Swakopmund Hotel and Entertainment Centre, Spitzkoppe Room.	Media focus group.
31 July 2014	15:00 PM	Swakopmund Hotel and Entertainment Centre, Spitzkoppe Room.	Key stakeholder meeting. Representatives of the following were invited: • NamWater; • Salt Works; • Other mines; • Regional Governor; • Ministry of Fisheries and Marine Resources); • Ministry of Environment and Tourism local office); • Namibian Coast Conservation and Management Project (NACOMA); • Gecko Water; • Swakop Matters; • EarthLife; • Swakopmund municipality; • MWUG; • Employees; • BEC; and

			• Ministry Of Water Affairs and Forestry: Department of Water Affairs and Forestry. • Areva • Erongo desalination company
31 July 2014	18:00 PM	Swakopmund Hotel and Entertainment Centre, Spitzkoppe Room.	Public meeting.
7 August 2014	09:00 AM	Government Office Park, Ministry Of Water Affairs and Forestry.	Meeting with representatives of the Ministry Of Water Affairs and Forestry (MAWF) Department of Water Environment.
7 August 2014	11:00 AM	NamWater.	Meeting with NamWater representatives.
19 August	15:00 PM	Telephonic discussion.	Ministry of Environment and Tourism: Department of Environmental Affairs (MET:DEA).

Similar project information was presented at all the meetings. A copy of the presentation is attached in Annexure B2. The minutes of these meetings are available for review in Annexure C.

8.4 COMMENT ON THE DRAFT SCOPING REPORT

The second stage of the public participation process involved the review of the draft scoping report by registered I&APs. Registered I&APs were involved in the draft scoping report public comment period via an email dated 1 December 2014. A summary of the draft scoping report was also included in the email to the registered I&APs. I&APs had until 20 January 2014 to submit comments or raise any issues or concerns with regard to the proposed project or SEIA process.

In addition to the emailed Report Summary, I&APs were notified of the availability of hard copies of the draft scoping report through adverts in the following newspapers (refer to Annexure B4 for copies of the adverts):

- Namibian;
- Republikein;
- Namib Times;
- Namib Independent;
- Informante; and
- Erongo news.

Hard copies of the draft scoping report were made available in the following locations:

- Swakopmund Public Library;
- Arandis Public Library;
- Walvis Bay Public Library; and
- National Library in Windhoek.

CD's containing electronic copies of the SEIA and all of its supporting documents were available on request to SLR and/or Aurecon. The SEIA was made available on the Aurecon and Rössing Uranium websites for download and details on how to access these were included in correspondence to I&APs at the commencement of the public comment period. Electronic copies of the full report were also provided to the Ministry of Fisheries and Marine Resources (MFMR) as well as the Ministry of Agriculture, Water and Forestry (MAWF) at the beginning of the comments period.

8.5 SUBMISSION OF THE SCOPING REPORT

On completion of the public comment period, the Scoping Report was finalised, where cognisance of further comments received/issues raised was taken, the report updated, where relevant and the final

scoping report submitted to MET:DEA on the 10 October 2014 for their review and decision regarding the approval of the Report and related Terms of Reference for SEIA.

All comments received on the Draft Scoping Report, together with the environmental team's responses, are included in the Comments and Response Report and submitted to MET. The latest revision of the Comments and Response Report is attached here as Annexure C9.

8.6 COMMENT ON THE DRAFT SEIA REPORT

The third stage of the public participation process involves the review of the draft SEIA report and SEMP by registered I&APs. Registered I&APs were informed of the draft SEIA report and SEMP public comment period via an email dated 1 December. A non-technical summary of the draft SEIA report was also included in the email to the registered I&APs. I&APs have until 20 January 2015 to submit comments or raise any issues or concerns with regard to the assessment findings and/or the SEMP.

In addition to the emailed Report Summary, I&APs were notified of the availability of hard copies of the draft SEIA report and SEMP through adverts in the following newspapers:

- Namibian;
- Republikein;
- Namib Times;

Hard copies of the draft SEIA report and SEMP are available in the following locations:

- Swakopmund Public Library;
- Arandis Public Library;
- Walvis Bay Public Library; and
- National Library in Windhoek.

CD's containing electronic copies of the EIA Report and all of its supporting documents were made available on request to SLR and/or Aurecon. The draft EIA Report was available on the Aurecon and Rössing Uranium websites for download and details on how to access these were included in correspondence to I&APs at the commencement of the public comment period.

8.7 DECISION AND WAY FORWARD

On completion of the public comment period, the SEIA Report and SEMP were finalised. The reports were updated where relevant and the final reports submitted to MET:DEA for their review and decision on whether the proposed desalination project may be implemented from an environmental point of view. MET:DEA must review the documentation (final SEIA Report and associated Appendices) take a decision and provide a record of that decision.

9 OPINIONS AND RECOMMENDATIONS

This section details project specific and noteworthy recommendations revealed through the SEIA process that the environmental assessment practitioner wishes to highlight as the most pertinent issues.

9.1 ENVIRONMENTAL ASSESSMENT PRACTITIONER'S OPINION ON PROJECT ACCEPTABILITY

In the interest of economic feasibility, Rössing Uranium decided to pursue its own source of desalinated water. Given the current poor uranium market, it is essential that Rössing Uranium implement measures to remain viable and in so doing, avoid the potentially significant regional socio-economic impacts that could arise as a result of its premature closure.

In the Environmental Assessment Practitioner's (EAP's) opinion, three key sensitive aspects were identified during the impact assessment process. The first relates to the projects potential impact on bird life in the area, given that the Mile 4 Salt Works is a recognised Important Bird Area (IBA) and an important breeding area for the Damara Terns (breeding endemic seabird, globally Near Threatened and also Near Threatened in Namibia). The second relates to the potential impacts on marine ecology as a result of the desalination process effuents. The third relates to the potentially significant negative socio-economic impacts if the project does not go ahead and the Rössing mine is forced to close prematurely as a result. Although visual impacts were rated as a medium negative impact because of the nature of the area being unobstructed, we don't consider this to form one of the key aspects to be considered in making a decision.

Regarding the bird aspect, special attention was given to the issue and was pivotal in the project team having to investigate various site locations for the desalination plant and finally informing the development of the "SEIA optimised layout", which is dealt with in the key recommendations to follow, and which seeks to mitigate the potential impact significance to birdlife. It is believed that the operation of the RO plant should not have an unacceptable level of impact to resident birdlife (given the recommended mitigations) however special care should be taken through the construction phase of the project to limit the potential disruption of the local bird assemblages and avoid disturbances to the Damara Terns during their annual breeding period.

Regarding marine ecology, and from a broader viewpoint, the marine ecology impacts associated with the operational phase were found to be within acceptable tolerances. As a result of this, the operational phase marine impacts associated with brine disposal need not factor significantly into the taking of the decision, although operations phase monitoring must be conducted to verify this.

The socio-economic impacts associated with the No-Go alternative and assuming Rössing closes prematurely as a result translates into a significant socio-economic impact for the region that should be avoided, especially now, during a period of depressed uranium market prices.

Other impacts, including noise, visual, and heritage are all within acceptable tolerances and not expected to result in significant impacts, if managed responsibly.

The EAP is of the opinion (subject to the implementation of the recommendations and mitigations measures identified, most notably the key recommendations that follow) that not only could the project go ahead on the basis of the potential environmental impacts, but should go ahead on the

basis of the potentially significant socio-economic impacts associated with not going ahead (if an alternative agreement between relevant parties cannot be reached timeously).

- **Key Recommendation 1: SEIA Optimised Layout:** The SEIA assessed three potential site locations (areas) for the RO plant, i.e. site areas (options) 1, 2 and 3 Base Case. Through the assessment, supported by the relevant specialist and technical studies, an optimised project layout took shape which was believed to be a healthy comprise between the technical, financial, and environmental aspects. This layout sees the RO plant shift to the far north or north-eastern corner of site area 1 (away from the core Damara Tern breeding area) but not as far as site option 2, where the RO plant could impact more significantly on the residents of the correctional services accommodation (noise and visual impacts) and tourists (visual impacts) or the birds on the guano platform. Additionally, to use the northern brine discharge point, associated with the above mentioned plant location, as this would route the pipeline away from the Salt Works inter-pond service road network (resulting in less disruption to the Salt Works during construction) and, importantly, the Damara Tern breeding area, but would also see the discharge making use of the derelict concrete Salt Works intake structure, which could mitigate the construction phase impact for the brine discharge. The optimised project layout is shown in Figure 103 at the end of this subsection. All the alternatives except the base case (unmitigated) could be approved by MET, subject to the implementation of all the commitments in the SEMP.
- **Key Recommendation 2: Earthen Berm Enclosure:** This key recommendation is closely linked to the foregoing SEIA optimised layout recommendation. It emerged during the course of the various specialist studies that enclosing the RO plant with a 1.8m to 2m high earthen berm serve a number of impact mitigation functions, as follows:
  - Visual impacts: an earthen berm would act as a visual screen and reduce the visual impacts associated with ground level activities and movements around the plant. The earth berm would also lessen the vertical prominence of the plant when viewed from a distance (provided that the earthen berm ties in with the surrounds). At night the berm would reduce the spillage of light into the adjoining areas, mitigating light pollution related impacts.
  - Noise impacts: an earthen berm would serve as an acoustic barrier and mitigate noise pollution generated at or near ground level and delinking noises from specific movements or activities (i.e. if you can see the bulldozer, the noise seems more intrusive to the receptor.)
  - Avifauna impacts: by reducing the noise and visual disturbances associated with the movement of people, plant and vehicles and associated activities around the RO plant, the potential impact to resident birdlife, most notably the Damara Terms (with their core breeding area located in the area adjacent the SEIA optimised layout) can be maintained within acceptable levels and is expected to have the following benefits:
    - Delinking noises from sudden visible movements, which could otherwise spook birds;
    - Reducing the overall noise level from the plant that could disturb nesting/roosting birds; and
    - Preventing low level light spillage from the RO plant or vehicle headlights around the plant, which would otherwise cause birds to cast a long shadow, increasing their visibility and susceptibility to would be predators.

- **Key Recommendation 3: ProGreen™ Technology**: The ProGreen™ technology is a new approach to desalination in southern Africa. As such the project is approaching the use of technology with precaution and has opted to retain a tried and tested pre-treatment process (i.e. dissolved air floatation (DAF)) and upon which the impact significance rating in the SEIA are based. In the event however that ProGreen™ does perform to full specification and full implementation is realised (i.e. all feedwater is treated to 100% by the ProGreen™ bio-flocculation technology), then this could reduce the potential impacts to marine ecology associated with the co-discharge of various water treatment, conditioning and cleaning chemicals, normally associated with a dissolved air floatation system. In the best case scenario, these impacts would reduce to zero or "Neutral". Note that the ProGreen™ would still produce a sludge that would be co-discharged with the brine effluent arising from the Reverse Osmosis process. The use of this technology is encouraging for the desalination industry and, if proven effective, could have far reaching cumulative environmental benefits for future desalination plants across the subcontinent. Rössing Uranium may even be in a position to investigate the option to discharge the brine into the Salt Works evaporation ponds, which could further reduce the operation phase impacts associated with brine discharge on the marine environment.

Figure 103: SEIA optimised Layout

10 CONCLUSION

This section briefly concludes the report and touches on a few key procedural aspects going forward.

Rössing Uranium proposes constructing and operating and new seawater desalination plant near the Swakopmund Salt Works north of Swakopmund as a means of reducing the overhead costs and improving the economic sustainability of the Rössing Uranium mining operation near Arandis. To allow this, Rössing Uranium must gain acceptance, in the form of an Environmental Clearance Certificate from MET:DEA as well as a number of permits and licenses as required by the prevailing water resources legislation, before commencing with such activities.

A “Base Case” project layout was envisaged at the completion of the pre-feasibility stage of the project and augmented by a number of trade-off studies. The Trade-off studies and this SEIA therefore considered a variety of options which were assessed, screened, and refined to reach a set of feasible alternatives. The Base Case project layouts, and the identified feasible alternatives, have been assessed in detail to determine the potential significance of the impacts on the social and bio-physical environment. A number of specialists were commissioned to conduct specialist studies on the key potential impacts. The specialist studies (all attached hereto as Annexure D) conducted includes: fancied

- Socio-economic;
- Archeology and heritage;
- Visual;
- Noise;
- Avifauna;
- Marine ecology;
- Marine discharge modelling; and
- Coastal dynamics.

Based on the outcome of the various assessments the EAP is of the opinion that, subject to the implementation of the SEMP and the recommendations contained herein, (including the pursuit of the SEIA optimised layout as the go forward project) that the project should be permitted to proceed.

This final SEIA will be submitted to MET:DEA for consideration and decision making.

11 BIBLIOGRAPHY

2030 Water Resources Group. (2013). Groundwater recharge: Omdel Dam, Namibia. Retrieved 08 15, 2014, from Water Scarcity Solutions: http://www.waterscarcitysolutions.org/assets/2030WRG_case_study_omdel_dam.pdf

Al-Barwani, H., & Purnama, A. (2008). Simulating brine plumes discharged into sea waters. Desalination, 221, 608-613.

Alonso, J., Alcantara-Carrio, Cabrera, J., 2002. Tourist resorts and their impact on beach erosion at Sotavento Beaches, Fuerteventura, Spain. Journal of Coastal Research 36, 1-7.

Anon. 2012. Government Gazette of the Republic of Namibia No. 4878, Windhoek, 6 February 2012.

ANZECC, (2000). Australian and New Zealand guidelines for fresh and marine water quality. Volume 2, Aquatic ecosystems. National water quality management strategy; no.4. Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand ,Canberra Australia. ISBN 0 642 19562 5 (www.deh.gov.au/water/quality/nwqms/introduction/).

Areva Resources Namibia. (2014). Areva Resources Namibia: More Than Just Mining. Retrieved 08 15, 2014, from http://www.areva.com/EN/operations-595/areva-resources-namibia-training-and-mining-projects.html

Areva Resources Namibia. http://www.areva.com/EN/operations-595/areva-resources-namibia-training-and-mining-projects.htMℓ

ASTER G Digital Elevation Model. METI / NASA. 2009. Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model Version 2 (GDigital Elevation Model V2 2011). Ministry of Economy, Trade, and Industry (METI) of Japan and United States National Aeronautics and Space Administration (NASA) Source: https://lpdaac.usgs.gov.

Australian Government: Department of the Environment. (unknown). Environment. Retrieved May 5, 2014, from http:/www.environment.gov.au/resource/definition-and-approach-sustainable-groundwater-yield

Bailey G.W., Chapman, P., 1991. Chemical and physical oceanography. In: Short-term variability during an Anchor Station Study in the southern Benguela Upwelling system. Progress in Oceanography 28, 9-37.

Bailey, G. W., Beyers, C. J., & Lipschitz, S. R. (1985). Seasonal Variation of oxygen deficiency in waters off southern South West Africa in 1975 and 1976 and its relation to catchability and distruibution of the Cape rock-lobster. South African Journal of Marine Science 3, 197-214.

Bally, R., McQuaid, C.D., Brown, A.C., 1984. Shores of mixed sand and rock: an unexplored marine ecosystem. South African Journal of Science 80, 500-503.

Barendse, J., Best, P.B., Thornton, M., Elwen, S.H., Rosenbaum, H.C., Carvalho, I., Pomilla, T.J.Q., Meÿer, M., Leeney, R.H., 2011. Transit station or destination? Attendance patterns, movements, and abundance estimate of humpback whales off west South Africa from photographic and genotypic matching. African Journal of Marine Science 33: 353-373.

Barnard, P. (1998). Biological diversity in Namibia: a country study. Windhoek: Ministry of Environment and Tourism.

Barnes, J.I., Alberts, M., 2008. Sustainable natural resource use on the coast of Namibia, DEA Research Discussion Paper. Number 78. October 2008

Barnes, J.I., Zeybrandt, F., Kirchner, C.H., Sakko, A.L., Macgregor, J., 2004. Economic valuation of the recreational shore fishery: a comparison of techniques. In: Sumaila, U.R., Steinshamn, S.I., Skogen, M.D., Boyer, D., (Eds). Ecological, Economic and Social Aspects of Namibian Fisheries. Delft; Eburon Academic Publishers, 215–230.

Barnes, K. N. (1998). The Important Bird Areas of southern Africa. Johannesburg: Birdlife South Africa.

Barnes, KN (ed.). 1998. The Important Bird Areas of southern Africa. BirdLife South Africa, Johannesburg.

Bartholomae, C.H., Hagen, E., 2007. Short-term variability in alongshore winds and temperature off Swakopmund, Namibia, during a non-upwelling event in 1998–1999. African Journal of Marine Science 29, 141-145.

Bartholomae, C.H., van der Plas, A.K., 2007. Towards the development of environmental indices for the Namibian shelf, with particular reference to fisheries management. African Journal of Marine Science 29, 25-35.

Batty, M., Tjipute, M., Sowman., M., Cardoso, P., Fielding, P., 2005. Overview and analysis of social, economic and fisheries information to promote artisinal fisheries in the BCLME Region – Namibia, BCLME Project LMR/AFSE/03/01/B, 40pp.

Belnap, J. (2001). Biological Soil Crusts and Wind Erosion. In J. Belnap, & O. L. Lange, Biological Soil Crusts: Structure, Function, and Managment.

Belnap, J., & Elridge, D. J. (2001). Disturbance and Recovery of Biological Soil Crusts. In J. Belnap, & O. L. Lange, Biological Soil Crusts: Structure, Function, and Management. Spinger-Verlag.

Belnap, J., & et al. (2001). Influence of Biological Soil Crusts on Soil Environments and Vascular Plants. In J. Belnap, & O. L. Lange, Biological Soil Crusts: Structure, Function, and Managment.

Belnap, J., & Gillette, D. A. (1998). Vulnerability of desert biological soil crusts to wind erosion: the influences of crust development, soil texture, and disturbance. Journal of Arid Environements.

Berg, J. A., and Newell, R. I. (1986). Temporal and spatial variations in the composition of seston available to the suspension-feeder Crassostrea virginica. Esturaine and Coastal Shelf Science 23, 375-386.

Berry, H. H. (1972). Flamingo breeding on the Etosha Pan, South West Africa, during 1971. Madoqua.

Best, P.B., 2007. Whales and Dolphins of the southern african Subregion. Cape Town: Cambridge University Press. pp 338.

Beyers C.J. De B., 1979. Stock assessment and some morphometric and biological characteristics of the rock-lobster Jasus lalandii on Marshall Rocks, its main commercial fishing area off South West Africa, 1971-1974. Investigational Report of the Sea Fisheries Branch, South Africa 117, 1-26.

Beyers, C.J. De B., Wilke, C.G., Goosen, P.C., 1994. The effects of oxygen deficiency on growth, intermoult period, mortality and ingestion rates of aquarium-held juvenile rock lobster Jasus lalandii. South African Journal of Marine Science 14, 79-88.

Bianchi, G., Carpenter, K.E., Roux, J.-P., Molloy, F.J., Boyer, D., Boyer, H.J., 1999. FAO species identification guide for fishery purposes. Field guide to the Living Marine Resources of Namibia, 256 pp.

Blaber, S.J.M., Blaber, T.G., 1980. Factors affecting the distribution of juvenile estuarine and inshore fish. Journal of Fish Biology 17, 143-162.

Borges, P. Andrade, C., Freitas, M.C., 2002. Dune, bluff and beach erosion due to exhaustive sand mining – the case of Santa Barbara Beach, Sao Miguel (Azores, Portugal). Journal of Coastal Research 36, 89-95.

Borgmann KL. 2011. A review of human disturbance impacts on waterbirds. Audubon California. [Online]. Available at www.sfbayjv.org/news-general.php.

Boyd, A. J., & Oberholster, G. P. (1994). Currents off the west and south coasts of South Africa. South Africa Shipping news and Fish Rev 49.

Braby, J. (2011). The Biology and Conservation of the Damara Tern in Namibia. Cape Town: Unpublished PHD Thesis (UCT).

Branch, G.M., 1981. The biology of limpets: physical factors, energy flow and ecological interactions. Oceanography and Marine Biology: An Annual Review 19, 235-380.

Branch, G.M., Griffiths, C.L., 1988. The Benguela ecosystem part V: the coastal zone. Oceanography and Marine Biology: An Annual Review 26, 395-486.

Brandão, A., Best, P.B., Butterworth, D.S., 2011. Monitoring the recovery of the southern right whale in South African waters. Paper SC/S11/RW18 submitted to IWC Southern Right Whale Assessment Workshop, Buenos Aires 13-16 Sept. 2011.

Bremmer, J. M., and Rogers, J. (1991). The Benguela Ecosystem. Part VII. Marine-geological aspects. Oceanography and Marine Biology: An Annual Review 29.

Bricelj, V. M., and Malouf, R. E. (1984). Influence of algal and suspended sediment concentrations on the feeding physiology of the hard clam. Marine Biology 84, 155-165.

Brown CJ, Scott A, Scott M. 2011. Assessment of the possible impacts between birds and a proposed mast to collect wind data at the NamPower Rotkop Substation near Lüderitz. Unpublished report for NamPower, Namibia.

Brown, A., 2000. Is the sandy beach isopod Tylos granulatus an endangered species? South African Journal of Science 96, 466.

Brüchert, V., Barker Jørgensen, B., Neumann, K., Riechmann, D., Schlösser M., Schulz, H., 2003. Regulation of bacterial sulfate reduction and hydrogen sulfide fluxes in the central Namibian coastal upwelling zone. Geochim. Cosmochim. Acta 67(23), 4505-4518.

Brüel & Kjær Sound & Vibration Measurement A/S. (2000). www.bksv.com. Retrieved October 14, 2011, from Brüel & Kjær: http://www.bksv.com

Bureau of Land Management (United States). USDI. 2004. Bureau of Land Management, U.S. Department of Interior. 2004. Visual Resource Management Manual 8400.

Burger, A. E., & Cooper, J. (Unkown). The Effects of fisheries on seabirds in South Africa and Namibia. Retrieved 09 04, 2014, from http://www.pacificseabirdgroup.org/publications/MB_FeedEcol/SP1984_CWS_EC_18.pdf

Cardboard Box Travel Shop. (2014). Cardboard Box Travel Shop. Retrieved May 21, 2014, from http://www.namibian.org/travel/rivers/kuiseb-river.htMℓ

Carr, A., 1987. Impact of non-degradable marine debris on the ecology and survival outlook of sea turtles. Marine Pollution Bulletin. 18: 352-356.

Carter, R.A., 2008. Walvis Bay coal fired power station environmental feasibility assessment. Marine ecology specialist study on cooling water discharges, Lwandle Technologies (Pty) Ltd for Ninham Shand (Pty) Ltd

Central Bureau of Statistics (CBS). 2006. Namibia Household Income and Expenditure Survey 2003/2004

Central Bureau of Statistics. (2004). Namibia Household Income and Expenditure Survey.

Cetus Projects CC, 2008. Specialist Report - Potential Environmental Impacts of Proposed 2D and 3D Seismic Surveys, Namibia. Document prepared for CCA Environmental (Pty) Ltd., 35 Roeland Square, 30 Drury Lane, Cape Town, 8001.

Chamber of Mines. (2013). Annual Review 2013.

Chang, K.-A., Ryu, Y., & Mori, N. (2009). Parameterization of Neutrally Buoyant Horizontal Round Jet in Wave Environment. J. Waterway, Port, Coastal, Ocean Eng, 135: p100-p107.

Chapman, P., and Shannon, L. V. (1985). The Benguela Ecosystem: Part II: Chemistry and related processes. Oceanogrphy and Marine Biology: An Annual Review 23, 183-251.

Chittenden H. 2007. Roberts Bird Guide. Trustees of the John Voelcker Bird Book Fund, Cape Town.

Christie, N.D., 1974. Distribution patterns of the benthic fauna along a transect across the continental shelf off Lamberts Bay, South Africa. Ph.D. Thesis, University of Cape Town, 110 pp and Appendices.

Christie, N.D., 1976. A numerical analysis of the distribution of a shallow sublittoral sand macrofauna along a transect at Lambert's Bay, South Africa. Transactions of the Royal Society of South Africa 42: 149-172.

Clark, B.M., 1997a. Variation in surf zone fish community structure across a wave exposure gradient. Estuarine and Coastal Shelf Science 44, 659-674.

Clark, B.M., 1997b. Dynamics and Utilisation of Surf Zone Habitats by Fish in the South-Western Cape, South Africa. Unpublished PhD Thesis, University of Cape Town.

Clark, B.M., Atkinson, L.J., Steffani, N., Pulfrich, A., 2004. Sandy Beach and Rocky Intertidal Baseline Monitoring Studies in the Bogenfels Mining Licence Area, Namibia. Monitoring Report 2004. Report to NAMDEB Diamond Corporation (Pty) Ltd., Oranjemund, Namibia.

Clark, B.M., Bennett, B.A., Lamberth, S.J., 1994. A comparison of the ichthyofauna of two estuaries and their adjacent surf-zones, with an assessment of the effects of beach-seining on the nursery function of estuaries for fish. South African Journal of Marine Science, 14, 121-131.

Clark, B.M., Nel, R., 2002. Baseline survey of sandy beaches in Mining Area 1. Unpublished Report, NAMDEB Diamond Corporation.

Clark, B.M., Pulfrich, A., Atkinson, L.J., 2006. Sandy Beach and Rocky Intertidal Monitoring Studies in the Bogenfels Mining Licence Area, Namibia. Monitoring Report 2006. Report to NAMDEB Diamond Corporation (Pty) Ltd., Oranjemund, Namibia. 133pp.

Climate-Data.org. (2014). Climate: Swakopmund. Retrieved May 8, 2014, from http://climate-data.org/

Cockroft, A.C., Schoeman, D.S., Pitcher, G.C., Bailey, G.W., Van Zyl, D.L.. 2000. A mass stranding or "walkout" of West Coast rock lobster Jasus lalandii in Elands Bay, South Africa: causes, results and implications. In: Von Kaupel Klein, J.C. and F.R. Schram (Eds), The Biodiversity Crises and Crustacea. Crustacean Issues 11, 673-688.

Collins, T., Cerchio, S., Pomilla, C., Loo J., Carvalho, I., Ngouessono, S., Rosenbaum, H.C., 2008. Revised estimates of abundance for humpback whale breeding stock B1: Gabon. Paper SC60/SH28 submitted to the 60th Meeting of the Scientific Committee of the International Whaling Commission.

CoM. (2014). Mining Industry Performance and Challenges during 2013. Retrieved from http://www.chamberofmines.org.na/fileadmin/user_upload/May_2014/1_Mining_Industry_Performance_and_Challenges_during_2013.pdf

Convention on Migratory Species (Convention on Migratory Species). 2011. Review of the Conflict between Migratory Birds and the Electricity Power Grids in the African-Eurasian Region.

Cooper J. 1995. Portnet Saldanha: proposed extension of the General Cargo Quay. Appendix 3. Specialist study on the impact of underwater blasting on marine vertebrates, especially African Pendguins, in Saldanha Bay. CSIR Report EMAS-C 94095D. 33 pp.

COWI, 2003a. Walvis Bay Local Agenda 21 Project. Coastal area study. Intensive monitoring campaign. Municipality of Walvis Bay, Danida and COWI Consulting Engineers. April 2003.

CSIR, 1989. A Study of Some of the Physical and Biotic Processes Affecting Dredging within the Walvis Bay Lagoon. Stellenbosch. CSIR Report Environmental Management Act-C 891009.

CSIR, 1992. Sedimentation History and Present State of the Walvis Bay Lagoon. Stellenbosch. CSIR Report EMAS-C 92040 (Unpublished). 92pp.

CSIR, 2005. Sedimentation of the Small-Craft Harbour at Swakopmund. CSIR Report ENV-S-C 2005-004, submitted to Desert Child and Windhoek Consulting Engineers, April 2005.

CSIR. (2002). A decision support tool: Operational time for the Namdeb inshore mining project.

CSIR. (2009). Environmental Impact Assessment for the Proposed Desalination Project at Mile 6 near Swakopmund, Namibia, Draft EIA Report (CSIR Report No. CSIR/CAS/EMS/ER/2009/0015/A). Stellenbosch.

CSIR. (2009). Modelling Study for the NamWater Desalination Plant.

CSIR. 2008a. Hydrographical and Geophysical Survey for Desalination Plant on Central West Coast of Namibia. Prepared for NamWater, pepared by Built Environment, CSIR. November 2008. pp. 8.

CSIR. 2009. Environmental Impact Assessment for the Proposed Desalination Project at Mile 6 near Swakopmund, Namibia, Draft EIA Report (CSIR Report No. CSIR/CAS/EMS/ER/2009/0015/A). Stellenbosch.

CSIR. 2009. Modelling Study for the NamWater Desalination Plant.

Cunningham, P. (2014). Biophysical Assessment (vertebrate Fauna & Flora): Schwarzekuppe-Swakopmund Pipeline Infrastructure Developments (Swakopmund & Walvis Bay area). Windhoek: Environment & Wildlife Consulting, Namibia.

Currie, H., Grobler, K., Kemper, J., 2008. Concept note, background document and management prosposal for the declaration of Marine Protected Areas on and around the Namibian offshore islands and adjacent coastal areas. Draft 4., Prepared by Feike Natural Resource Management advisors for the Ministry of Fisheries and Marine Resources, NACOMA - Namibian Coast Conservation and Management Project and World Wide Fund For Nature. pp. 119 + Appendices.

Daly, M.A., Mathieson, A.C., 1977. The effects of sand movements on intertidal seaweeds and selected invertebrates at Bound Rock, New Hampshire. Marine Biology 43, 45-55.

David, J.L., Benavente, E., Bres-Patry, C., Dusautoir, J.C., Echaide, M., 2004. Are neopolyploids a likely route for a transgene walk to the wild? The Aegilops ovata × Triticum turgidum durum case. Biol. J. Linn. Soc., 82: 503–510.

De Decker, A.H., 1970. Notes on an oxygen-depleted subsurface current off the west coast of South Africa. Investigational Report: Division of Sea Fisheries, South Africa, 84, 24 pp.

Defeo, O., De Alava, A., 1995. Effects of human activities on long-term trends in sandy beach populations: wedge clam Donax hanleyanus in Uruguay. Marine Ecology Progress Series 123, 73-82.

Defeo, O., McLachlan, A., 2005. Patterns, processes and regulatory mechanisms in sandy beach macrofauna: a multi-scale analysis. Marine Ecology Progress Series 295, 1-20.

Department of Water Affairs and Forestry. (1995). South African water quality guidelines for coastal marine waters (Volume 1, 2 and 3). Pretoria: DWAF.

Desprez, M., 2000. Physical and biological impact of marine aggregate extraction along the French coast of the Eastern English Channel: short-and long-term post-dredging restoration. ICES Journal of Marine Science 57: 1428–1438.

Dethier, M.N., 1984. Disturbance and recovery in intertidal pools: maintenance of mosaic patterns. Ecological Monographs 54, 99-118

Diniz, V. (2014, 08 13). Uranium Price Finally Makes an Upward Move. Retrieved 08 17, 2014, from Uranium Investing News: http://uraniuminvestingnews.com/19396/uranium-price-u3o8-fission-forum-athabasca-basin-cameco.htMℓ

Donn, T.E., 1986. Intertidal Macrofauna. In: McLachlan, A. (ed.). Ecological surveys of sandy beaches on the Namib coast. Unpublished ICR Report no. 13.

Donn, T.E., Cockcroft, A.C., 1989. Macrofaunal community structure and zonation of two sandy beaches on the central Namib coast, South West Africa/Namibia. Madoqua 16, 129-135.

Dooling, R. (2002). Avian Hearing and the Avoidance of Wind Turbines.

Dooling, R. J., & Popper, A. N. (2007). The Effects of Highway Noise on Birds.

Drake, D.E., Cacchione, D.A., Karl, H.A., 1985. Bottom currents and sediment transport on San Pedro Shelf, California. Journal of Sedimentary Petrology 55, 15-28.

DWA. 2008. Kuiseb Basin Water Resources Management Project - Development of a Water Resources Plan for the Kuiseb Basin and Development of a Planning Procedure for use by Other Basins – Part Geohydrology. Accessed on http://www.iwrm-namibia.info.na/downloads/4-kuiseb-basin-wm-plan-geo-hydrology.pdf

Dwyer, K.L., Ryder, C.E., Prescott R., 2003. Anthropogenic mortality of Leatherback Sea turtles in Massachusetts waters. p. 260. In: J.A. Seminoff (compiler). Proceedings of the Twenty-Second Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-503.

EC WG-AEN. (2003). Good Practice Guide for Strategic Noise Mapping and the Production of Associated Data on Noise Exposure.

EIS 2014. Environmental Information Service, www.the-eis.com.

Ellingsen, K.E., 2002. Soft-sediment benthic biodiversity on the continental shelf in relation to environmental variability. Marine Ecology Progress Series 232, 15-27.

Elwen, S.H., Best, P.B., Thornton, M., Reeb, D., 2010. Near-shore distribution of Heaviside's (Cephalorhynchus heavisidii) and dusky dolphins (Lagenorhynchus obscurus) at the southern limit of their range in South Africa. African Zoology 45(1).

Elwen, S.H., Findlay, K.P., Kiszka, J., Weir, C.R., 2011a. Cetacean research in the southern African subregion: a review of previous studies and current knowledge. African Journal of Marine Science 33 (3): 469–493.

Elwen, S.H., Leeney, R.H., 2009. Report of the Namibian Dolphin Project 2009: Ecology and conservation of coastal dolphins in Namibia. Submitted to the Ministry of Fisheries and Marine Resources, 20 Nov 2009. 25 pp. and 1 appendix.

Elwen, S.H., Leeney, R.H., 2010. Injury and Subsequent Healing of a Propeller Strike Injury to a Heaviside's dolphin (Cephalorhynchus heavisidii). Aquatic Mammals 36 (4): 382-387.

Elwen, S.H., Leeney, R.H., 2011. Interactions between leatherback turtles and killer whales in Namibian waters, including possible predation. South African Journal of Wildlife Research

Elwen, S.H., Snyman, A., Leeney, R.H., 2011b. Report of the Namibian Dolphin Project 2010: Ecology and conservation of coastal dolphins in Namibia. Submitted to the Ministry of Fisheries and Marine Resources, 27 Feb 2011. 36 pp. and 5 appendices.

Emanuel, B.P., Bustamante, R.H., Branch, G.M., Eekhout, S., Odendaal, F.J., 1992. A zoogeographic and functional approach to the selection of marine reserves on the west coast of South Africa. South African Journal of Marine Science 12, 341-354.

Emeis, K.-C., Brüchert, V., Currie, B., Endler, R., Ferdelman, T., Kiessling, A., Leipe, T., Noli-Peard, K., Struck, U., Vogt, T., 2004. Shallow gas in shelf sediments of the Namibian coastal upwelling ecosystem. Continental Shelf Research 24, 627-642.

Environmental Consulting. (2010). Cities and Climate Change Initiative Walvis Bay, Namibia: Mapping of Walvis. Windhoek: Environmental Consulting.

Environmental Management Plan for the Town of Swakopmund. (2010). Retrieved from NACOMA: http://www.nacoma.org.na/Downloading/EMP_Swakopmund.pdf

Facts about Swakop. (2014). Retrieved 08 21, 2014, from Swakopmund - a place where you must have been: http://www.swakopmund.com/14.htMℓ

Fegley, S. R., Macdonald, B. A., & Jacobsen, T. R. (1992). Short-term variation in the quantity and quality of seston available to benthic suspension feeders. Estuarine and Coastal Shelf Science 34, 193-412.

Field, J.G., Griffiths, C.L., 1991. Littoral and sublittoral ecosystems of southern Africa. In: A.C. Mathieson and P.H. Nienhuis (eds). Ecosystems of the World 24. Intertidal and Littoral Ecosystems, Elsevier Science Publishers, Amsterdam.

Findlay, K.P., 1996. The impact of diamond mining noise on marine mammal fauna off southern Namibia. Specialist Study #10. In: Environmental Impact Report. Environmental Evaluation Unit (ed.) Impacts of deep sea diamond mining, in the Atlantic 1 Mining Licence Area in Namibia, on the natural systems of the marine environment. No. 11-96-158, University of Cape Town. Report to De Beers Marine (Pty) Ltd. pp. 370

Findlay, K.P., Best, P.B., Ross, G.J.B., Cockcroft, V.G., 1992. The distribution of small odontocete cetaceans off the coasts of South Africa and Namibia. South African Journal of Marine Science 12: 237-270.

Finley, K.J., Miller, G.W., Davis, R.A., Greene, C.R., 1990. Reactions of belugas, (Delphinapterus leucas) and narwhals (Monodon monoceros) to ice-breaking ships in the Canadian high arctic. Can. Bull. Fish. Aquat. Sci. 224: 97-117.

Flach, E., Thomsen, L., 1998. Do physical and chemical factors structure the macrobenthic community at a continental slope in the NE Atlantic? Hydrobiologia 375/376, 265-285.

Galvin, C. (1971). Wave Breaking in Shallow Water. In R. E. Meyer, Waves on Beaches and Resulting Sediment Transport (pp. 413-456). New York: Academic Press.

Garcia-Pichel, F., and Belnap, J. (1996). Microenvironments and microscale productivity of cyanobacterial dessert crusts. Journalof Phycology.

Glassom, D., Branch, G.M., 1997. Impact of predation by greater flamingos Phoenicopterus ruber on the macrofauna of two southern African Lagoons. Mar. Ecol. Prog. Ser. 149: 1-12.

Gomez-Pina, G. Munoz-Perez, J. Ramirez, J.L., Ley, C., 2002. Sand dune management problems and techniques, Spain. Journal of Coastal Research 36, 325-332.

Goosen, A.J.J., Gibbons, M.J., McMillan, I.K., Dale, D.C., Wickens, P.A., 2000. Benthic biological study of the Marshall Fork and Elephant Basin areas off Lüderitz. Prepared by De Beers Marine (Pty) Ltd. for Diamond Fields Namibia, January 2000. 62 pp.

Griffin, M., 1998. The species diversity, distribution and conservation of Namibian mammals. Biodiversity and Conservation 7: 483-494.

Griffin, M., Coetzee, C.G., 2005. Annotated checklist and provisional national conservation status of Namibian mammals. Technical Reports of Scientific Services No. 4. Directorate of Scientific Services, Ministry of Environment and Tourism, Windhoek, Namibia. 207 pp.

Griffiths, M.H., Heemstra, P.C., 1995. A contribution to the taxonomy of the marine fish genus Argyrosomus (Perciformes: Sciaenidae), with descriptions of two new species from southern Africa. Ichthyol. Bull., J.L.B. Smith Inst. Ichthyol. No. 65, 40 p

Hagen, E., and Bartholomae, C. H. (2007). Short-term Variability in alongshore winds and temperature off Swakopmund, Namibia, during a non-upwelling event in 1998-1999.

Hampton, I., 2003. Harvesting the Sea. In: Molloy, F. and T. Reinikainen (Eds), 2003. Namibia`s Marine Environment. Directorate of Environmental Affairs, Ministry of Environment and Tourism, Namibia, 31-69.

Hansen. F.C., Cloete. R.R., Verheye, H.M., 2005. Seasonal and spatial variability of dominant copepods along a transect off Walvis Bay (23ºS), Namibia. African Journal of Marine Science 27, 55-63.

Harrison JA, Allan DG, Underhill LG, Herremans M, Tree AJ, Parker V, Brown CJ (eds). 1997. The atlas of southern African birds. Vol 1: Non-Passerines, and Vol 2: Passerines. BirdLife South Africa, Johannesburg.

Hays, G.C., Houghton, J.D.R., Isaacs, C., King, R.S., Lloyd, C., Lovell, P., 2004. First records of oceanic dive profiles for leatherback turtles, Dermochelys coriacea, indicate behavioural plasticity associated with long-distance migration. Animal Behaviour 67: 733-743.

Henties Bay Tourism Association. (2012). Hentiesbay Tourism. Retrieved January 30, 2014, from http://www.hentiesbay.com/dorob.htm

Hockey PAR 1983. The distribution, population size, movements and conservation of the African Black Oystercatcher Haematopus moquini. Biol. Conserv. 25: 233-262.

Hockey PAR, Dean WRJ, Ryan PG (eds). 2005. Roberts Birds of southern africa, 7th Edition. The Trustees of the John Voelcker Bird Book Fund, Cape Town.

Hockey PAR, Leseberg A, Loewenthal D. 2003. Dispersal and migration of juvenile African Black Oystercatchers Haematopus moquini. Ibis 145:E114-E123.

Hockey, P. A. (1983). The distribution, population size, movements and conservation of the African Black Oystercatcher Haematopus moquini.

Hockey, P. A., Leseberg, A., & Loewenthal, D. (2003). Dispersal and migration of juvenile African Black Oystercatchers Haematopus moquini. Ibis.

Holtzhausen, J.A., Camarada, T.G., 2007. Migratory Behaviour and Assessment of the Bronze Whaler (Carcharhinus brachyurus), Final Report: BCLME Project Number LMR/CF/03/16.

Holtzhausen, J.A., Kirchner, C.H. 1998. Kob fishery in Namibia. Namibia Brief 20, 130-133.

Holtzhausen, J.A., Kirchner, C.H., 2001. An assessment of the current status and potential yield of Namibia's northern West Coast steenbras Lithognathus aureti population. South African Journal of Marine Science 23, 157-168.

Holtzhausen, J.A., Kirchner, C.H., Voges, S.F., 2001. Observations on the linefish resources of Namibia, 1999-2000, with special reference to West Coast steenbras and silver kob. South African Journal of Marine Science 23, 135-144.

Holtzhauzen, J.A., 2000. Population dynamics and life history of westcoast steenbras Lithognathus aureti (Sparidae), and management options for the sustainable exploitation of the steenbras resource in Namibian waters. PhD Thesis, University of Port Elizabeth: 233 pages.

Holtzhauzen, J.A., Mann, B.Q., 2000. Westcoast steenbras (Lithognathus aureti). In Mann, B. Q. (Ed), southern african Marine Linefish Status Reports. Special Publication Oceanogaphic Research Institute 7:152-154.

Hsiao, S.-C., Hsu, T.-W., Lin, J.-F., & Chang, K.-A. (2011). Mean and Turbulence Properties of a Neutrally Buoyant Round Jet in a Wave Environment. J. Waterway, Port, Coastal, Ocean Eng. , 137:109-122.

Hutchings, L., and Nelson, N. (1983). The Benguela Upwelling area.

IBID. (n.d.).

IFC. (2007). General Environmental, Health and Safety Guidelines.

International Finance Corporation. (2012). Performance Standard1: Assessment and Management of Environmental and Social Risk and Impacts.

IUCN. (2014, 02). IUCN Red List of Threatened Species. Retrieved from www.iucnredlist.org

James, M.C., Ottensmeyer, C.A., Myers, R.A., 2005. Identification of high-use habitat and threats to leatherback sea turtles in northern waters: new directions for conservation. Ecology Letters 8: 195-201.

Jenkins, AR, Smallie, JJ, Diamond, M. 2010. Avian collisions with powerlines: a global review of causes and mitigation with a South African perspective. Bird Conservation International. pp1-16.

Kendall, M.A., Widdicombe, S., 1999. Small scale patterns in the structure of macrofaunal assemblages of shallow soft sediments. Journal of Experimental Marine Biology and Ecology 237:127-140.

Kenny, A.J., Rees, H.L., Greening, J., Campbell, S., 1998. The effects of marine gravel extraction on the macrobenthos at an experimental dredge site off north Norfolk, U.K. (Results 3 years post-dredging). ICES CM 1998/V:14, pp. 1-8.

Kensley, B., 1978, Interaction between coastal processes and lagoonal fauna between Walvis Bay and Lüderitzbucht, South-West Africa. Madoqua 11(1):55-60.

Kensley, B.F., Penrith, M.J., 1977. Biological survey of Sandvis 1, introduction and faunal list. Madoqua 10(3), 181-190.

Kensley, B.F., Penrith, M.J., 1980. The constitution of the fauna of rocky intertidal shores of South West Africa. Part III: The north coast from False Cape Frio to the Kunene River. Cimbebasia Series A 5(4), 201-214.

Kikkert, G. (2006). Buoyant jets with two and three-dimensional trajectories . Ph.D Thesis. New Zealand: University of Canterbury.

Kinahan, J. (2014). EnvironmentalImpact Assessment and compilation of an Environmental Management Plan for the Swakopmund - Mile 7 Water Supply Phase 2 Project. Windhoek: QRS.

Kinoshita, I., Fujita, S., 1988. Larvae and juveniles of blue drum, Nibea mitsukurii, occurring in the surf zone of Tosa Bay, Japan. Japanese Journal of Ichthyology 35, 25-30.

Kirchner, C.H., 2001. Fisheries regulations based on yield per recruit analysis for the linefish silver kob Argyrosomus inodorus in Namibian waters. Fisheries Research 52, 155–167.

Kirchner, C.H., Beyer, J.E., 1999. Estimation of total catch of silver kob Argyrosomus inodorus by recreational shore-anglers in Namibia using a roving-roving creel survey. South African Journal of Marine Science 21, 191–199.

Kirchner, C.H., Holtzhausen, J.A., Voges, S.F., 2001. Introducing size limits as a management tool for the recreational linefishery of silver kob, Argyrosomus inodorus (Griffiths and Heemstra), in Namibian waters Fisheries Management and Ecology, 8: 227-237.

Kirchner, C.H., Sakko, A., Barnes, J.I., 2000. Estimation of the economic value of the Namibian recreational rock-and-surf fishery. South African Journal of Marine Science 22, 17-25.

Kirkman, S.P., Oosthuizen, W.H., Meyer, M.A., Kotze, P.G.H., Roux, J-P. Underhill L.G., 2007, Making sense of census and dealing with missing data:

trends in pup counts of Cape fur seal Arctocephalus pusillus pusillus for the period 1972-2004, African Journal of Marine Science, 29(2),

Kolberg, H. (n.d.). Preliminary inventory of Namibia's wetlands. Ministry of Environment.

Kruger R, Maritz A, Van Rooyen C. Undated. Vulture electrocutions on vertically configured medium voltage structures in the Northern Cape Province, South Africa. Eskom/EWT Strategic Partnership.

Lamberth, S.J., Branch, G.M. Clark, B.M., 2010. Estuarine refugia and fish responses to a large anoxic, hydrogen sulphide, "black tide" event in the adjacent marine environment. Estuarine, Coastal and Shelf Science, 86: 203-215.

Lamberth, S.J., van Niekerk, L., Hutchings, K., 2008. Comparison of, and the effects of altered freshwater inflow on, fish assemblages of two contrasting South African estuaries: the cool-temperate Olifants and the warm-temperate Breede. African Journal of Marine Science 30: 311-336.

Lane, S.B., Carter, R.A., 1999. Generic Environmental Management Programme for Marine Diamond MIning off the West Coast of South Africa. Marine Diamond Mines Association, Cape Town, South Africa. 6 Volumes.

Lange, E. 1994: Integration of computerized visual Simulation and visual Assessment in environmental Planning. Landscape and Urban Planning.

Langer Heindrich Uranium. http://www.paladinenergy.com.au/default.aspx?MenuID=227

Langer Heindrich Uranium. Project Update June 2014, http://www.paladinenergy.com.au/default.aspx?MenuID=113

Lasiak, T.A., 1981. Nursery grounds of juvenile teleosts: evidence from surf zone of King's beach, Port Elizabeth. South African Journal of Science 77, 388-390.

Leeney, R.H., Carslake, D., Elwen, S.H., 2011. Using Static Acoustic Monitoring to Describe Echolocation Behaviour of Heaviside's Dolphins in Namibia. Aquatic Mammals 37 (2): 151-160.

Leeney, R.H., Post, K., Best, P.B., Hazevoet, C.J., Elwen, S.H., (in rev.) Pygmy right whale records from Namibia.

Leseberg A, Hockey PAR, Loewenthal D. 2000. Human disturbance and the chick-rearing ability of African Black Oystercatchers (Haematopus moquini): a geographical perspective. Biol. Conserv. 96: 379-385.

Leseberg A. 2001. The foraging ecology, demographics and conservation of African Black Oystercatchers Haematopus moquini in Namibian nursery areas. MSc thesis, University of Cape Town.

Lessenberg, A. (2001). The foraging ecology, demographics and conservation of African Black Oystercatchers Haematopus moquini in Namibian nursery areas. UCT.

Liebenberg-Enslin, H., & Krause, N. (2011). Cocko Holdings Namibia (Pty) Ltd. VIP Site Option Ranking: Air Quality and Noise Impact Evaluation. Report No. APP/11/GHN-01 Rev 1. Midrand: Airshed Planning Professionals (Pty) Ltd.

Liebenberg-Enslin, H., and Krause, N. (2011). Cocko Holdings Namibia (Pty) Ltd. VIP Site Option Ranking: Air Quality and Noise Impact Evaluation. Report No. APP/11/GHN-01 Rev 1. Midrand: Airshed Planning Professionals (Pty) Ltd.

Louw, D.C., 2008. Internal memorandum. Phytoplankton Bloom along the Namibian Coast. Ministry of Fisheries and Marine Resources: Directorate of Resource Management. Date: 10/03/2008.

Lutcavage, M.E., Plotkin, P., Witherington, Lutz, P.L., 1997. Human impacts on sea turtle survival. In: The Biology of Sea Turtles, Vol. 1. P.L. Lutz and J. Musick (eds.) CRC Press, Boca Raton, Fla. pp. 387-410.

Lutz, P.L., Alfaro-Shulman, A.A., 1991. The effects of chronic plastic ingestion on green sea tutles. Report NOAASB21-WCH06134, U.S. Dept. of Commerce, Miami, FL.

Lynam, C.P., Gibbons, M.J., Axelsen, B.A., Sparks, C.A.J., Coetzee, J., Heywood, B.G., Brierley, A.S., 2006. Jelly Fish overtake fish in a heavily fished ecosystem. Curr. Biol. 16, 492–493.

Martin G, Shaw J. 2010. Bird collisions with powerlines: Failing to see the way ahead? Biological Conservation 143: 2695-2702.

Martin GR, Katzin, G. 1999. Visual field in Short-toed Snake-Eagles Circaetus gallicus and the function of binocularity in birds. Brain, Behaviour And Evolution 53: 55-56.

Martin GR, Portugal SJ, Murn CP. 2012. Visual fields, foraging and collision vulnerability in Gyps vultures. Ibis (2012), doi: 10.1111/j.1474-919X.2012.01227.x.

Martin, GR. 2011. Understanding bird collisions with man-made objects: a sensory ecology approach. Ibis (2011), 153, 239–254.

Matthews, S.G., Pitcher, G.C., 1996. Worst recorded marine mortality on the South African coast. In: Harmful and Toxic Algal Blooms. Eds. Yasumoto, T, Oshima, Y., Fukuyo, Y. Intergovernmental Oceanographic Commission of UNESCO, pp 89-92.

Maurihungirire, M., Griffin, K., 1998. Mariculture- a Namibian Perpective. Namibia Brief 20, 134-135.

MAWF. 2008. Integrated Water Resources Management (IWRM): Kuiseb River Basin p.12.

MAWF. 2008. Kuiseb Basin Water Resources Management Project - Development of a Water Resources Plan for the Kuiseb Basin and Development of a Planning Procedure for use by Other Basins: Part: Geohydrology. Retrieved 08 18, 2014, from http://www.iwrm-namibia.info.na/downloads/4-kuiseb-basin-wm-plan-geo-hydrology.pdf

McCulloch, G., & Irvine, K. (2004). Breeding of Greater and Lesser Flamingos at Sua Pan, Botswana, 1998-2001. Ostrich.

McLachlan, A., 1980. The definition of sandy beaches in relation to exposure: a simple rating system. South African Journal of Science 76, 137-139.

McLachlan, A., 1985. The ecology of two sandy beaches near Walvis Bay, Madoqua 14(2), 155-163.

McLachlan, A., 1986. Ecological surveys of sandy beaches on the Namib coast. Report No. 13, Institute for Coastal Research, University of Port Elizabeth, Port Elizabeth, 135 pp.

McLachlan, A., De Ruyck, A., 1993. Survey of sandy beaches in Diamond Area 1. A report to Consolidated Diamond Mines, Oranjemund, Namibia.

McLachlan, A., Jaramillo, E., Donn, T.E., Wessels, F., 1993. Sandy beach macrofauna communities and their control by the physical environment: a geographical comparison. Journal of coastal Research, Special Issue 15, 27-38.

McQuaid, C.D., Branch, G.M., 1984. Influence of sea temperature, substratum and wave exposure on rocky intertidal communities: an analysis of faunal and floral biomass. Marine Ecology Progress Series 19, 145-151.

McQuaid, C.D., Branch, G.M., Crowe, A.A., 1985. Biotic and abiotic influences on rocky intertidal biomass and richness in the southern Benguela region. South African Journal of Zoology 20, 115-122.

Mecenero, S., Roux, J-P., Underhill, L.G., Bester, M.N., 2006. Diet of Cape fur seals Arctocephalus pusillus pusillus at three mainland breeding colonies in Namibia. 1. Spatial variation. African Journal of Marine Science 28: 57-71.

Mendelsohn J, Jarvis A, Roberts C, Robertson T. 2002. Atlas of Namibia. David Philip Publishers, Cape Town.

Metago 2011. Environmental Scoping Report for the proposed Stage 4 Expansion Project…at Langer Heinrich Mine. P6-9

Metago. (2010). EIA report for the proposed Husab Mine.

Metago. (2011). Environmental Scoping Report for the proposed Stage 4 Expansion Project and Langer Heindrich Mine.

Meyer, W.F., Ewart-Smith, C., Nel, R., Clark, B.M., 1998. Ecological impact of beach diamond mining on beach, rocky intertidal and surf zone biological communities in the Sperrgebiet, Namibia. Phase 1 – baseline surveys. AEC Unpublished Report. 77 pp.

MFMR, 2001. Towards Responsible Development of Aquaculture. Namibia's Aquaculture Policy. Ministry of Fisheries and Marine Resources (MFMR), Namibia, 22pp.

MFMR, 2004. Namibia's Aquaculture Strategic Plan, Ministry of Fisheries and Marine Resources (MFMR), Namibia, 34pp.

MFMR, 2008. Ministry of Fisheries and Marine Resources: Directorate of Resource Management. Monthly Marine Environmental Update. March 2008. No. 03/2008. Compiled by C.H. Bartholomae.

Ministry of Environment and Tourism . (2013). MET. Retrieved January 29, 2014, from http://www.met.gov.na/Pages/EnvironmentalManagement.aspx

Ministry of Environment and Tourism. (2002). Digital Atlas of Namibia. Retrieved 08 16, 2014, from http://www.uni-koeln.de/sfb389/e/e1/download/atlas_namibia/index_e.htm

Ministry of Environment and Tourism. (2012). The National Policy on Coastal Management for Namibia. Retrieved January 29, 2014, from http://www.met.gov.na/Pages/PoliciesandLegislations.aspx

Molloy, F., Reinikainen T., (Eds), 2003. Namibia`s Marine Environment. Directorate of Environmental Affairs, Ministry of Environment and Tourism, Namibia, 160 pp.

Mori, N., & Chang, A.-N. (2003). Experimental study of a horizontal jet in a wavy environment. J. Eng. Mech, 129: p1149–p1155.

NACOMA. (2008). Strategic Environmental Assessment (SEA) for the Coastal Areas of the Erongo and Kunene Regions. Windhoek: MET.

NACOMA. 2013. Namibian Coast Conservation and Management Project. Retrieved January 30, 2014, from http://www.nacoma.org.na/Downloading/DorobNationalPark_Regulations_6Dec2011.pdf

Namibia Statistics Agency (NSA). 2013. Namibia 2011 Population and Housing Census Main Report. Revised 26 April 2013. 214 pp.

Namibia Statistics Agency. 2012. Namibia Household Income and Expenditure Survey 2009/2010

Namibia Tourism. (2012). Namibia Tourism: Your guide to Namibia. Retrieved January 28, 2014, from http://www.namibiatourism.org/place/dorob-national-park

NamWater. (2003). Feasability Study Update: Bulk Water Supply from Swakopmund to Walvis Bay (Draft). Windhoek: NamWater.

NamWater. (2013). Development Proposal on the Collector 2 - Scwarzekuppe-Swakopmund Pipeline Replacement. Windhoek: NamWater.

NamWater. (2014). Aquifers: The Omaruru Delta (Omdel) Scheme. Retrieved 08 16, 2014, from http://www.namwater.com.na/index.php?option=com_content&view=article&id=105

NamWater. 2003. Feasability Study Update: Bulk Water Supply from Swakopmund to Walvis Bay (Draft). Windhoek: NamWater.

NamWater. 2014. Aquifers: The Omaruru Delta (Omdel) Scheme. Retrieved 08 16, 2014, from http://www.namwater.com.na/index.php?option=com_contentandview=articleandid=105

NamWater. The Omaruru Delta (Omdel) Scheme. http://www.namwater.com.na/index.php?option=com_contentandview=articleandid=105.; accessed on 16 Aug 2014.

Nashima, F.P., 2013. Structure and composition of intertidal communities at exposed and sheltered habitat, Central Namibian Coast. Journal of Agriculture and Biodiversity Research 2(3): 67-72.

National Planning Commision. (2012). Namibia's Fourth National Development Plan 2012 - 2017.

Nel, R., Ewart-Smith, C., Meyer, W.F., Clark, B.M., 1997. Macrofauna baseline study of three pocket-beaches in the Sperrgebiet, Namibia. AEC Unpublished Report. 23pp.

Nelson, G. (1989). Poleward motion in the Benguela area:. In Poleward Flows along Eastern Ocean Boundaries. New York: Springer.

Nelson, G., Hutchings, L., 1983. The Benguela Upwelling area. Prog. Oceanogr. 12, 333-356.

Newman, G.G., Pollock, D.E., 1971. Biology and migration of rock lobster Jasus lalandii and their effect on availability at Elands Bay, South Africa. Investigational Report: Division of Sea Fisheries, South Africa 94, 1-24.

NRC (National Research Council). 1990. Decline of the sea turtles: causes and prevention. National Academy Press, Washington, D.C.

NSA. (2011). Population and Housing Census: Erongo Regional Profile.

Oberholzer, B. 2005. Guideline for involving visual and aesthetic specialists in EIA processes: Edition 1. CSIR Report No ENV-S-C 2005 053 F. Republic of South Africa, Provincial Government of the Western Cape, Department of Environmental Affairs and Development Planning, Cape Town.

O'Connor, S.R., Campbell, H., Cortez, Knowles, T., 2009. Whale Watching Worldwide: tourism numbers, expenditures and expanding economic benefits, a special report from the International Fund for Animal Welfare, Yarmouth MA, USA, prepared by Economists at Large.

Oliver, C. J. (2012, January 30). Near field mixing of negatively buoyant jets. Ph. D. Thesis. Christchurch, New Zealand: University of Canterbury.

Oosthuizen, W.H., 1991. General movements of South African (Cape) fur seals Arctocephalus pusillus pusillus from analysis of recoveries of tagged animals. S. Afr. J. Mar. Sci. 11: 21-30.

Paladin Energy Ltd. (2013). Sustainability Report: Environment: Water. Retrieved from Paladin Energy Ltd: http://www.paladinenergy.com.au/default.aspx?MenuID=227

Parkins, C.A., Field, J.G., 1998. The effects of deep sea diamond mining on the benthic community structure of the Atlantic 1 Mining Licence Area. Annual Monitoring Report – 1997. Prepared for De Beers Marine (Pty) Ltd by Marine Biology Research Institute, Zoology Department, University of Cape Town. pp. 44.

Parry, D.M., Kendall, M.A., Pilgrim, D.A., Jones, M.B., 2003. Identification of patch structure within marine benthic landscapes using a remotely operated vehicle. J. Exp. Mar. Biol. Ecol. 285– 286: 497–511.

Pearson, J., Guymer, I., Coates, L., & West, J. (2009). On-off shore Solute Mixing in the Surf-Zone. Journal of Waterways, Port, Coastal and Ocean Engineering.

Penrith, M.-L., Kensley, B.F., 1970a. The constitution of the intertidal fauna of rocky shores of South West Africa. Part I. Lüderitzbucht. Cimbebasia Series A 1(9), 191-239.

Penrith, M.-L., Kensley, B.F., 1970b. The constitution of the fauna of rocky intertidal shores of South West Africa. Part II. Rocky Point. Cimbebasia Series A 1(10), 243-268.

Pollock, D.E., Shannon, L.V., 1987. Response of rock-lobster populations in the Benguela ecosystem to environmental change – a hypothesis. South African Journal of Marine Science 5, 887-899.

Potter, I.C., Beckley, L.E., Whitfield, A.K., Lenanton, R.C.J., 1990. Comparisons between the roles played by estuaries in the life cycles of fishes in temperate Western Australia and southern Africa. Environmental Biology of Fishes 28, 143-178.

Potts, W.M., Heriques, R,, Sauer, WHH, Santos, C.V., Shaw, P., 2012. Are changing water temperatures in the Benguela about to alter the evolutionary history of our Argyrosomus fishes? Proceedings of the 4th South African Marine Linefish Symposium, in press.

Potts, W.M., Sauer, W.H.H., Henriques, R., Kirchner, K., Munnick, K., Santos, C.V., Shaw, P.W., in prep. Rapid climate driven distributional shifts, complicates coastal fisheries management and alters the evolutionary history of fishes.

Potts, W.M., Sauer, W.H.H., Henriques, R., Sequesseque, S., Santos, C.V., Shaw, P.W., 2010. The biology, life history and management needs of a large sciaenid fish, Argyrosomus coronus in Angola. African Journal of Marine Science 32 (2): 247 — 258.

Project Status for the Langer Heinrich Mine. (2014, 06). Retrieved 08 15, 2014, from Paladin Energy Ltd: http://www.paladinenergy.com.au/default.aspx?MenuID=113

Pulfrich, A., 1998. Assessment of the impact of diver-operated nearshore diamond mining on marine benthic communities in the Kerbe Huk area, Namibia. Report to NAMDEB Diamond Corporation (Pty) Ltd, 29pp.

Pulfrich, A., 2004a. Baseline Survey of Sandy Beach Macrofaunal Communities at Elizabeth Bay: Beach Monitoring Report – 2004. Prepared for NAMDEB Diamond Corporation (Pty) Ltd., Oranjemund, Namibia, on behalf of CSIR Environmentek, 53pp.

Pulfrich, A., 2004b. Baseline survey of intertidal and subtidal rocky shore communities at Elizabeth Bay: Intertidal and subtidal monitoring report – 2004. Prepared for NAMDEB Diamond Corporation (Pty) Ltd., Oranjemund, Namibia, on behalf of CSIR Environmentek, 36pp.

Pulfrich, A., 2005. Survey of intertidal and subtidal rocky shore communities at Elizabeth Bay: Intertidal and subtidal monitoring report – 2005. Report to NAMDEB Diamond Corporation (Pty) Ltd., Oranjemund, Namiba, 39pp.

Pulfrich, A., 2006. Survey of intertidal and subtidal rocky shore communities at Elizabeth Bay: Intertidal and subtidal monitoring report – 2006. Report to NAMDEB Diamond Corporation (Pty) Ltd., Oranjemund, Namibia, 52pp.

Pulfrich, A., 2007a. Survey of intertidal and subtidal rocky shore communities at Elizabeth Bay: Intertidal and subtidal monitoring report – 2007. Report to NAMDEB Diamond Corporation (Pty) Ltd., Oranjemund, Namibia, 64pp.

Pulfrich, A., Atkinson, L.J., 2007. Monitoring environmental effects of sediment discharges from the Marine Dredging Treatment Plant on sandy beach and rocky intertidal biota in Mining Area 1, Namibia. Prepared for NAMDEB Diamond Corporation (Pty) Ltd., Oranjemund, Namibia, 85pp.

Pulfrich, A., Parkins, C.A., Branch, G.M., 2003a. The effects of shore-based diamond-diving on intertidal and subtidal biological communities and rock lobsters in southern Namibia. Aquatic Conservation: Marine and Freshwater Ecosystems 13, 257-278.

Pulfrich, A., Parkins, C.A., Branch, G.M., Bustamante, R.H., Velásquez, C.R., 2003b. The effects of sediment deposits from Namibian diamond mines on intertidal and subtidal reefs and rock-lobster populations. Aquatic Conservation: Marine and Freshwater Ecosystems 13, 233-255.

Pulfrich, A., Penney, A.J. 1999. Assessment of the impact of diver-operated nearshore diamond mining on marine benthic communities near Lüderitz, Namibia. Final Report to NAMDEB Diamond Corporation (Pty) Ltd, 33pp.

Pulfrich, A., Penney, A.J. 2001. Assessment of the impact of diver-operated nearshore diamond mining on marine benthic communities near Lüderitz, Namibia. Phase III. Report to NAMDEB Diamond Corporation (Pty) Ltd, 50pp.

Pulfrich, A., Penney, A.J., 1998. Assessment of the impact of diver-operated nearshore diamond mining on marine benthic communities in the Zweispitz area, Namibia. Report to NAMDEB Diamond Corporation (Pty) Ltd, 33pp.

Pulfrich, A., Penney, A.J., 1999b. The effects of deep-sea diamond mining on the benthic community structure of the Atlantic 1 Mining Licence Area. Annual Monitoring Report – 1998. Prepared for De Beers Marine (Pty) Ltd by Marine Biology Research Institute, Zoology Department, University of Cape Town and Pisces Research and Management Consultants CC. pp 49.

Pulfrich, A., Penney, A.J., Brandão, A., Butterworth, D.S., Noffke, M., 2006. Marine Dredging Project: FIMS Final Report. Monitoring of Rock Lobster Abundance, Recruitment and Migration on the Southern Namibian Coast. Prepared for De Beers Marine Namibia, July 2006. 149pp.

Pulfrich, A., Steffani, N., 2007. Environmental impact assessment: Proposed Trekkopje Reverse Osmosis Plant. Marine Ecological Aspects. Prepared by Pisces Environmental Services for Turgis Consulting (Pty) Ltd., pp. 119 + Appendices.

Pulfrich, A., Steffani, N., 2008. Report on Swakopmund Field Survey - Marine Baseline Assessment. In: CSIR 2009. Environmental Impact Assessment for the Proposed Desalination Project at Mile 6 near Swakopmund, Namibia, Draft EIA Report, CSIR Report No. CSIR/CAS/EMS/ER/2009/0015/A, Stellenbosch.

Robertson T, Jarvis A, Mendelsohn J, Swart R. 2012. Namibia's coast. Ocean riches and desert treasures. RAISON, Windhoek.

Rogers, J. (1991). Dispersal of sediments from the Orange River along the Namibian desert coast. African Journal of Science.

Rogers, J., 1979. Dispersal of sediments from the Orange River along the Namibian desert coast. S. Afr. J. Sci. 75(12), p567.

Rogers, J., Bremner, J.M., 1991. The Benguela Ecosystem. Part VII. Marine-geological aspects. Oceanography and Marine Biology: An Annual Review 29, 1-85.

Rose, B., Payne, A.I., 1991. Occurrence and behavior of the southern right whale dolphin, Lissodelphis peronii, off Namibia. Marine Mammal Science 7(1): 25-34.

Ross, G.J.B., 1984. The smaller cetaceans of the east coast of southern Africa. Ann. Cape. Prov. Mus. (nat. Hist.)., 15 (2).

Rössing Uranium. 2014. Rössing Uranium – Looking ahead. Retrieved 08 15, 2014, from Rio Tinto: http://www.rossing.com/bullet/rossing-looking-ahead.htm

Rössing Uranium. June 2014. Media Release: Rössing announcing organisational restructuring accessed on http://www.rossing.com/bullet/rossing-looking-ahead.htm

Roux, J-P., Best, P.B., Stander, P.E., 2001. Sightings of southern right whales (Eubalaena australis) in Namibian waters, 1971-1999. Journal of Cetacean Research and Management (Special Issue 2): 181-185.

Roux, J-P., Braby, R., Best, P.B., 2010. Southern right whales off Namibia and their relationship with those off South Africa. Paper SC/S11/RW16 submitted to IWC Southern Right Whale Assessment Workshop, Buenos Aires 13-16 Sept. 2011.

Royal HaskoningDHV. (2014). Trade-off Study 8: Plant size vs Product Water Storage. Cape Town.

Royal HaskoningDHV. (2014). Trade-Off Study Report 11: Electrical Supply To The Seawater Intake. Cape Town.

Royal HaskoningDHV. (2014). Trade-Off Study Report 4,7 & 9: Seawater Pipeline vs Seawater Channel. Cape Town.

Royal HaskoningDHV. (2014). Trade-Off Study Report 5: Optimum Plant Location. Cape Twon.

Royal HaskoningDHV. (2014). Trade-Off Study Report 6: Optimum Plant Size - Energy Efficiency. Cape Town.

Royal HaskoningDHV; WSP. (2014). Trade Off Study Report 1: Intake Site Selection. Cape Town.

Royal HaskoningDHV; WSP. (2014). Trade-Off Study Report 2: Brine Outfall Locations . Cape Town.

Royal HaskoningDHV; WSP. (2014). Trade-Off Study Report 3: Brine Discharge Methods. Cape Town.

Ryu, Y., Chang, K.-A., & Mori, N. (2005). Dispersion of Neutrally Buoyant Horizontal Round Jet in Wave Environment. J. Hydraul. Eng. ., 131:1088-1097.

SAIEA. (2010). Strategic Environmental Assessment for the central Namib Uranium Rush. Windhoek: Ministry of Mines and Energy.

Samuel, Y., Morreale, S.J., Clark, C.W., Greene, C.H., Richmond, M.E., 2005. Underwater, low frequency noise in a coastal sea turtle habitat. Journal of the Acoustical Society of America 117: 1465-1472.

SAN (South African Navy), 2007. South African Tide Tables, Hydrographer, South African Navy, Private Bag X1, Tokai 7966, 260pp.

SANS 10210. (2008). Calculating and Predicting Road Traffic Noise. Pretoria: Standards South Africa.

Scott HA, Dean WRJ, Watson LH. 2011. Breeding success and changes in numbers of African Black Oystercatchers Haematopus moquini in relation to habitat quality and protection status. Marine Ornithology 39: 189–199.

Seiderer, L.J., Newell, R.C., 1999. Analysis of the relationship between sediment composition and benthic community structure in coastal deposits: Implications for marine aggregate dredging. ICES Journal of Marine Science 56: 757–765.

Shannon L.V., P. S. (1985). The Benguela Ecosystem III. Plankton. Oceanography & Marine Biology: An Annual Review 24.

Shannon, L. V., & O'Toole, M. J. (1982). Application of satellite ocean colour imagery in the study of the Benguela Current system. South AfricaJournal of Phoyogrammetry, Remote Sensing and Cartography.

Shannon, L.J., Moloney, C.L., Jarre, A., Field, J.G., 2003. Trophic flows in the southern Benguela during the 1980s and 1990s. Journal of Marine Systems 39, 83 - 116.

Shannon, L.V., Anderson, F.P., 1982. Application of satellite ocean colour imagery in the study of the Benguela Current system. South African Journal of Photogrammetry, Remote Sensing and Cartography 13(3), 153-169.

Shannon, L.V., O'Toole, M.J., 1998. BCLME Thematic Report 2: Integrated overview of the oceanography and environmental variability of the Benguela Current region. Unpublished Report, 58pp.

Shannon, L.V., Pillar, S., 1985. The Benguela Ecosystem, Part III. Plankton. Oceanography and Marine Biology: An Annual Review, 24: 65-170.

Sheppard, S.R.J. 2005. Validity, reliability, and ethics in visualization. In: Bishop, I. and Lange, E. (Eds.) Visualization in Landscape and Environmental Planning: Technology and Applications. Taylor and Francis, London. Chapter 5, pp. 79-97. Source: www.calp.forestry.ubc.ca/Coe of Ethics_July03.pdf.

Shillington, F. A., Peterson, W. T., Hutchings, L., Probyn, T. A., Waldron, H. N., & Agenbag, J. J. (1990). A cool upwelling filament off Namibia, South West Africa: Preliminary measurements of physical and biological properties. Deep Sea Res. 37.

Shillington, F.A., Peterson, W.T., Hutchings, L., Probyn, T.A., Waldron, H.N., Agenbag, J.J., 1990. A cool upwelling filament off Namibia, South West Africa: Preliminary measurements of physical and biological properties. Deep-Sea Res. 37 (11A), 1753-1772.

Simmons RE, Boix-Hinzen C, Barnes KN, Jarvis AM, Robertson A. 1998a. Important Bird Areas of Namibia. in: The Important Bird Areas of southern Africa. Barnes, KN (ed.). pp295-332. BirdLife South Africa, Johannesburg.

Simmons RE, Brown CJ. In press. Birds to watch in Namibia: red, rare and endemic species. Ministry of Environment and Tourism, Namibia Nature Foundation, Windhoek.

Simmons RE, Cordes I, Braby R. 1998b. Latitudinal trends, population size and habitat preferences of the Damara Tern Sterna balaenarum on Namibia's desert coast. Ibis 140: 439-445.

Simmons RE, Roux JP. 2001. A survey of African Black Oystercatchers along Namibia's Diamond Coast. Lanioturdus 34:14-18.

Simmons RE. 2005. Declining coastal avifauna at a diamond mining site in Namibia: comparisons and causes. Ostrich 76: 97-103.

Simmons, R. E., & Brown, C. J. (In Press). Birds to watch in Namibia: red, rare and endemic species. Windhoek: Ministry of Environment.

Simmons, R. E., Barnes, K. N., Jarvis, A. M., & Robertson, A. (1999). Important Bird Areas in Namibia. Windhoek: MET:DEA. Retrieved from http://www.drfn.info:85/pdf/RDP31.pdf

Simmons, R. E., Boix-Hinzen, C., Barnes , K. N., Jarvis, A. M., & Robertson, A. (1998). Important Bird Areas of Namibia. Johannesburg: Birdlife South Afirca.

Simmons, R.E., Barnes, K.N. Jarvis, A.M., Robertson, A., 1999. Important Bird Areas in Namibia. Research Discussion Paper No. 31. DEA of MET, 68pp.

Sinclair I, Hockey PAR, Tarboton W, Ryan P. 2011. Sasol Birds of southern africa. Fourth edition. Struik Nature, Cape Town, South Africa.

Sink, K., Holness, S., Harris, L., Majiedt, P., Atkinson, L., Robinson, T., Kirkman, S., Hutchings, L., Leslie, R., Lamberth, S.J., Kerwath, S., Von Der Heyden, S., Lombard, A., Attwood, C., Branch, G., Fairweather, T., Taljaard, S., Weerts, S., Cowley, P., Awad, A., Halpern, B., Grantham, H., Wolf, T., 2012. National Biodiversity Assessment 2011: Marine and Coastal Component Report. Pretoria: South African National Biodiversity Institute

Skov, H., Bloch, R., Stuer-Lauridsen, F., Uushona, D., 2008. Strategic Environmental Assessment (SEA) for the coastal areas of the Erongo and Kunene Regions, Prepared for Namibian Coast Conservation and Management Project (NACOMA) 172pp.

SLR/Aurecon. 2014. Project 110914 File 2014-07-18 ~ Rössing Uranium Desalination EIA Specialist TOR. 18 JULY 2014.

Smallie J, Diamond M, Jenkins A. 2009. Lighting up the African continent – what does this mean for our birds? pp. 38-43. In: Harebottle DM, Craig AJFK, Anderson MD, Rakotomanana H, Muchai (eds). Proceedings of the 12th Pan-African Ornithological Congress, 2008. Cape Town, Animal Demography Unit.

Smit, E. (2011, March Unknown). The Namibian Sun. Retrieved May 6, 2014, from http://sun.com.na/node/5820

Smith, G. G., & Mocke, G. P. (2002). Interaction between breaking/broken waves and infragravity-scale phenomena to control sediment sediment suspension and transport in the surf zone. Marine Geology.

Snelgrove, P.V.R., Butman, C.A., 1994. Animal-sediment relationships revisited: cause versus effect. Oceanography and Marine Biology: An Annual Review 32, 111-177.

South African Navy. (2007). South African Tide Tables.

southern african Institute for Environmental Assessment (SAIEA). 2012. Guidelines for Integrating HIV and Gender-related Issues into Environmental Assessment in Eastern and southern africa. Prepared for UNDP Regional Centre for Eastern and southern africa.

Stage, J., Kirchner, C.H., 2005. An economic comparison of the commercial and recreational linefisheries in Namibia. African Journal of Marine Science 27, 577-584.

Stattersfield, A. J., & Capper, D. R. (2000). Threatened birds of the world. Barcelona and Cambridge: Lynx Edicions and Birdlife.

Steffani, C.N., Pulfrich, A., 2004a. Environmental Baseline Survey of the Macrofaunal Benthic Communities in the De Beers Mℓ3/2003 Mining Licence Area. Prepared for De Beers Marine South Africa, April 2004., 34pp.

Steffani, C.N., Pulfrich, A., 2004b. The potential impacts of marine dredging operations on benthic communities in unconsolidated sediments. Specialist Study 2. Specialist Study for the Environmental Impact Report for the Pre-feasibility Phase of the Marine Dredging Project in Namdeb's Atlantic 1 Mining Licence Area and in the nearshore areas off Chameis. Prepared for PISCES Environmental Services (Pty) Ltd, September 2004.

Steffani, C.N., Pulfrich, A., 2007. Biological Survey of the Macrofaunal Communities in the Atlantic 1 Mining Licence Area and the Inshore Area between Kerbehuk and Lüderitz 2001 – 2004 Surveys. Prepared for De Beers Marine Namibia, March 2007, 288pp.

Steffani, N., 2007a. Biological Baseline Survey of the Benthic Macrofaunal Communities in the Atlantic 1 Mining Licence Area and the Inshore Area off Pomona for the Marine Dredging Project. Prepared for De Beers Marine Namibia (Pty) Ltd. pp. 42 + Appendices.

Steffani, N., 2009a. Biological Monitoring Surveys of the Benthic Macrofaunal Communities in the Atlantic 1 Mining Licence Area and the Inshore Area – 2006/2007. Prepared for De Beers Marine Namibia (Pty) Ltd. (Confidential Report) pp. 81 + Appendices.

Steffani, N., 2009b. Assessment of Mining Impacts on Macrofaunal Benthic Communities in the Northern Inshore Area of the De Beers Mℓ3 Mining Licence Area - 18 Months Post-mining. Prepared for De Beers Marine. pp. 47 + Appendices.

Steffani, N., 2009c. Baseline Study on Benthic Macrofaunal Communities in the Inner Shelf Region and Assessment of Mining Impacts off Chameis. November 2009. Prepared for Namdeb. pp. 45 + Appendices.

Steffani, N., 2010. Biological Monitoring Surveys of the Benthic Macrofaunal Communities in the Atlantic 1 Mining Licence Area – 2008. Prepared for De Beers Marine Namibia (Pty) Ltd. (Confidential).

Stuart, C.T., 1975. Marine fauna collected at Sandwich Harbour, Namibia Desert Park, South West Africa. Madoqua Series II 4, 101-102.

Taljaard, S., Botes, W.A.M, Oelofse, SHH and Viljoen, P., 2006. Operational policy for disposal of land-derived wastewater to the marine environment of South Africa, WaterSA Vol 32(.4), 437-433

Tarr, J.G., Griffiths, C.L., Bally, R., 1985. The ecology of three sandy beaches on the Skeleton Coast of South West Africa, Madoqua 14(3), 295-304.

The National Planning Commission. (2011). Namibia 2011 Population and Housing Census. Windhoek: Namibian Government.

The Watchers. (2011, March 22). The Watchers. Retrieved May 6, 2014, from http://thewatchers.adorraeli.com/2011/03/22/flooding-in-angola-and-namibia/

Timonin, A.G., Arashkevich, E.G., Drits, A.V., Semenova, T.N., 1992 Zooplankton dynamics in the northern Benguela ecosystem, with special reference to the copepod Calanoides carinatus. In Benguela Trophic Functioning. Payne, A. I. L., Brink, K. H., Mann, K. H. and R. Hilborn (Eds). S. Afr. J. mar. Sci. 12, 545–560.

Tjipute, M., Shuuluka, D., 2006. Zoobenthos survey in the Walvis Bay Lagoon. University of Namibia, Windhoek. Report to the Municipality of Walvis Bay.

Tomalin, B.J., 1995. Specialist study on impacts of diamond mining on rock-lobster populations and the fishery. In: CSIR 1996. Environmental Impact Assessment for marine diamond mining in the Namibian Islands concession, Council for Scientific and Industrial Research Report EMAS-C96023. 33pp.

Travel News Namibia. (2012, August 2). TNN Online. Retrieved January 30, 2014, from http://travelnewsnamibia.com/archives/travel-news/a-park-of-extremes-dorob/#.UunyivmSwdp

U.K Institute of Environmental Management and Assessment (IEMA). 'Guidelines for Landscape and Visual Impact Assessment' Second Edition, Spon Press, 2002. Pg 44.

Ullman, I., and Brudel, B. (2001). Biological Soil Crusts of Africa. In J. Belnap, and L. Lange, Biological Soil Crusts: Structure, Function, and Management.

Underhill LG. 2000. African Black Oystercatcher Haemotopus moquini. In: Barnes, KN (ed.) The Eskom Red data Book of birds of South Africa, Lesotho and Swaziland. Page 142. Birdlife South Africa. Johannesburg.

Underhill, L. G., & Whitelaw. (1977).

Van Dalfsen, J.A., Essink, K., Toxvig Madsen, H., Birklund, J., Romero, J., Manzanera, M., 2000. Differential response of macrozoobenthos to marine sand extraction in the North Sea and the Western Mediterranean. ICES J. Mar. Sci. 57: 1439–1445.

Van Rooyen CS. 2004. The Management of Wildlife Interactions with overhead lines. In: The Fundamentals and Practice of Overhead Line Maintenance (132 kV and above). pp 217-245. Eskom Technology Services International, Johannesburg, South Africa.

Van Rooyen CS. 2009. Chapter 9. Impacts on birds. Environmental Impact Assessment for the proposed desalination project at Mile 6, Swakopmund, Namibia. CSIR, Stellenbosch, South Africa.

Van Tamelen, P.G., 1996. Algal zonation in tidepools: experimental evaluation of the roles of physical disturbance, herbivory and competition. Journal of Experimental Marine Biology and Ecology 201, 197-231.

Visser, G. A. (1969). Analysis of Atlantic waters off the coast of southern Afirca.

Waldron, F.W., 1901. On the appearance and disappearance of a mud island at Walfish Bay. Transactions of the South African Philosophical Society 11(1), 185-194.

Ward, L.G., 1985. The influence of wind waves and tidal currents on sediment resuspension in Middle Chesapeake Bay. Geo-Marine Letters 5, 1-75.

Warwick, R.M., Goss-Custard, J.D., Kirby, R., George, C.L., Pope, N.D., Rowden, A.A., 1991. Static and dynamic environmental factors determining the community structure of estuarine macrobenthos in SW Britain: why is the Severn estuary different? J. Appl. Ecol. 28: 329–345.

Water Scarcity Solutions 2013. Groundwater recharge: Omdel Dam, Namibia; accessed from http://www.waterscarcitysolutions.org/assets/2030WRG_case_study_omdel_dam.pdf

Water Technology.net. 2004. http://www.water-technology.net/projects/swakopmund/

Weeks, S.J., Currie, B., Bakun, A., Peard, K.R., 2004. Hydrogen sulphide eruptions in the Atlantic Ocean off southern Africa: implications of a new view based on SeaWiFS satellite imagery. Deep-Sea Research I 51,153-172.

Wessels, D. C., & van Vuuren, D. R. (1986). Landsat imagery - its possible use in mapping the distribution of major Lichen Communities in the Namib Desert, South West Africa.

Wheeler M. 2001. The origins, distribution, demographics and behaviour of African Black Oystercatchers (Haematopus moquini) in the Walvis Bay Lagoon. Unpublished Report, Polytechnic of Namibia, Windhoek.

Wickens, P., 1995. Namibian sealing debacle, an environmental and managerial disaster. Afr. Wildl. 49: 6-11.

Williams, A.J., Dyer, B.M., Randall, R.M., Komen, J., 1990. Killer whales Orcinus orca and seabirds: "Play", predation and association. Marine Ornithology 18: 37-41.

Witherington, B.E., Martin R.E., 2000. Understanding, assessing and resolving light-pollution problems on sea turtle nesting beaches, 2nd ed. Rev. Florida Marine Research Institute Technical Report TR-2.73 pp.

Witt, M.J., Bonguno, E.A., Broderick, A.C., Coyne, M.S., Formia, A., Gibudi, A., Mounguengui, G.A., Moussounda, C., Safou, M., Nougessono, S., Parnell, R.J., Sounguet, G.-P., Verhage, S., Godley, B.J., 2011. Tracking leatherback turtles from the world's largest rookery: assessing threats across the South Atlantic. Proceedings of the Royal Society B. doi:10.1098/rspb.2010.2467

Witzell, W.N., 1999. Distribution and relative abundance of sea turtles caught incidentally by the U.S. pelagic longline fleet in the western North Atlantic Ocean, 1992-1995. Fisheries Bulletin 97: 200-211.

World Wildlife Fund. (2014). Worldwildlife. Retrieved July 10, 2014, from http://www.worldwildlife.org/ecoregions/at1315

Yates, M.G., Goss-Custard, J.D., McGrorty, S.M., Lakhani, Dit Durrell, S.E.A., Levit, Clarke, R.T., Rispin, W.E., Moy, I., Yates, T., Plant, R.A., Frost, A.J., 1993. Sediment characteristics, invertebrate densities and shorebird densities on the inner banks of the Wash. J. Appl. Ecol. 30: 599–614.

Zajac RN, Lewis RS, Poppe LJ, Twichell DC, Vozarik J, Digiacomo-Cohen Mℓ (2000) Relationships among sea-floor structure and benthic communities in Long Island Sound at regional and benthoscape scales. J. Coast. Res. 16: 627– 640.

Zeybrandt, F., Barnes, J.I., 2001. Economic characteristics of demand in Namibia's marine recreational shore fishery. South African Journal of Marine Science 23, 145-156.

Zoutendyk, P. (1992). Turbid water in the Elizabeth Bay region: A review of the relevant literature. CSIR.

Zoutendyk, P. (1995). Turbid water literature review: a supplement to the 1992 Elizabeth Bay Study. CSIR.

ANNEXURE A

CVs of the Environmental Assessment Practitioners

ANNEXURE A1

CV for Andries van der Merwe

ANNEXURE A2

CV for Patrick Killick

ANNEXURE A3

CV for Simon Charter

ANNEXURE A4

CV for Werner Petrick

ANNEXURE B

Public Awareness and Notifications

ANNEXURE B1

Background Information Document

ANNEXURE B2

Project meetings presentation

ANNEXURE B3

Site Notices

ANNEXURE B4

Newsprint Advertisements

ANNEXURE B5

Rössing Uranium staff notifications

ANNEXURE C

Public Engagement and Response

ANNEXURE C1

Meeting Minutes with MUN

ANNEXURE C2

Meeting Minutes with Media Focus Group

ANNEXURE C3

Meeting Minutes with Swakopmund stakeholder groups

ANNEXURE C4

Meeting Minutes with Swakopmund public

ANNEXURE C5

Meeting Minutes with MAWF

ANNEXURE C6

Meeting Minutes with NamWater

ANNEXURE C7

Record of discussion with MET

ANNEXURE C8

I&AP Register

ANNEXURE C9

Comments and Responses Report

ANNEXURE D

Specialist Studies

ANNEXURE D1

Socio-economic impact assessment

ANNEXURE D2

Archaeology impact assessment

ANNEXURE D3

Visual impact assessment

ANNEXURE D4

Noise impact assessment

ANNEXURE D5

Avifauna impact assessment

ANNEXURE D6

Marine ecology impact assessment

ANNEXURE D7

Brine dilution modelling study

ANNEXURE D8

Shoreline dynamics study

ANNEXURE E

Social and environmental management plan

CNNC
Rössing Uranium
Working for Namibia

Rössing Uranium Limited

Environmental Management Plan

Effective Date:	**06 September 2024**	
Status:	**Revision**	
Version No:	**1.4**	
Document No:	**JE20/MMP/011**	
Custodian(s):	**Specialist Environment**	
Reviewed by:	**S Gaeseb**	**Original signed**
Authorised by:	**J Mwenze**	**Original Signed**

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

Executive Summary

When mining activities at Rössing commenced in the 1970s, no environmental assessment was required. Despite this the early operations took due cognisance of the sensitive environment in which the mine was established. Consequently, pro-active and responsible management measures were set as voluntary operational standards since the design and planning phases of the mine.

Built on the early commitment, all present operations at Rössing – from the planning to the decommissioning stages – are governed through applicable national legislative and regulatory frameworks and are managed through an integrated Health, Safety and Environment Management System (HSE MS). The HSE MS conforms to the International standards ISO 14001:2015, ISO 45001:2018 and ISO 9001:2015, of which Rössing is certified to ISO 14001 since 2001. Based on an understanding of potential health, safety and environment hazards / aspects, the HSE MS allows Rössing to identify key aspects and impacts, guide operating procedures and attain to continual improvement in managing these. All potential impacts are listed on a risk register, coupled to mitigating and operational controls guided by the Rössing internal HSE Performance Standards. An audit programme evaluates the HSE MS periodically.

Ultimately, environmental management at Rössing aims at achieving the following:

- Assess environmental impacts of mining activities throughout the design and planning, construction, operational and decommissioning phases
- Develop, implement and manage monitoring systems to ensure maximizing of avoidance, mitigating and rehabilitation of adverse environmental impacts
- Comply with all environmental regulatory and legislative frameworks during all phases of the mine's operations through approved Environmental Management Plans
- Investigate and exploit measures to reduce usage of non-renewable resources
- Maximize positive environmental impacts
- Avoid, mitigate and rehabilitate adverse impacts
- Limit contamination through prevention measures (escapes into aquatic and atmospheric pathways), appropriate containment, recycling and removal measures
- Protect, conserve and enhance cultural, heritage and archaeological resources
- Keep communities informed and involved in decision making about mining activities
- Ensure the health and safety of employees, contractors and surrounding communities through agreed performance criteria
- Support and encourage awareness, training and responsibility of environmental management

This document contains a description of the current environmental management practice and plans at Rössing. The document is organized as five chapters with four appendices and references. Chapter 1 provides brief background information about Rössing; Chapter 2 describes the environment within which Rössing operates; Chapter 3 describes the current operational activities; Chapter 4 summarizes the Environmental Impact Assessments conducted over time and Chapter 5 describes the current management of environmental impacts at Rössing.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

Table of content

1 BRIEF BACKGROUND INFORMATION 7

1.1 CONTACTS OF MINE 7
1.1.1 Name 7
1.1.2 Address 7
1.1.3 Telephone and fax numbers 7

1.2 MINE OWNER 7
1.2.1 Responsible person / manager 7

1.3 CONTACTS OF MINERAL RIGHTS HOLDER 7
1.3.1 Name 7
1.3.3 Telephone and fax numbers 7

1.4 CONTACTS OF APPLICANT 7
1.4.1. Name 7
1.4.2. Address 7
1.4.3. Telephone and fax numbers 8

1.5 CONTACTS OF LAND OWNER 8
1.5.1 Name 8

1.6 LOCATION AND REGIONAL SETTING 8
1.6.1. Direction and distance to neighbours 8
1.6.2. Land tenure and use of immediately adjacent land 10
1.6.3. River catchment in which the mine is situated 11
1.6.4. Surface infrastructure and servitudes 12

1.7 BACKGROUND ABOUT THE MINING OPERATION 14
1.7.1. Historical overview of the development of the mine 15
1.7.2. Current shareholding 16
1.7.3. Current scale of operation 16
1.7.4. Current Life of Mine 16

2. DESCRIPTION OF THE ENVIRONMENT 18

2.1 GEOLOGY 18

2.2 CLIMATE 19

2.3 TOPOGRAPHY 20

2.4 SOILS 22

2.5 LAND CAPABILITY 22

2.6 LAND USE 23

2.7 VEGETATION 24

2.8 ANIMAL LIFE 26

2.9 SURFACE WATER 27

2.10 GROUNDWATER 28

2.11 AIR QUALITY 31

2.12 SITES OF ARCHAEOLOGICAL AND CULTURAL INTEREST 33

2.13 SENSITIVE LANDSCAPES 34

2.14 VISUAL ASPECTS 35

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.

A PRINTED COPY IS AN UNCONTROLLED COPY

2.15 REGIONAL SOCIO-ECONOMIC STRUCTURE 36
2.16 INTERESTED AND AFFECTED PARTIES 36
3. DESCRIPTION OF THE CURRENT OPERATION 38
3.1 PRODUCTION PROCESS 38
3.1.1 Mining 39
3.1.2 Crushing 39
3.1.3 Milling and leaching 40
3.1.4 The sands / slimes split 41
3.1.5 The slimes washing – CCD thickeners 41
3.1.6 Tailings disposal 42
3.1.7 Continuous ion exchange 42
3.1.8 Solvent extraction 43
3.1.9 Final Product Recovery 44
3.2 COMPONENTS OF THE CURRENT LAND FOOTPRINT 45
3.2.1 Linear infrastructure 46
3.2.2 The open pit 48
3.2.3 The waste rock dumps 50
3.2.4 The tailings facility 52
3.2.5 The plant, offices and administrative buildings 54
3.2.6 Exploration activities 57
3.3 COMPONENTS OF THE SOCIO-ECONOMIC FOOTPRINT 58
3.3.1 The workforce 58
3.3.2 The hosting communities 59
3.3.3 THE RöSSING FOUNDATION 60
4 DESCRIPTION OF ENVIRONMENTAL IMPACT ASSESSMENTS AT RÖSSING 61
4.1 FROM PRE-MINING AND CONSTRUCTION TO NAMIBIA'S INDEPENDENCE 61
4.2 OPERATING IN INDEPENDENT NAMIBIA – THE FIRST 20 YEARS 62
4.3 STRATEGIC ASSESSMENTS 69
5 IMPACT MANAGEMENT AT RÖSSING 71
5.1 THE IMPACT MANAGEMENT SYSTEM IN EFFECT AT RÖSSING 71
5.1.1 Planning 73
5.1.2 Implementation and operation 78
5.1.3 Checking and corrective action 81
5.1.4 Review 83
5.2 HSE MANAGEMENT PROGRAMMES 83
5.2.1 Management of Radiation 83
5.2.1. Management of Air Quality 91
5.2.2. Management of Water 97
5.2.3. Management of Biodiversity and Rehabilitation 104
5.2.4. Management of Non-mineral Waste 108
5.2.5. Management of Mineral Waste 111
5.3 THE DECOMMISSIONING PHASE 115
5.3.1 Closure Planning: The approach 115
5.3.2 Closure Planning at Rössing 116
6 APPENDIX 1: LEGISLATIVE FRAMEWORK 118
6.1 Statutory requirements 118
6.1.1 International Conventions and regional agreements 118
6.1.2 Domestic Legislation and policies 118

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

7 APPENDIX 2: RÖSSING PROCEDURES 121
7.1 Operational Procedures relevant to the Health, Safety and Environment Management System 121
7.1.1 Health, Safety and Environment Management Plans 122
7.1.2 Health, Safety and Environment Policies 122
7.2 Operational Procedures relevant to Health 123
7.4.1 Operational procedures relevant to Radiation 124
7.3 Operational procedures relevant to Safety 125
7.4 Operational procedures relevant to Environment 126
7.4.1 Operational procedures relevant to Water 127
8 APPENDIX 3: SUMMARY OF AUDITS AND CERTIFICATION 128
9 REFERENCES 129
10 ABBREVIATIONS USED IN THIS DOCUMENT 134
11 CHANGES AND REVISION STATUS 136

List of Figures

Figure 1.1: Location of Rössing Mine 8
Figure 1.2: Rössing's Mining Licence and surrounding land 9
Figure 1.3: River drainage systems, average rainfall and topography 11
Figure 1.4: Lay-out of linear infrastructure at Rössing 13
Figure 2.1: Variation in annual rainfall at Rössing 19
Figure 2.2: Temperature ranges at Rössing during 2023 20
Figure 2.3: Satellite image showing the dissected terrain of the Khan and Swakop Rivers 21
Figure 2.4: General groundwater flow directions and control at Rössing 29
Figure 2.5: Archaeological and sensitive sites at Rössing 34
Figure 3.1: A simplified flow diagram of the production process at Rössing 38
Figure 3.2: The coarse ore stock pile at Rössing 40
Figure 3.3: The leach process at Rössing 40
Figure 3.4: Washing circuits 41
Figure 3.5: CCD Thickeners 42
Figure 3.6: Continuous Ion Exchange (CIX) 43
Figure 3.7: Solvent extraction 44
Figure 3.8: Processes of the Final Product Recovery 45
Figure 3.9: Aerial view of Rössing 46
Figure 3.10: The pit void at Rössing, looking northeast from the current viewpoint. 49
Figure 3.11: The location of waste rock dumps at Rössing 51
Figure 3.12: Location and lay-out of the tailings facility at Rössing 53
Figure 3.13: Lay-out of the processing plant at Rössing 55
Figure 5.1: The RUL HSE Performance Standards 71
Figure 5.2: Overview of the HSE management system in effect at Rössing 72
Figure 5.3: The three-tier risk assessment model 74
Figure 5.4: Hierarchy of controls 76
Figure 5.5: HSE monitoring work flow 81
Figure 5.6: Sources of radioactivity at Rössing 84
Figure 5.7: Exposure pathways and critical groups for public dose assessments 89
Figure 5.8: Water monitoring and seepage control at Rössing 100
Figure 5.9: Schematic water balance for Rössing in cubic meters per day, 2023 102
Figure 5.10: Biotopes at Rössing 106

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

List of Tables

Table 2.1: Stratigraphy and rock types at Rössing 18
Table 2.2: Typical Khan River quality (in 2023) compared with Namibian stock-water guidelines 30
Table 2.3: Geographical position of localities relative to wind direction 31
Table 3.1: Potential hazardous chemicals and materials present in the processing plant area 56
Table 5.1: Qualitative risk matrix 75
Table 5.2: Descriptors for the consequence of an impact occurring 75
Table 5.3: Descriptors for the likelihood of an impact occurring 76
Table 5.4: Particulate matter (PM10) 93
Table 5.5: Water management procedures relevant to the effluence disposal exemption permit 103
Table 5.6: Water monitoring procedures at Rössing 104

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

1 BRIEF BACKGROUND INFORMATION

1.1 CONTACTS OF MINE

1.1.1 NAME

Rössing Uranium Limited

1.1.2 ADDRESS

Postal address: Private Bag 5005 Swakopmund Namibia

Registered address with the Ministry of Trade and Industry: 360 Sam Nujoma Drive, Klein Windhoek, Windhoek

1.1.3 TELEPHONE AND FAX NUMBERS

Telephone: +264 (64) 520 9111
Fax: +264 (64) 520 3017

1.2 MINE OWNER

1.2.1 RESPONSIBLE PERSON / MANAGER

CNNC is the majority shareholder of Rössing Uranium Limited and owns 69% of the shares. The Namibian state has a 3% shareholding, and a 51% majority vote when it comes to issues of national interest. The Iran Foreign Investments Company (IFIC) owns 15%. The Industrial Development Corporation (IDC) of South Africa owns 10% while local individuals own a combined 3% of Rössing shares. The minority shareholders have no rights to production take-off.

1.3 CONTACTS OF MINERAL RIGHTS HOLDER

1.3.1 NAME

Rössing Uranium Limited

1.3.2 Address

Private Bag 5005 Swakopmund

1.3.3 TELEPHONE AND FAX NUMBERS

Telephone: +264 (64) 520 9111
Fax: +264 (64) 520 3017

1.4 CONTACTS OF APPLICANT

1.4.1. NAME

Rössing Uranium Limited

Original application was done in 1959. In 1985 the Mining Grant M46/4/17 in the name of G P Louw (Pty) Ltd was consolidated with Rössing Uranium Limited's mining grant M46/4/5 to form Mining Grant M.46/4/28 and then converted to Mining Licence No. 28 in 2006.

1.4.2. ADDRESS

Postal address: Private Bag 5005 Swakopmund Namibia

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

Registered address with the Ministry of Trade and Industry: 360 Sam Nujoma Drive, Klein Windhoek, Windhoek

1.4.3. TELEPHONE AND FAX NUMBERS

Telephone: +264 (64) 520 9111
Fax: +264 (64) 520 3017

1.5 CONTACTS OF LAND OWNER

1.5.1 NAME

State-owned

1.6 LOCATION AND REGIONAL SETTING

Rössing Uranium Limited mines a large-scale low-grade uranium ore body in the Namib Desert, in the sparsely populated Erongo Region of Namibia (Figure 1.1).

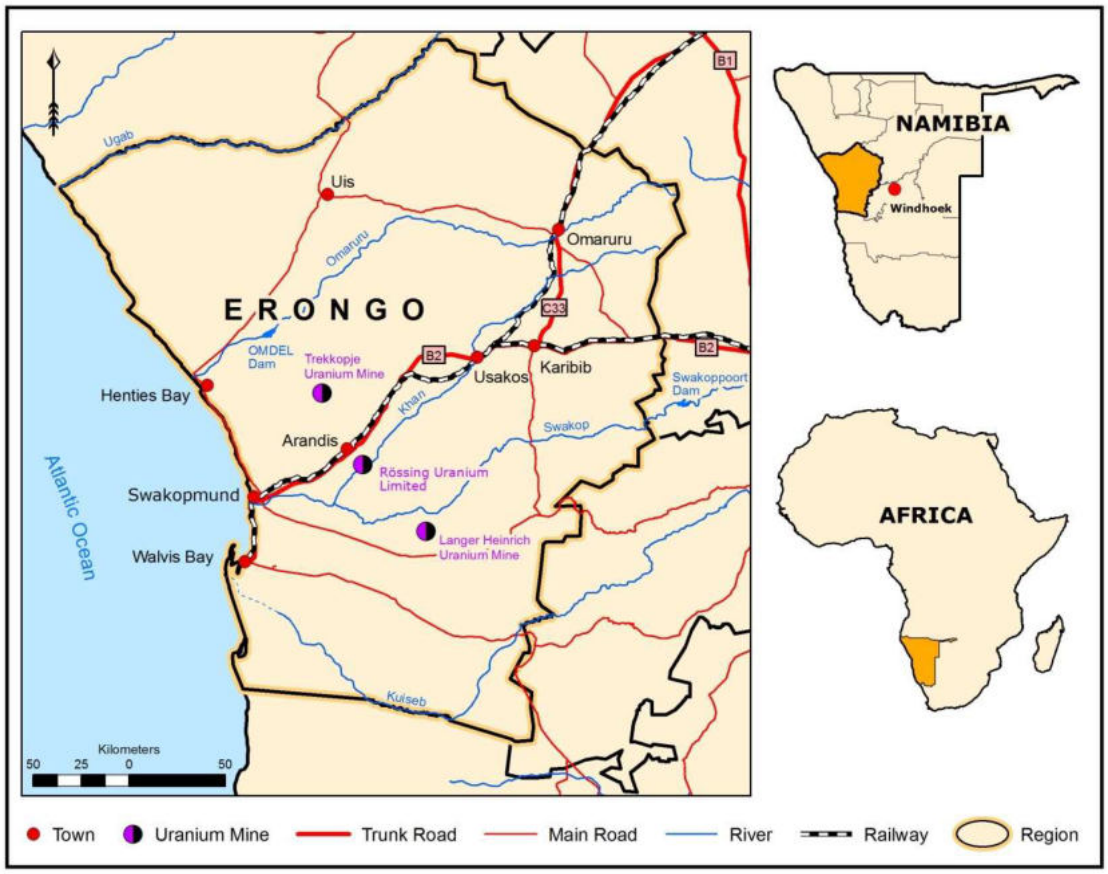


Figure 1.1: Location of Rössing Mine

1.6.1. DIRECTION AND DISTANCE TO NEIGHBOURS

Rössing is part of the Arandis Constituency, one of the seven political constituencies that make up the Erongo Region. A section of the northern boundary of Rössing's

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

Accessory Works Area borders overlaps Arandis Townlands (Figure 1.2). Arandis is situated less than 10 km from the mine's main entrance gate.

The coastal town of Swakopmund is about 70 km away and Walvis Bay is located 30 km south of Swakopmund (Figure 1.1). To the east, the nearest town to Arandis is Usakos – about 80 km away.

The #Gaingu Conservancy is one of the immediate neighbours of the Mining Licence area. The largest part of communal and state land that forms part of this conservancy is totally uninhabited. The closest commercial farmland is about 15 km to the east of the Mining Licence area while the rural settlements of the conservancy are much further away from the mine – near Spitzkoppe (more than 60 km to the northeast).
An Exploration Prospecting Licence (EPL) 3138 is bordering Rössing's Mining Licence (ML 28) to the south and has been granted to Swakop Uranium. This EPL covers the Husab uranium deposit. To the east ML 28 is bordered and the Accessory Works Area of Rössing overlapped by EPL 3602, which is granted to Zhonghe Resources (Namibia) Development (Pty) Ltd., a Chinese exploration company exploring for uranium occurrences. EPL 3624 overlaps with Rössing's Accessory Works Area to the northwest and has been taken out by the Namibian company Creative Enterprises to explore for base and rare metals, industrial minerals, precious metals and dimension stone.

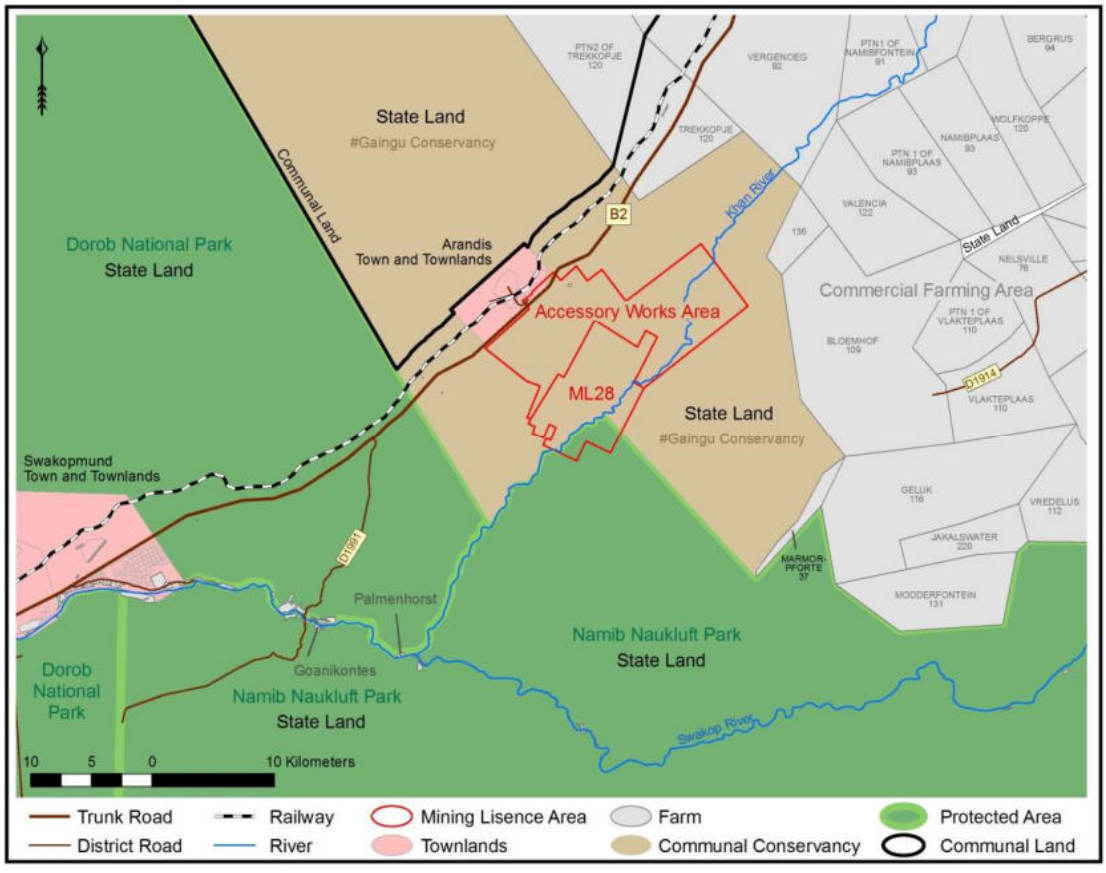


Figure 1.2: Rössing's Mining Licence and surrounding land

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

1.6.2. LAND TENURE AND USE OF IMMEDIATELY ADJACENT LAND

The Namibian state manages state land uses directly through the line ministries of the present government. The Ministry of Environment, Forestry and Tourism controls conservation areas, the Ministry of Works and Transport administers infrastructure on governmental land. Water management is mandated through the Ministry of Agriculture, Water and Land Reform which is also the custodian of surveyed and unsurveyed state land. Mining activities are regulated by the Ministry of Mines and Energy and the Ministry of Urban and Rural Development regulates the management of urban settlements.

Before Namibia's Minerals (Prospecting and Mining) Act, 1992 (No. 33 of 1992) came into force, Rössing Uranium Limited was granted a Mining Licence (ML28) on 8 May 1985, which is valid until 11 July 2036. Permission to extend the licence area with an Accessory Works Area was granted in February 1972 (15 A and B), March 1973 (17 A and B) and March 1977 (19), in terms of Section 50 of the Mines, Works and Minerals Ordinance 1968 (Ordinance no 20 of 1968).

The licensing arrangement was confirmed in May 1994 under the post-independent Minerals (Mining and Prospecting) Act 1992 (Act 33 of 1992). Extensions were also granted in December 1994 and July 1996 under Section 31.3 (a) and (e) as well as 57.1 (a), (d) and (e) of the Minerals (Mining and Prospecting) Act 1992.

Together, the current ML28 area and accessory works cover 13,003 ha, of which 91% is located on the northern bank of the Khan River (Figure 1.2), on relatively hilly terrain. By the end of 2023, the Rössing Mine complex covered 2,640ha. Thus, the total footprint of the mine is about 20% of the land under Rössing auspices, and consists of the open pit, waste rock dumps, the processing plant and tailings facility, offices, and infrastructure such as power lines, pipelines and roads. In 2024, construction of a 15MWe Photovoltic Solar Plant commenced on 115 ha of the RUL Acessory Works Area (AWA).

In the southwest about 720 ha of the ML28 area overlaps with the Namib-Naukluft National Park (NNNP) on the southern bank of the Khan River. The portion overlapping the NNNP is bordered to the south by ML171 (Swakop Uranium Mine). The Dorob National Park is a near neighbour with its eastern border about 10 km to the west of the Mining Licence area (Figure 1.2). The overlap with the Namib-Naukluft National Park secures rights for Rössing to mine potential minable uranium occurrences in a thin stretch of land parallel to the river. The ML28 area is otherwise bordered by the #Gaingu Conservancy in the west and south-east. The rest is bordered by the accessory works area, which in turn is overlain by the #Gaingu Conservancy except for the northern part that borders, and partly overlaps, the town of Arandis and its Townlands. In 1997, the accessory works area was extended to include portions of the Khan River where an aquifer recharge scheme was planned by the mine. Although the construction of the scheme did not go ahead, the area was retained.

Arandis Airport is situated southwest of Arandis. A Rössing plane was operated from the airport until 2000, after which the airport infrastructure was sold to a private company.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

1.6.3. RIVER CATCHMENT IN WHICH THE MINE IS SITUATED

Virtually the whole of the Central Namib Desert is drained by four river systems, from north to south the Omaruru, Khan, Swakop and Kuiseb rivers. The Omaruru, Swakop and Kuiseb rivers flow westwards to the Atlantic Ocean while the Khan forms a major branch of the Swakop River. Each of the rivers originates on the high interior plateau of Namibia.

Rössing is situated about 25 km upstream of the Khan / Swakop River confluence (Figure 1.3). The Khan River, which flows for a distance of about [1]) of the larger Swakop River catchment. Both the Khan and Swakop rivers are classified as episodic ephemeral drainage lines, which mean that they only contain discharge for a brief period after sufficient downpours in their catchments on the higher interior.

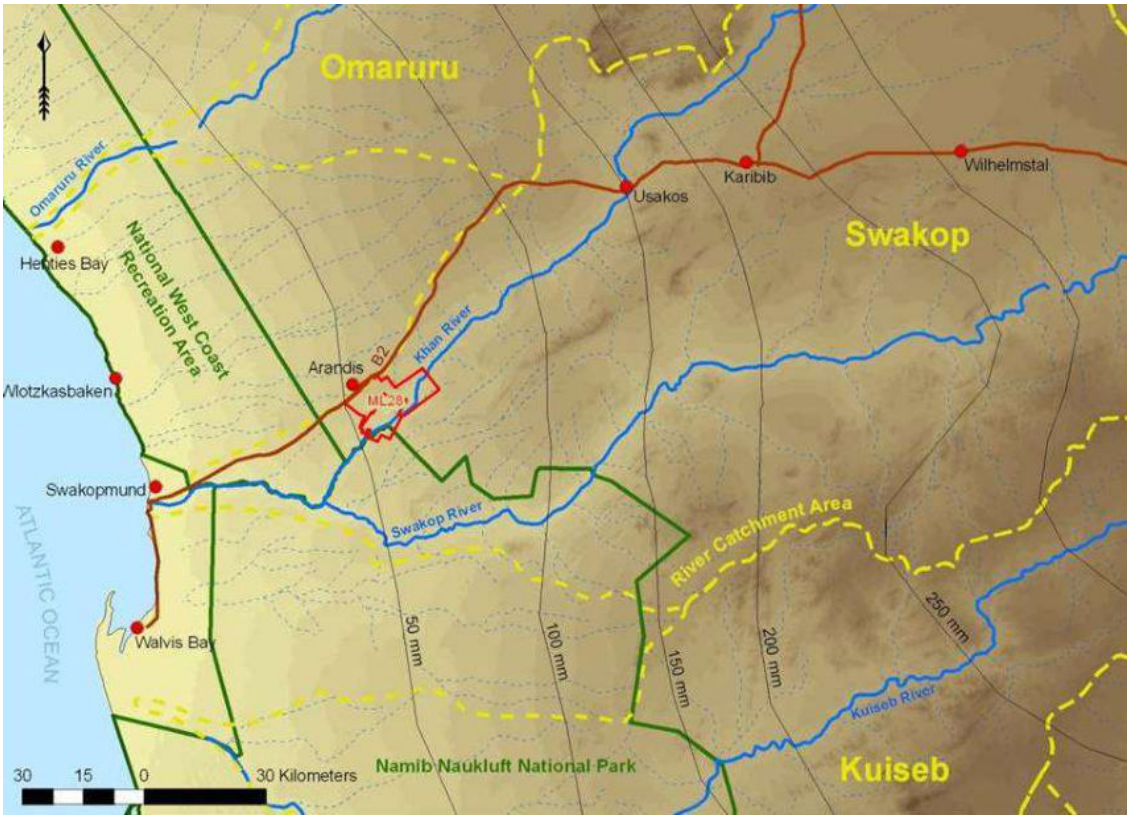


Figure 1.3: River drainage systems, average rainfall and topography

Surface floods in the Khan River below Dome gorge have been recorded on six occasions during a 26 year period (1966-1992). Further flood events occurred in 1995, 1997, 2000, 2010-11, 2017-18, and 2022. Recharge to the aquifer, as well as movement and deposition of alluvium and silt occurs during these high flow events. During the dry season the water flow down the rivers is sub-surface. Surface run-off partly infiltrates

[1] Aurecon, (2011)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

and recharges the groundwater in the alluvium or fractured bedrock, so that a continuous flow is maintained.

The Khan River originates in central Namibia, near Okahandja at an elevation of about 1,500 metres above mean sea level (mamsl) and joins the Swakop River 45 km from the mouth at Swakopmund. The sharp decrease in rainfall totals from east to west, combined with the erratic nature of run-off and the increase in evaporation potential from east to west, results in highly episodic functioning of central Namib rivers and give them distinct convex longitudinal profiles. The average gradient of the Khan between its origin and the point where it joins the Swakop River at an elevation of 190 mamsl is approximately 1:180. In the Rössing area the Khan River forms a deeply incised, steep-sided gorge. Three tributaries, from east to west Dome, Pinnacle and Panner Gorge, traverse the mine area and discharge into the Khan River.
The Khan River contains appreciable quantities of groundwater that sustains riparian vegetation in spite of its brackish quality. Rössing abstracts water from the Khan River for dust suppression in the open pit. The sediment fill of the tributaries is about 5-10 m thick, and can be very permeable in the lower stretches of the gorges.

No farming activity takes place and no people live along the Khan River downstream from Rössing.

In the second half of the 1990s the possibility to establish an aquifer recharge scheme in the Khan River was investigated by Rössing. Several in-depth technical studies were conducted and in the end it was decided not to develop this scheme.

1.6.4. SURFACE INFRASTRUCTURE AND SERVITUDES

A number of parastatal enterprises are mandated to provide infrastructure of national importance in Namibia: TransNamib (railways); NamPower (bulk electricity supply); NamWater (bulk water supply); Telecom (telecommunication) and Roads Authority (roads). In many cases the linear infrastructure provided by TransNamib, NamPower, Telecom, NamWater and Roads Authority are concentrated within developed ribbons, often parallel to a main road.

With regard to Rössing the railway line between Usakos and Swakopmund, the Telecom line and water pipelines are located within the narrow strip on both sides of the main road (B2) north of the Accessory Works Area. Near the turn-off to Arandis, the infrastructure branch-off from the main networks, to follow a corridor of linear infrastructure along a private roadway, which enters the Rössing Mining Licence area from the north (Figure 1.4.).

In short, existing service infrastructure connected to Rössing includes the following:

- A 10 km long tarred private roadway from the main Swakopmund–Usakos national road (B2).
- A full-gauge railway line linking the mine's service areas with the main Windhoek–Usakos–Swakopmund–Walvis Bay railway line from the Arandis siding.
- A water supply pipeline and storage reservoirs; four (4) with capacity of 80 000m^3 and additional six (6) with combined capacity of 60 000m^3 storage.
- A link to the NamPower 220 kV power line supplying electricity to Swakopmund and Walvis Bay and Telecommunication networks.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

- Fibre-optic communication line connecting the mine with the Swakopmund office which runs parrallel to the railway line.
- 15MWe Photovoltaic Solar Power Plant (with 18MWA peak capacity) and connecting 11kV power line to the RUL substation, which are under construction on the RUL accessory works area, to be commissioned by end 2024.

District road D1911 provides access from the B2 national road to Arandis, partly running over the Accessory Works Area. The private road that provides access to Rössing turns off from the D1911. A right-of-way servitude was surveyed in April 1994 over the Arandis Townlands to secure access to Rössing's railway line and private access road to the mine. This servitude was, however, not registered with the Registrar of Deeds.

The main road towards the mine leads to the main entrance gate. On site this road forms the spine of a network of various bitumen and gravel access and haulage roads and tracks with a total distance of more than 30 km.

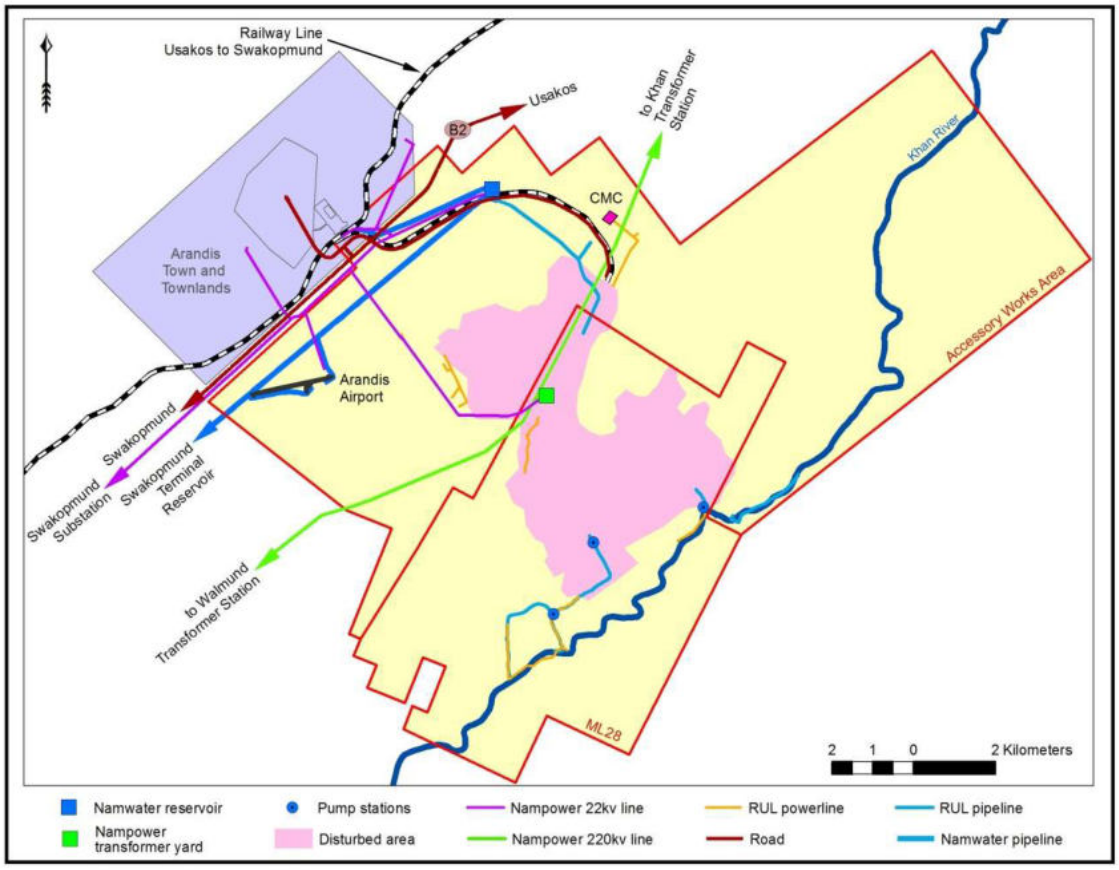


Figure 1.4: Lay-out of linear infrastructure at Rössing

The railway line is connected to four branched sidings. Main supplies brought in by rail include sulphuric acid, diesel, ammonia, manganese, and ammonium nitrate with drums of U_3O_8 product loaded into containers and railed to Walvis Bay for export.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

Water for the central coastal region is provided by the parastatal bulk water supplier, NamWater, which sources fresh water from the Desalination plant at Wlotzkasbaken. NamWater distributes the water via a network of pump stations, reservoirs and pipelines to Henties Bay, Swakopmund and Walvis Bay, Langer Heinrich Uranium Mine, Husab Mine, Rössing Mine, and Arandis.

Water to Rössing is supplied through a mounted pipeline with three booster pumping stations from a main water reservoir near Swakopmund. This 600-mm pipeline runs parallel to the B2 on its southern side. The pipeline's positioning allows secure and easy access for maintenance purposes. Fresh water is supplied to NamWater's Rössing terminal reservoir and additional six (6) reservoirs which Rossing commissioned in 2022, these are all located south of the B2, close to the linear infrastructure corridor that enters the mining area from Arandis. The conduit system serving Rössing from the terminal reservoir has a capacity of 8,000 m^3 a day. Water to Arandis is also supplied from this reservoir with a pipeline.

Power to the mine is supplied from the national grid by NamPower, from the line between the Khan Transformer substation and Walmund transformer substation (close to Swakopmund) via a 220 kV overhead transmission line. A ring feed exists via the Kuiseb close to Walvis Bay, linking it to the Walmund Substation. NamPower's current supply capacity to Rössing consists of two 40 MVA transformers in parallel, with a declared maximum demand of 35 MVA, fed from the 220 kV supply.

Rössing is a large user of electricity and an agreement between Rössing and NamPower in this context exists since 1973. An addendum to this agreement was signed with NamPower in 1997. NamPower owns and operates all 220 kV equipment up to and including the 220/11 kV transformers and 11 kV metering.

Rössing secured regulatory approval to construct a 15 MWe Photovoltiac (PV) solar plant on the RUL accessory works area. Construction on the PV plant is scheduled for completion in 2024.

For internal and external landline telecommunication, Rössing uses a grid of copper lines connected to Telecom in Arandis. Telecom operates the use and maintenance of a grid of landlines on-site, while the mobile telecommunications operator MTC has been contracted since 2002 to provide a base station with a mast, four global system for mobile communications antennas, one microwave antenna with a co-axial cable, and antenna brackets.

1.7 BACKGROUND ABOUT THE MINING OPERATION

During its early years, and after Namibia's independence, prospecting for uranium elsewhere in the Erongo Region was at a relatively low intensity. This has changed markedly over the past few years. Global concerns about the security of uranium supplies and sharp increases in uranium prices triggered renewed interest in uranium exploration in Namibia, and 2005 to 2007 saw a sudden scramble for prospecting rights in the central Namib. In 2007, when the State placed a moratorium on further uranium prospecting licences, 36 exploration licences for nuclear fuels had already been granted in the central Namib.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

1.7.1. HISTORICAL OVERVIEW OF THE DEVELOPMENT OF THE MINE[2]

People have known about the presence of radioactive mineralisation in the Rössing area since the beginning of the 1900s. The first significant discovery of radioactive mineralisation was made in 1928, when prospector Captain Peter Louw and his wife conducted an autoradiograph test on a supposed sample of pitchblende. Over the years they tried to interest major mining groups in investigating the potential of the area. Only in the late 1950s was the potential confirmed by the Anglo American Corporation of South Africa after intensive exploration. The company's geologists concluded, however, that the mineralisation was of an erratic occurrence and of a very low grade. The poor economic prospects for uranium at that time induced the company to abandon the search. It was only in the 1960s that a renewed interest in uranium motivated the Rio Tinto Zinc Corporation (RTZ) to reinvestigate the Rössing deposit intensively.

Rössing Uranium Limited (RUL) was formed in 1970 to develop the deposit. RTZ was its leading shareholder, with 41.35% of the equity; other shareholders included Rio Algom, the Industrial Development Corporation of South Africa, and Gencor. In 1972, Rössing awarded a management contract for the design, engineering, procurement and construction of the project to a joint venture of Arthur G McKee Western Knapp Engineering Division and Davy Powergas.

Mine development commenced in 1974 and commissioning of the plant and the initial production commenced in July 1976. The original production target was 2,500 short tons (2,268 t) of uranium oxide (U_3O_8) per year. Forward sales contracts were arranged to assure a market for the product. The United Kingdom Atomic Energy Authority was initially an important customer for Rössing's product, as was the French Total Compagnie Miniere et Nucleaire.

The objective was to reach full design capacity of 5,000 short tons (4,536 t) per year of uranium oxide during 1977. In 1979, the target production figure of 5,000 short tons (4,536 t) of uranium oxide was reached. The significance of weaknesses in the plant and the abrasiveness of the ore were not apparent during the pilot stage and the plant was extensively modified. The process plant – after a year of extensive modification in 1978 and total reconstruction of one of the two solvent extraction sections that was destroyed by fire in May 1978 – was operating effectively at the rated throughput of 40,000 t of ore per day.

Production between 1980 and 2004 fluctuated in response to the volumes required by the long-term sales contract portfolio. Contract prices were in turn influenced by market price and exchange rate fluctuations. The drop in the uranium price in the early 1990s necessitated a reduction in production to a minimum of 2,800 t per day in 1998. The drop in price also caused other significant changes at Rössing. Consequently, Rössing was forced to reduce production and withdraw from many external developmental initiatives.

The grim economic outlook of the 1990s was followed by regained flexibility to respond to changes in uranium price and exchange rates. Production was increased to above

[2] The exploration history (Section 3.1 on p 43), the investigation of the Rössing deposit (Section 3.2 on p 44 – 45) and the project outline and schedule (Section 3.3 on p 45) is well documented in Ashton, *et al.,* (1991) and could be read in addition.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

3,000 t per day and, in July 2004, a study was completed into the feasibility of extending mining operations. The study indicated that profitability could be extended until the end of 2009. A second phase of mining with an additional 8 years of operation was foreseen, subject to a number of sales contracts being ratified and the parent company – that had since become simply Rio Tinto – approving the proposed expansions, including the replacement of mining equipment, a tailings extension, and plant upgrade. From the mid 2000s the grim economic outlook of the 1990s was finally something of the past. As a result of the upward trend in uranium prices on the international market, Rössing considered possible expansions to extend the Life of Mine plan beyond 2020.

1.7.2. CURRENT SHAREHOLDING

After acquiring shares from Rio Tinto in 2019, CNNC is the majority shareholder of Rössing Uranium Limited, holding 69% of the shares. The Namibian Government has a 3% shareholding, yet has the majority (51%) when it comes to voting on issues of national interest. The Industrial Development Corporation of South Africa owns 10%, while local individual shareholders own a combined 3% shareholding. The Iranian Foreign Investment Company owns 15%, a stake that was acquired during the set-up of the company in the early 1970s, prior to the revolution in Iran, i.e. when the Shah was still in power. In 2010, the United Nations (UN) Security Council passed Resolution 1929 (UNSCR 1929), which prohibits UN member countries – of which Namibia is one – from allowing Iran to acquire an interest in a commercial activity involving uranium mining or to obtain access to nuclear technology. The two shareholder representatives of the Iranian Foreign Investment Company have not attended Board meetings and have not received Board material since the beginning of 2010, in compliance with UNSCR 1929.

The minority shareholders have no uranium product off-take rights.

1.7.3. CURRENT SCALE OF OPERATION

In 2023, Rössing produced 6.4 million pounds of U3O8, and sold 6.9 million pounds of U3O8. Around 1.8 million pounds were shipped to western converters and sold to customers in North America, Asia (excluding China) and Europe, Middle East and Africa (“EMEA”). A total of 3.7 million pounds were shipped and sold to China. An additional 1.4 million pounds were sold to non-utility customers (traders and funds) on the spot market, capitalising on the sudden price spike during the year. Rössing has benefited from the spot prices under CNNC sales agreement.

1.7.4. CURRENT LIFE OF MINE

Piloting to start mining the SJ Pit started in 1974, and after commissioning in 1976, full production was reached in 1979. Originally prepared for closure in 2009, an increase in long-term uranium market prices in 2005 allowed the extension of the Life of Mine plan to 2016. As mine planning continues to adapt to changing internal and external conditions, the Life of Mine plan developed in 2015 foresees the end of mining activities in 2025.

The piloting of the expansion – known as *Phase 2* – started in the north-western part of the pit in 2006. The Phase 3 also referred to as Phase 2B pushback on the southern side of the pit commenced in 2007 in mainly waste rock.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

At the end of current mining activities in 2026, the final depth of the open pit will be reached at Bench 36, about 30 mamsl.

The Rössing Uranium Life-Of-Mine Extension Project (LoME) from 2027 to 2036 was approved by the Rössing Board in February 2023. One month later, a 13-year contract was signed with Beifang Mining to commence with a full contract mining service from 2024 to 2036. By the end of 2023, Beifang had mobilised a new fleet of heavy mining equipment ("HME") to site, together with an experienced workforce trained to operate this equipment. The first blast was taken in the new Phase 4 pushback, ahead of schedule, on 21 December 2023. The upper benches of the Phase 4 pushback will be mined concurrently with the final benches of the Phase 2/3 pushback at the bottom of the pit. The latter will supply most of the ore until the end of 2026, while mining waste in Phase 4 to expose more ore from 2027 onwards. To enable this, funds were allocated for the execution of various infrastructure projects in the mining area. The largest of these is the construction of a high-energy rock-fall catch fence on Trolley 11 that will protect mining activities in the bottom of the pit from rockfalls arising from Phase 4 mining above. This project is still under construction and will be completed by mid-2024. Smaller infrastructure projects included the removal of power lines from the Phase 4 mining area, as well as the allocation of facilities to Beifang. While mining continues in both areas until the end of 2026, Rössing will continue to operate its remaining HME, after which Beifang will take over all mining from 2027 onwards.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

2. DESCRIPTION OF THE ENVIRONMENT

2.1 GEOLOGY[3]

The Rössing uranium deposit lies within the central part of the late-Precambrian Damara orogenic belt that occupies an area of approximately 50 km wide and extends northeast for over 100 km in west-central Namibia.

The Damara lithology consists mainly of folded, steeply dipping meta-sediments (gneiss, schist, quartzite and marble) arranged in a northeast-southwest striking belt (Table 2.1).

Table 2.1: Stratigraphy and rock types at Rössing

Period	Formation	Lithology
Recent		Alluvium and scree
Damara System	Intrusives	Dolerite dykes
		Alaskite
		Red granite-gneiss
	Karibib Formation	Metasediments
	Chuos Formation	Meta-tillite
	Rössing Formation	Feldspathic quartzite
		Upper cordierite gneiss
		Upper marble
		Lower cordierite gneiss
		Lower marble
	Khan Formation	Amphibole schist
		Upper banded gneiss
		Mottled gneiss
		Amphibolite
		Lower banded gneiss
	Etusis Formation	Biotite gneiss
		Feldspathic quartzite

Several tectonic phases caused intensive folding, shearing and jointing of the Damara rocks, especially around the Rössing Dome, but open fractures are rare due to the predominantly compressive nature of the tectonic stress. The closed nature of the fractures causes the generally low hydraulic conductivity of the meta-sediments. Younger fractures were often intruded by post-Karoo dolerite dykes, which often act as barriers to groundwater flow. The youngest sediments in the area are the alluvial fills of the Khan River and its tributaries, as well as other quaternary deposits.

The geology of the mining area at Rössing is associated with a dome structure and occurs in pegmatitic granite known as alaskite, which intruded into the meta-sediments.

[3] The regional geological setting as well as the geological origin, local setting and structure and the mineralogy of uraniferous deposits is described by Ashton, *et al.,* (1991), Section 2.3 (p 9 – 14).

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

The Rössing ore body is unique in that it is the largest known deposit of uranium occurring in granite. The nature and grade of uranium ore is extremely variable and can be present as large masses or narrow inter-bands within the barren meta-sediments. All of the primary uranium mineralisation and the majority of the secondary uranium mineralisation occur within the alaskite. However, the alaskite is not uniformly uraniferous and much of it is unmineralised or of sub-economic grade.

Uraninite is the dominant ore mineral (55%); secondary uranium minerals constitute 40%, while the refractory mineral betafite makes up the remaining 5%. Ore grades at the mine are very low, averaging 0.035%. The uranium ore consists of 70-90% alaskite and is subdivided into four ore types according to the composition of the host rock.

2.2 CLIMATE[4]

The climate of the central Namib Desert is hyper-arid with an average precipitation of less than 50 mm per annum over the greatest part. Rainfall is episodic and highly erratic with a variation coefficient of more than 90%, which means that the average might be obtained from single showers, with years of minimal rainfall recordings in between. The effect of these enormous variations may extend over decades.

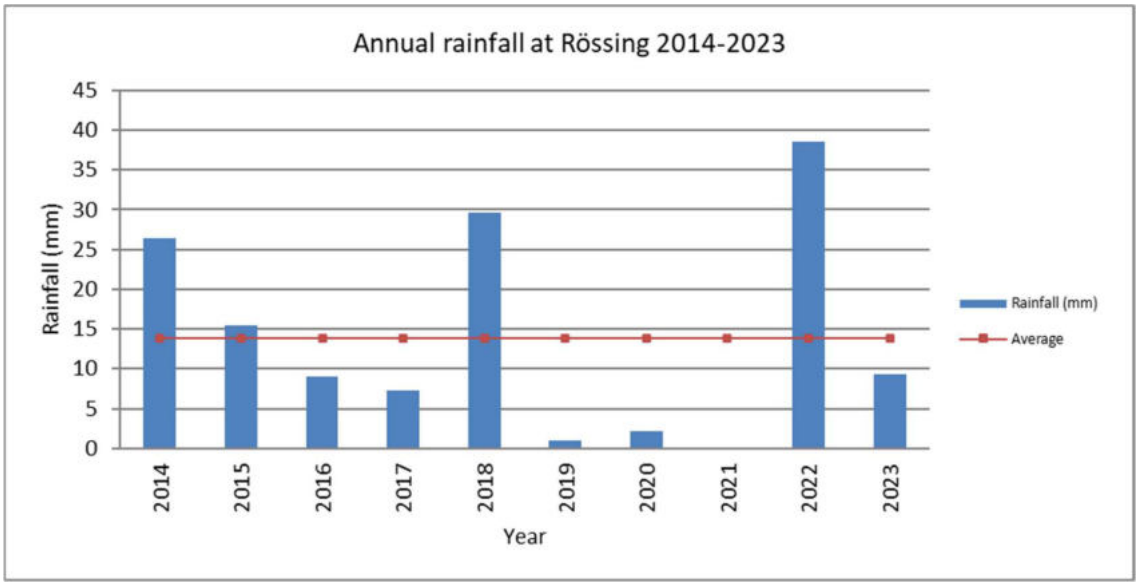


Figure 2.1: Variation in annual rainfall at Rössing

At Rössing rainfall measurements indicate an average rainfall of about 14mm, over the past 10 years (Figure 2.1). Much of the rainfall occurs as an episodic late summer thunderstorm of high intensity and short duration with virtually no rainfall recorded in the winter months. Rainfall increases inland from Rössing (See also Figure 1.3).

[4] Although outdated, additional information about climatic aspects at Rössing is contained in Ashton, *et al.,* (1991), Section 2.2 (p 3 – 8).

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

Advection fog is a highly significant source of precipitation over the central Namib Desert, especially close to the coast, but its effect decreases rapidly the further it moves away from the coast. Fog occurs more often than rain over the coastal Namib. The frequency differs spatially and between seasons. Biota has adapted miraculously to utilize this form of precipitation and the fog is a significant source of moisture for some of the species, especially those that occur on higher terrain, also at Rössing. Besides providing precipitation, the fog can ameliorate the otherwise torrid temperatures of the Namib Desert up to 100 km inland.

Associated with the cold Benguela Current and the occurrence of fog is the presence of high humidity along the coast. Even when fog is absent, the humidity along the coast remains the highest in Namibia with night values of more than 80% not unusual. Further away from the coast the humidity drops sharply while temperatures rise steeply. Extending inland for a distance up to 60 km during many nights, the fog is densest at an elevation of between 300 and 600 m. This phenomenon creates a foggy and cool coastline, followed by a zone between 30 and 60 km inland from the coast where fog and high humidity is common during the morning, but disappears before noon when the temperatures rise. Rössing is thus located in a zone of extremes, experiencing great diurnal fluctuations in temperature and humidity.

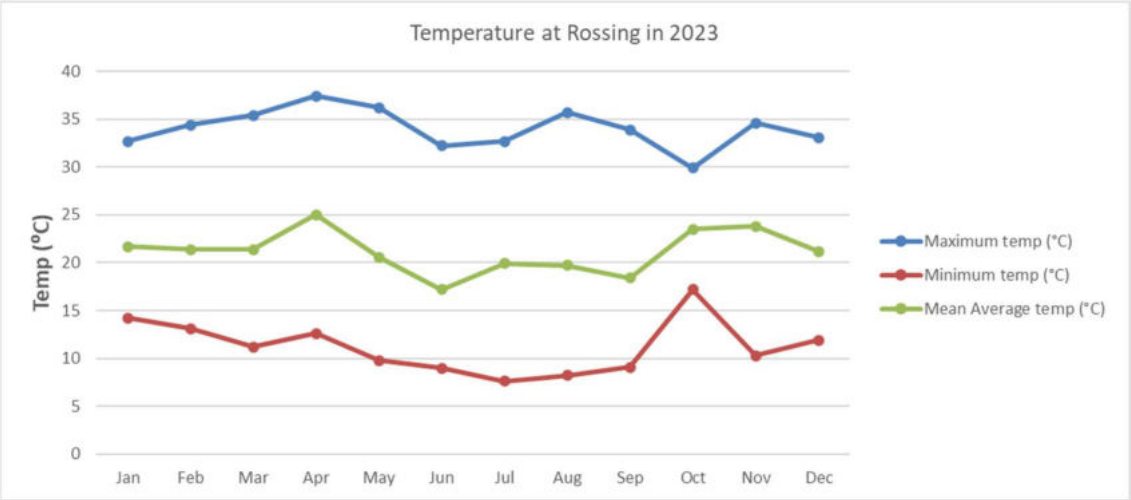


Figure 2.2: Temperature ranges at Rössing during 2023

2.3 TOPOGRAPHY

Generally, the surface of the Namib Desert has a slow rise towards the escarpment but does not exceed an altitude of more than 1,000 m above sea level (Figure 1.3). Consisting of broad gravel peneplains (open outwash plains) with a low relief, the central Namib Desert is also known as the Namib Desert Pavement.

At a mean altitude of 575 m above sea level, most of the Rössing tenement in the west, north and northeast consists of broad peneplains[5]. The flat terrain is traversed by shallow drainage lines and stormwater gullies that aim at the Khan River. Close to the Khan

[5] The topography at Rössing is also described in Ashton, *et al.*, (1991), Section 2.1 (p 3).

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

River the undulating plains change to an increasingly rugged terrain, which further increases towards the Swakop River, as illustrated in Figure 2.5.

Several dissected gorges coalesce as dry tributaries from both sides to the dry Khan River before its confluence with the Swakop River 25 km to the southwest of the mine property. The gorges are separated by steep-sided ridges, which give the terrain a hostile and impassable appearance.

The peneplains are also traversed by sporadic dykes and intrusions, mostly of a low altitude. A steep-sided ridge of dolerite hills stretches from southwest to northeast between Pinnacle Gorge and Dome Gorge, rising to a peak of 707 m above sea level. To the north and west of the ridge the landscape is less hilly and rugged, the plains more dominant and the gullies less pronounced. To the east and south the landscape is dominated by rolling hills, the plains are absent, and the gullies clearly defined.

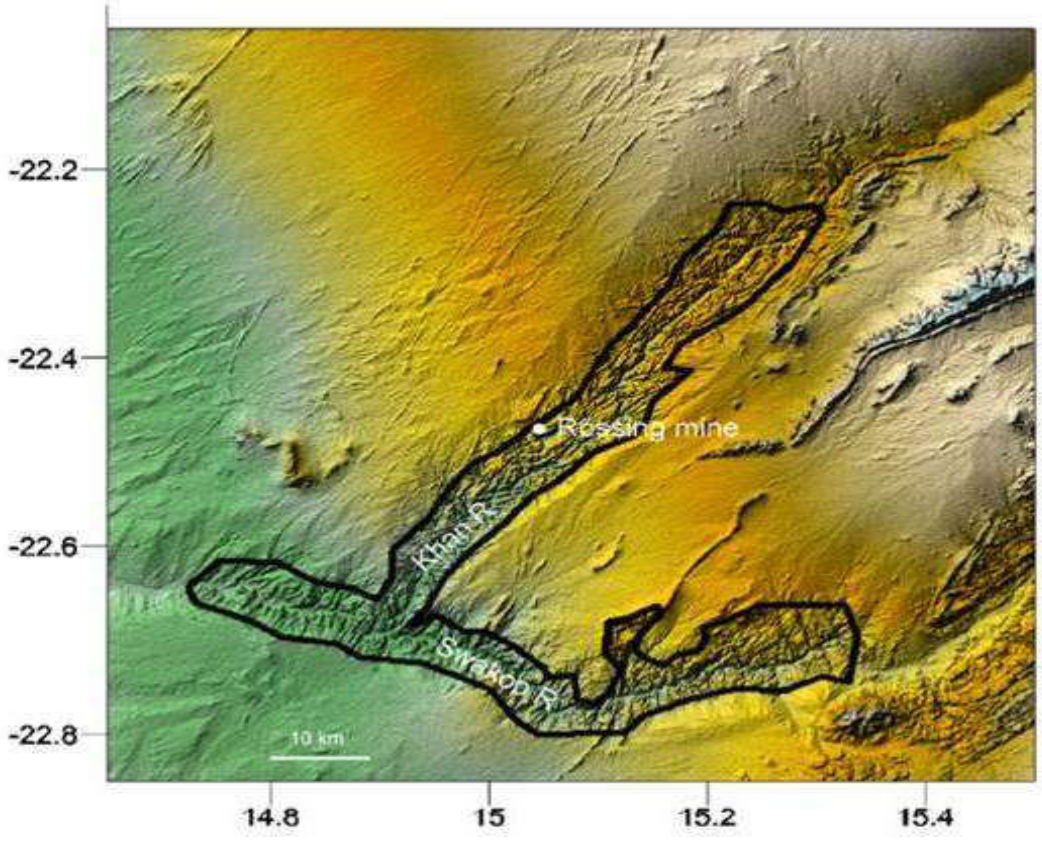


Figure 2.3: Satellite image showing the dissected terrain of the Khan and Swakop Rivers

On the southern side of the Khan River the rugged landscape dissipates abruptly giving way to the gravel plains of the Welwitschia Plains. These plains cover almost the entire area between the Khan and Swakop Rivers, down to their confluence, and are called like this because of the many Welwitschia plants that occur here.

Despite the low elevations over a large part of the tenement, sporadic flash floods of a high intensity have the potential to cause extensive erosion. This is even more

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

pronounced in areas where topographic features have been impacted by mining (for example excavations in the sand borrow pits and steep slopes on the tailings facility and waste rock dumps) and waste disposal sites. Stabilisation of these features against water erosion is an important management aspect in maintaining the environmental and aesthetic integrity of the landscape.

2.4 SOILS

Soils in the vicinity of Rössing could be described as shallow (<25 cm), greyish or ochre leptosols and petric calcisols, with a large proportion of coarse fragments and occasional calcium carbonate or gypsum concretions[6]. Solid material is broken down first by physical weathering processes, after which chemical decomposition processes transform the fragments to progressively finer particles. The predominance of chemical weathering processes is accentuated by the dry climate and the occasional deposition of wind-blown salt of marine origin.

The soils are characterized by high soil pH-values. Hard surface and near-surface crusts, due to calcrete or limestone deposits, are common and these soils are known as "Schaumboden" or "foam soils"[7]. Sometimes the surface crusts are bound by an overlying layer of blue-green algae (cyanobacteria), like in the case of soils in lower Panner Gorge. The crusts reduce rainfall infiltration rates and enhance run-off.

Aeolian sand deposits of varying depth are found in sheltered areas in the upper gorges and are particular prominent on the leeward (wind protected) slopes of Rössing Mountain. These sands are a mixture of dark to light brown grit, quartz and feldspar fragments, and biotite flakes. Colluvium is present on the slopes of some hills. Thickness varies, but may reach a depth of up to about 1.5 m. The material consists of grey-brown silty sands with an open, angular pebble layer and the consistency varies from medium-dense to dense.

Despite the low elevations over a large part of the tenement, sporadic flash floods of a high intensity have the potential to cause extensive fluvial erosion. Fluvial erosion causes an accumulation of unconsolidated alluvium, mainly sand and gravel, in the drainage lines. These deposits up to a few meters thick fan the valley bottoms horizontally, in laminated layers of coarse sand mixed with angular gravel and sorted pebbles. The plains are also exposed to wind erosion, which constantly removes fine material and enhances the soilless appearance of the gravel plains.

The deepest soil is thus confined to the drainage lines, comprising of mainly infertile – almost sterile – alluvium, that vary in thickness. Moreover, topsoil is shallow, poorly developed, infertile and even absent over the largest part of the hill slopes and gravel plains of the mine tenement.

2.5 LAND CAPABILITY

Much of the Erongo Region is occupied by the Namib Desert, which runs parallel to Namibia's entire coastline. As the average annual rainfall increases and the altitude elevates to the escarpment in the east, the Namib Desert gradually transforms to the

[6] Soils are also described in Ashton, *et al.,* (1991), Section 2.5 (p 15 – 19).
[7] Aurecon, (2011)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

savannah-like landscapes of the interior. In general, land capability in the Erongo Region is marginal and land use is of a low intensity.

About two-thirds of the total area in Erongo is owned by the State. One third is under state conservation management, which includes protected areas such as the Namib-Naukluft Park and Dorob National Park, while the other third is made up of communal land, most of which is under communal conservation management[8] (Figure 1.2).

Much of the communal land is of very low agricultural potential and cannot support formal farming activities. As the agricultural potential increases towards the east, small-scale subsistence livestock farming is practised. On commercial farmland a mixture of livestock and game farming is practiced and some land owners secure additional income through tourism and professional hunting.

Although tourism is regarded as an important economic mainstay of Swakopmund, the town becomes increasingly important as a location of mining-support businesses. More than 60% of Rössing's workforce resides in Swakopmund. Walvis Bay, on the other hand, is Namibia's only deep-water harbour and the town is an important hub for the fishing, shipping, storage and transporting industries of Namibia. About 19% of the workforce at Rössing resides in Walvis Bay. In Arandis, where 21% of the workforce resides, economic activities are restricted to local supplies and retail.

Mining activities have affected Swakopmund where all of the corporate offices of the mining companies are located, and most of the employees also reside here. Arandis, to a lesser extent, is home to some of the employees and the town has witnessed some signs of development during the last few years.

2.6 LAND USE

Rössing's Mining Licence area encompassed the open pit, rock dumps and processing plant, whereas activities related to tailings disposal, sand mining, seepage control around the tailings facility, the Arandis Airport and other infrastructure including power lines, pipelines and roads are situated in the accessory works area.

Apart from Arandis, there is no active land use in the proximity of Rössing's Mining Licence area[9]. Around Rössing water is severely limited, meaning that agriculture is of marginal potential only, even along the ephemeral water sources of the Khan and Swakop River. The closest commercial farmland is about 15 km to the east, and the border of communal land is about 15 km to the north. Along the lower Swakop River, close to the coast, commercial farming is undertaken on several smallholdings. Production aims to supply the needs of Swakopmund and Walvis Bay and includes asparagus, olive, mushroom and vegetable farming, as well as tourism- and leisure-oriented activities.

Both the Rössing mining license area and the Accessory Works Area lay within the #Gaingu Conservancy area (Figure 1.2). The #Gaingu Conservancy was registered in 2004. Not many people reside within the #Gaingu Conservancy area south of the main

[8] Rössing Land Use Management Plan, (2008)
[9] Rössing Land Use Management Plan, (2008)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

road. The Khan Mine is located on the unoccupied land of the #Gaingu Conservancy southwest of Rössing's operational area. Game migrates freely between the various parts of the conservancy, the proclaimed conservation areas and the properties of Rössing in response to pasture and water availability.

About 720 ha of the Mining Licence area overlaps with the Namib-Naukluft Park on the southern bank of the Khan River. The Dorob National Park, about 10 km to the west of the Mining Licence area, is a near neighbour of the mine. Both parks fall within Category 2 of the International Union for Conservation of Nature (IUCN).

With an overall size of almost 50,000 km^2 in surface cover, the Namib-Naukluft Park is Africa's largest game park. Originally established in 1907, the park is an amalgamation of three previous conservation areas, of which the boundaries were finalised in 1978. The Dorob Park was proclaimed in 2010 and incorporates the old National West Coast Tourist Recreational Area, which was proclaimed in 1968, as well as adjacent areas that were previously unprotected. Dorob Park links the coastal Skeleton Coast Park (north) with the Namib-Naukluft Park (central), which is connected to the Sperrgebiet (south) to ensure that the entire Namibian coast is protected.

2.7 VEGETATION

On the gravel plains at Rössing vegetation is dominated by sparsely scattered dwarf shrubs and ephemeral grasslands[10]. This is also the case for the undulating hills and mountains, but grass is less. Sparse riparian vegetation marks the drainage lines, in particular the Khan River.

In 2003 Rössing decided to assess the vulnerability of the area adjacent to the tailings facility when extensions were proposed. Dr Antje Burke, a Namibian specialist of arid ecology was consulted in this regard. The presence of *Adenia pechuelli* and *Lithops ruschiorum* was found and a follow-up study was recommended. Subsequently a plant red list[11] assessment was carried out by the National Botanical Research Institute (NBRI). More populations of *Lithops ruschiorum* were found in further work in the same area under a Rio Tinto – Kew Botanical Gardens Partnership[12].

In 2004 it was realized that biodiversity management at Rössing requires a systematic approach and a biodiversity assessment was commissioned in 2005[13]. The aim was to delineate ecologically homogenous units, with a specific emphasis on floral biodiversity, reconstruct pre-mining conditions and provide a biodiversity assessment of these mapped units. In this way the "biotope method" was adapted to the local conditions at Rössing[14]. The methodology was developed and tested over two years[15] and applied to assess extensions of the mining lease in 2007[16] and south of the Khan River in 2009 for exploration work[17].

[10] Although outdated, more information about the vegetation at Rössing is also contained in Ashton, *et al.*, (1991), Section 2.8.1 (p 28 – 34).
[11] Red list status refers to the International Union for Conservation of Nature (IUCN) categorization of species under threat as *vulnerable*, *near threatened* or *threatened with extinction*.
[12] Loots, (2006)
[13] Burke, (2005a)
[14] Burke, (2005b)
[15] Burke, *et al.*, (2008)
[16] Burke, (2007)
[17] Burke, (2009)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

It was decided to use plant species as practical indicators for overall biodiversity management at Rössing for several reasons:

- Plants are the key component of most terrestrial ecosystems, providing food, shelter and habitat for many other living components of an ecosystem.
- Plants are the basis for all terrestrial food chains delivering primary production without which very little other biodiversity can thrive.
- Plant species in Namibia can be identified within a reasonable time frame (before the next season starts).
- The conservation status of individual plant species is known and has been assessed nationally and internationally.

Certainly this does not mean that other components of biodiversity are not important, and one cannot assume that all trends shown by plants will be the same for other biodiversity components (e.g. reptiles or insects), but on the current knowledge base plants prove a powerful proxy for biodiversity in most situations. There is no question that the diverse habitats encompassed in Rössing's licence area have resulted in very high plant species richness in this arid environment and make it an important sanctuary for the maintenance of biodiversity in the region. However, quantifying Rössing's contribution is difficult, as readily available and published information on plant species distributions in this area reflects a significant sampling bias, meaning that the plant inventory at Rössing now stands out as the most comprehensive in the central Namib Desert[18].

In addition to the key perennial plant species *Arthraerua leubnitziae* (pencil bush)*, Aloe asperifolia* (Sand paper aloe) and *Zygophyllum stapffii* (Dollar bush) on the plains, and *Euphorbia virosa* (Milk bush) and various *Commiphora* species (Kanniedood[19]) on the hillsides, other common species include *Asclepias buchenaviana*, *Salsola tuberculata, Pelargonium otaviense, Adenolobus pechueli, Aizoanthemum membrumconnectens, Sarcocaulon marlothii*, *Trichocaulon pedicellatum, Euphorbia virosa* and *Hereroa puttkamerana.* A few tree species, *Acacia erioloba* (Camel thorn), *Acacia reficiens* (Red umbrella thorn) and *Parkinsonia africana* (Green-hair tree) dominate along the drainage lines while *Faidherbia albida* (Ana boom), *Tamarix usneoides* (Tamarisk) and thickets of *Salvadora persica* (Mustard tree) are more common along the Khan River. Two endemic plant species of particular importance to Rössing are the cryptic rock plant *Lithops ruschiorum* (Stone plant) and the larger succulent *Adenia pechueli*, or Elephant's foot.

Biological soil crusts, comprising lichens, micro-fungi, algae and blue-green algae (cyanobacteria) at Rössing are present in a somewhat reduced form compared to their occurrence in other Namib Desert habitats. Lichens are largely absent, while hypolithic organisms are abundant[20].

The ephemeral flooding of the Khan River provides an important source of water to its riparian vegetation. In general vegetation relates strongly to the frequency, intensity and duration of flooding events. A few species dominate – Ana boom, Camel thorn, Tamarisk

[18] Burke, (2011)
[19] The Afrikaans word *Kanniedood* literally means *cannot die*, which describes the appearance of these succulent-stemmed plants that only show signs of life after it has rained, remaining leafless for most of the year.
[20] EEAN, (2008)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

and thickets of Mustard tree. The relative more dense riparian vegetation provides food and shelter to many animal species and sustains important migration and dispersal routes as a result.

2.8 ANIMAL LIFE

While specialist work has, since 2004, increasingly focused on floral biodiversity, it was realized that faunal biodiversity at Rössing deserves more specialized investigation as well. From work done in the 1980s it was known that unnamed or undescribed taxa, and known only from a few localities, could be present at Rössing. Accordingly, eight invertebrate species were regarded as Critical, nine as Endangered and one as Vulnerable, using the IUCN categories. The list includes four spiders of critical conservation priority.

The Dome area was identified as particularly critical in terms of faunal biodiversity conservation because of single finds of species during the 1980s. In 2007, therefore, the Environmental Evaluation Association of Namibia (EEAN) was contracted to conduct a biodiversity survey. Unlike floral biodiversity, which requires spatial division at a fine resolution (biotope scale), faunal biodiversity at Rössing could be adequately described according to broad demarcations. EEAN argued that habitats at Rössing could broadly be divided into the following[21]:

- Rocky hillsides with loose surface rocks and no soil or soil that is very shallow, and having the least vegetation, relatively speaking
- Open plains with deeper soil and scattered bushes and shrubs. The plains are interrupted with rocky outcrops of varying dimension, and
- Ephemeral watercourses marked by having more bushes and scattered trees along their length than in other areas, and having a substrate that is usually sandy and unconsolidated.

The abundance and diversity of spiders is relatively lower than expected, and the numbers of solifuges is exceptionally low, in contrast to the central Namib which is known as a world hotspot of solifuge diversity. Fourteen scorpion species are known to inhabit the Rössing licence area, of which three are classified as threatened. A total of 271 species of ground-living insects are recorded from Rössing, and this excludes flying groups such as moths and lacewings. Of the 271 species, 20 are classified as threatened.

The Namib Desert is known for its reptile diversity, particularly of lizards and geckos. At Rössing 33 reptile species are expected to occur. Of these, one (a tortoise) is classified as threatened but it prefers moister habitat and its occurrence in the area is very marginal. The Namib chameleon (*Chamaeleo namaquensis*) is more common. Information about the endemic Husab Sand Lizard (*Pedioplanis husabensis*) is limited. Only small numbers of this species and relatively small areas of occurrence – rocky terrain along the lower Khan and Swakop Rivers – are recorded. By the precautionary principle the species is classified as threatened.

Three species of frogs are known to occur at Rössing, none of which are classified as threatened. The Namib Desert has relatively low avifauna species diversity, but does

[21] Ibid

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

have a relatively high occurrence of endemics and near endemics[22]. From a local perspective the Khan River has the highest bird species diversity, indicating the importance of water availability and consequent supported plant life as well as the diversity of cliff habitats. Two species are classified as threatened.

According to EEAN the rocky hillsides, in particular those located in Lower Dome and along the Khan River are regarded as the most important habitats of the scarce invertebrates at Rössing. EEAN also concluded that it would be possible but unlikely, that the identified species would be extinct by a new mining development and that the apparently high level of endemism might be real or it might be from the sampling bias of earlier research[23].

Mammal diversity at Rössing is not very high, as is typical in the central Namib. Climatic variation is closely coupled with marked changes in the abundance of animal species[24]. Many of the animal species that occur around Rössing use a wide range of habitats, or may cross a wide range in the course of migrating from one habitat to another. Short-lived annuals dominate the plains after local showers of rainfall and provide a vital source of pasture to opportunistic grazers. Large mammal species occur occasionally because they are nomadic and use three main migration routes[25]. Watering points like the pools of the Khan River and the springs are particularly important in attracting animals and serve as orientation guides along migration routes. Common animal species include Klipspringer, Springbok, Ostrich, Kudu, Hartmann's zebra, dassie (Rock hyrax), Black-backed jackal, Baboon and rodents (particularly gerbils).

2.9 SURFACE WATER

Open surface water in the Namib Desert is a rarity and may occur only ephemerally during the rainy season. Flowing surface water on the Mining Licence area only occurs after heavy rainfall. Run-off in the drainage lines is an episodic, brief event and peaks and periods of run-off vary widely. At Rössing[26] average flow rates of the Khan River recorded over three decades vary between 2 m^3/s and 100 m^3/s, indicating the formidable (but highly infrequent) transportation potential of the river.

The many drainage lines that originate on the higher elevations to the north of Rössing form part of the Panner, Pinnacle, Boulder and Dome Gorge drainage systems. These smaller drainage lines function even more episodically than the Khan River, many of them are dry for decades before they may carry torrent flash floods for brief periods.

The local drainage patterns in the vicinity of the Rössing mine site are particularly well defined by lithological and structural features, generally directed towards the Khan River. The regional flow pattern shows a gradient from northeast to southwest in accordance with the local topography. Flow in the alluvial aquifers follows the course of the dry riverbeds, which are aligned roughly north-south.

[22] Stacey, (2006)
[23] Brett, (2009)
[24] Although outdated, more information about animal life at Rössing is also contained in Ashton, *et al.*, (1991), Section 2.8.2 (p 34 – 40).
[25] Campbell, (1998)
[26] Although outdated, aspects relevant to the hydrology and surface water quality at Rössing is described in Ashton, *et al.*, (1991), Section 2.6 (p 19 – 23).

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

The watershed of Pinnacle Gorge is characterised by an intensely dissected drainage, reflecting the local fracture density. Pinnacle Gorge has its catchment to the southern part of the tailings facility and flows along the south western side of the open pit. The Panner Gorge watershed area, to the west of the tailings facility, is characterised by a strong linear dendritic pattern reflecting structural and lithologic controls in the underlying strata. Panner Gorge is orientated in a southerly direction and drains to the west of the mine. The drainage lines of Dome Gorge flow in a south easterly direction and captures run-off east of the tailings facility. The drainage lines of Boulder Gorge contain the run-off from the mine plant and the watercourse to the east of the plant.

Due to the alluvium the tributaries of the Khan River contain subsurface water flow for most of the year. Permeability of the alluvium is high – as much as 10^{-3} m/sec, resulting in subsurface flows between 4 and 8 m per day. The alluvium has also a high storage capacity with the water table being within 2 to 3 m of the surface. In the Khan River alluvial deposits may reach a depth of several meters, where they act as an important subsurface aquifer. The aquifer is recharged fairly frequently by run-off from its headwaters in the interior. Recharge rates depend on factors such as flood size, flood frequency, silt load, and local surface conditions.

Seasonal springs and small pools may occasionally form in the Khan River and in the gorges that drain into the Khan River. Pools relate to bands of impervious rock that traverse the river bed beneath the alluvium, forcing the subsurface water to the surface. Ephemeral springs may last for a short period after local rainfalls. Their flows are insignificant and persist for short periods after local rainfalls only. Many of them are saline, but provide important sources of drinking water for animals, despite their salinity.

Insignificant occurrences of permanent natural surface water can be found at small springs in the vicinity of the mine. These occurrences vary from areas of wet soil to small puddles. The water is normally very saline, but the springs are frequently used by wildlife for drinking. Only one natural perennial spring occurs in the Rössing area and is located in a side-arm of Panner Gorge.

2.10 GROUNDWATER[27]

Local geological formations show extensive patterns of folding, jointing and cracking, trending predominantly in a northwest-southeast or north-northwest-south-southeast direction at Rössing. This direction is perpendicular to the strike of the regional fold structures, which influences the geo-hydrology strongly. Consequently, groundwater flows and rainfall seepage at Rössing is mainly along the fractures and thus focused towards the gorges that drain into the Khan River (Figure 2.6).

[27] Aspects relevant to the geohydrology and groundwater quality at Rössing are also described in Ashton, *et al.*, (1991), Section 2.7 (p 23 – 26).

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

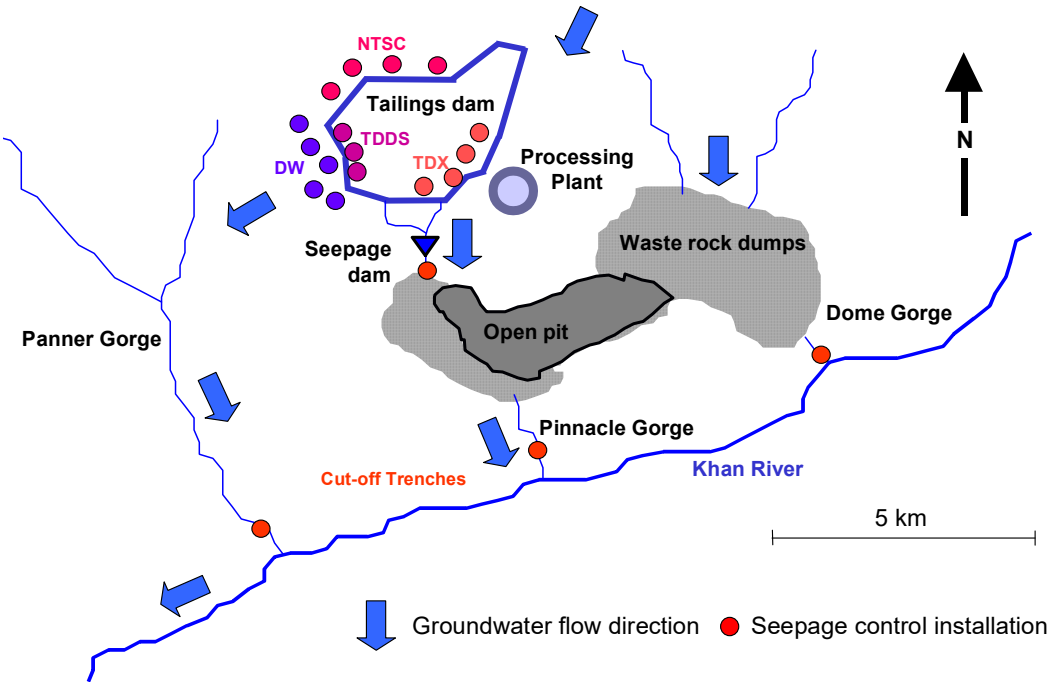


Figure 2.4: General groundwater flow directions and control at Rössing

In general, fracturing in the gneiss-like rocks is highly developed, with joint planes exhibiting well-defined blocks and rectangular patterns. In the schistose rocks, fracture density is more intensive. Many of the fracture zones in the latter type of rock intersect valley walls; this causes groundwater to be collected in the fractures; thus providing potential pathways for seepage flow. In the bedrock, groundwater flow is mainly along fractures.

Superimposed on the natural groundwater system are sources and sinks created by mining. The open pit, more than 300 m deep presently, crosscuts the hydrogeological connection between the existing processing plant situated above the Boulder Gorge fracture system and the Khan River receiving environment (Figure 2.6). It acts as a cut-off trench thus and enables the interception and subsequent evaporation of potentially contaminated water moving downstream from the plant area. Furthermore, it creates a cone of groundwater table depression that cuts off groundwater flow through bedrock and alluvial channels. Around the open pit hydrogeological parameters of storage and permeability are very low; permeability of the bedrock ranges between 1 x 10-8 cm/s and 4 x 10-6 cm/s; porosity is less than 0.01 m per day. The amphibole schist horizon and the SJ Fault are two thin but substantial features of higher permeability (0.2 m per day compared to 0.005 m per day of the surrounding rocks) that cut the pit longitudinally. They connect the void to the bounding fracture systems of the Pinnacle Gorge to the west and Dome Gorge to the east. The two horizons cause a redirection of groundwater flow towards the pit void cone of depression, away from the Khan River. Thus, these features act as natural drains for potential fracture flow of tailings seepage water from underneath the gorges into the pit, passively assisting long-term seepage control.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

The current elevation of the bottom of the pit is substantially lower than the level of the Khan River – 3 km to the south, and the regional water table – about 20 m below ground. The Khan River is also separated from the pit by a low-permeability rock mass and the possibility of water from the Khan River entering the pit void is significantly reduced this way.

The natural groundwater quality in the vicinity of Rössing is very saline with Total Dissolved Solids (TDS) concentrations of 20 000-40 000 mg/L on the desert plains in the north-west. The water quality improves gradually to TDS <10 000 mg/L in a south-easterly direction towards the Khan river. The tailings facility creates an anomaly of more saline water (20 000-40 000 mg/L) in an area of naturally intermediate salinity (10 000-20 000 mg/L). The tailings solution itself is highly saline (>40 000 mg/L), but it is reused in the process and not allowed to interact with the environment.

Table 2.2: Typical Khan River quality (in 2023) compared with Namibian stock-water guidelines

Determinant	Stock-watering standard	Khan River borehole (BH 1.6A)
Conductivity (mS/m)	3500	696
Sodium (mg/ℓ)	2000	1180
Calcium (mg/ℓ)	1000	452
Magnesium (mg/ℓ)	500	227
Chloride (mg/ℓ)	3000	3150
Sulfate (mg/ℓ)	700	557
Nitrate (as N mg/ℓ)	400	4.7
Fluoride (mg/ℓ)	6	0.2

Groundwater quality data for the Khan and Swakop rivers indicate a variable composition that improves after floodwater recharge, but generally deteriorates with distance downstream.

Khan groundwater in the vicinity of the mine is brackish with an average TDS concentration around 5000 mg/L. The lower courses of the Khan and Swakop rivers contain brackish to saline groundwater that is not suitable for human consumption.

The only groundwater potentially suitable for agricultural use near Rössing is found in the Khan River. This water is brackish and only suitable for livestock watering[28]. Table 2.2 shows typical selected analyses of Khan River water abstracted from boreholes in the river bed, compared with Namibian guidelines for stock watering.

As a result of the high salinity of the water in the Khan River the only beneficial uses of the water are for industrial purpose, such as for dust suppression. Despite its salinity, the very hardy natural vegetation along the river depends on this water and abstraction is closely coupled to monitoring of the water table. Current groundwater use of the Khan River is limited to environmental use downstream of the mine and there is no danger of an adverse effect on the primary use potential of this resource.

[28] SRK, (2010)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

2.11 AIR QUALITY[29]

The arid climate at Rössing is typified by daily temperature ranges that often exceed 20°C, an average annual rainfall of around 14 mm and evaporation potential is about 6,784 m3/day. Under these conditions air quality is prone to airborne dust and other impurities, a situation which is enhanced by atmospheric movements. Average daily wind speed is 4.35 m/s with the highest maximum wind speed over a one-hour period recorded at 17.20 m/s. These velocities usually occur during the winter and gusts of up to 34.90 m/s have been known to occur. The mean maximum gust is 26.17 m/s. Predominant winds are southwest in direction, or alternatively, east to northeast.

Potential for the transport of dust and other impurities via atmospheric pathways towards inhabited areas is dependent on the direction of receptor points relative to wind direction. Table 2.3 summarizes localities relevant to wind direction at Rössing.

Table 2.3: Geographical position of localities relative to wind direction

Locality	Distance	Direction	Relative to wind direction
Arandis Town	5 km	Northwest	Does not lie in the direction of E, NE, or SW winds
Arandis Airport	6 km	West	Lies in the direction of E wind
Swakopmund small holdings	50 km	Southwest	Lies in the direction of NE wind at a distance
Swakopmund Town	60 km	Southwest	Lies in the direction of NE wind at a distance
Walvis Bay	75 km	South-southwest	Lies in the direction of NE wind at a distance
Henties Bay	88 km	Northwest	Does not lie in the direction of E, NE, or SW winds
Husab (Swakop Uranium)	44 km	South	Does not lie in the direction of E, NE, or SW winds

Occasionally during winter, wind blows from the interior, mainly from the east or the east-northeast. These sometime high-velocity winds (average of 11.9 m/s with peaks exceeding 34.2 m/s) are accompanied by marked increases in temperature and sharp decreases in humidity, which causes the anomaly that the west of Namibia frequently experience the highest temperatures, lowest humidity figures and strongest wind during winter. These winds, known as *Bergwinds*, can carry large quantities of dust and can prevail from a few hours to a few days.

Generally deposited dust is not a health hazard, but because it is visible it is the cause of most complaints. While dust is in suspension, particulates with a diameter of less than 10μm might be inhaled, causing lung function disorders. If the dust contains silica, lead or radio-nuclides for example, it can present an additional health risk in the form of silicosis, lead poisoning or irradiation respectively. The degree of hazard is determined by the dust concentrations and the period of exposure. It is not only human health that can be adversely affected by dust: The fall-out of heavy metals onto soil and the foliage of plants also results in an adverse impact on the environment. The metal is either taken

[29] Additional information is contained in the Rössing Dust Management Plan, (2012)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

up directly from the dust deposits on the foliage, or it is taken up by plants and concentrated in the leaves of the plants. This can result in the bio-accumulation of heavy metals and radio-nuclides in the food chain, with severe adverse impacts in some cases.

It is important to distinguish between total dust, which includes all fractions, and inhalable dust, i.e. particles with a diameter of less than 10μm (PM10). The sources of dust are divided into two: particulates and fugitive dust. Particulate dust is derived from controlled sources such as emissions and other point sources. Fugitive emissions refer to those air pollutants that enter the atmosphere without first passing through a stack or duct designed to direct or control their flow. Fugitive dust sources therefore can be considered as uncontrolled, or non-point sources which are mobilised by the forces of the wind or machinery acting on exposed materials. Examples of fugitive dust sources at Rössing are the tailings dam, the crushing circuit and the open pit. Furthermore, dust sources are classified as localised (from blasting, loading trucks, crushing ore or transfer by conveyor); diffused (from waste rock dumps or areas of disturbed ground) or linear (from roads, for example).

While most of the dust generated in the pit at Rössing is of a fugitive nature, blasting activities can be considered as a point source of particulates, from where dust is dispersed into the surroundings of the mine. The exact size of the blasting plume is unknown at present, but it is unlikely to increase in size because as the pit deepens, the effects of blast dust will become less. The dust plumes from the smaller blasts tend to disperse along the length of the pit and the dust settles on the benches and roads within the pit, only to be remobilised again by wind action and vehicles.

From the primary crushers coarse ore is loaded onto an open conveyor which feeds to the coarse ore stockpile. The ore on the conveyor is moist and therefore the potential for dust generation from the coarse ore conveyor is low. Once it is tipped onto the stockpile, the material dries out to and the fines becomes susceptible to wind action. There can be up to 20% fine particles (<45μm) by mass in the primary crusher feed, especially when weathered ore is being processed.

Of the eight (8) common air impurities identified, five (SO_2, CO, NO_x PM10 and dust deposition) are released at Rössing. However, only two are recognized as significant i.e. particulate matter smaller than 10 microns in diameter (PM10) and dust deposition, which are regularly monitored. Rössing conducts annual monitoring of SO_2, CO and NO_x that could be emitted as a result of the yellow cake roasting at the Final Product Recovery (FPR). Gas emissions sources include stacks, process fugitives and mobile equipment. Only the stack emissions gases from the final product recovery are currently quantified annually. In addition, greenhouse gas (GHG) emissions are estimated as carbon dioxide equivalent (CO_2-e) on a monthly basis, deduced from fuel consumption, electricity usage and explosives used for blasting.

Noise and vibration arising from exploration and operations, including mining, mineral processing, materials handling, infrastructure and on-site transport may have significant impacts on employees, communities and the surrounding environment. Noise, ground vibrations and air blasts can have an adverse impact on the general living conditions of species and / or lifestyle of its neighbours and need to be monitored in order to mitigate adverse impacts. For this purpose spot-checks, specific surveys and investigations and regular risk assessments need to be conducted. Air blast and ground vibration are

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

monitored to provide information for geo-technical purposes as well, specifically to assess stability of man-made landforms.

2.12 SITES OF ARCHAEOLOGICAL AND CULTURAL INTEREST[30]

An assessment conducted in 2007 documented a total of 49 archaeological and historical sites at Rössing, mainly outside the mining operational areas, meaning that it is unlikely that important archaeological and historical sites were destroyed in the course of mining activity. Although there is some evidence of upper Pleistocene occupation, most of the archaeological sites date to within the last 5,000 years. Historical sites relate to the narrow gauge railway that operated between Khan Mine and Arandis siding until about 1918.

Many of the archaeological sites were confined to Panner Gorge and date between 2800 BC and AD 380. The third millennium BC, in climatic terms the mid-Holocene, was a period of above average rainfall in the Namib. This cluster of sites relate to the high quality chert for stone artefact manufacture and the strategic use of Panner Gorge as a hunting area. The chert artefacts mainly came from the prominent dolerite dyke striking in a SW-NE direction in the northwest corner of the mine tenement (Figure 2.7). Fragments of ostrich eggshell were also found at some sites in this cluster.

A second cluster of sites relates to grass seed digging activities in well-drained soils derived from weathered granite, estimated to post-date AD 1000. These sites occur mainly in the northern and north-eastern parts of the mine tenement (Figure 2.7) and relate to the seed-digging activities that still exist among Damara-speaking Namibians today. The seed digging sites are concentrated around a number of low-lying granite outcrops associated with shallow depressions, which may contain water after rain, in between. Two shelters and some coarse-tempered pottery as well as a pestle were found in this area, indicating that the possible ephemeral water supplies were used as base camps during the seed digging activities.

Thus, the Rössing tenement is not an area of outstanding archaeological importance and does not have the dense site clusters which are characteristic of some parts of the escarpment and ephemeral river systems of the Namib. The areas of highest heritage value lie outside the main focus of mining activity and the mining area and related high disturbance locations have a rather low heritage value. The sites also show a low vulnerability potential to disturbance. In general the archaeological and historical sites are mainly of a low individual significance.

[30] Further information is contained in a specialist report conducted for Rössing by Quaternary Research Services, (2007)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

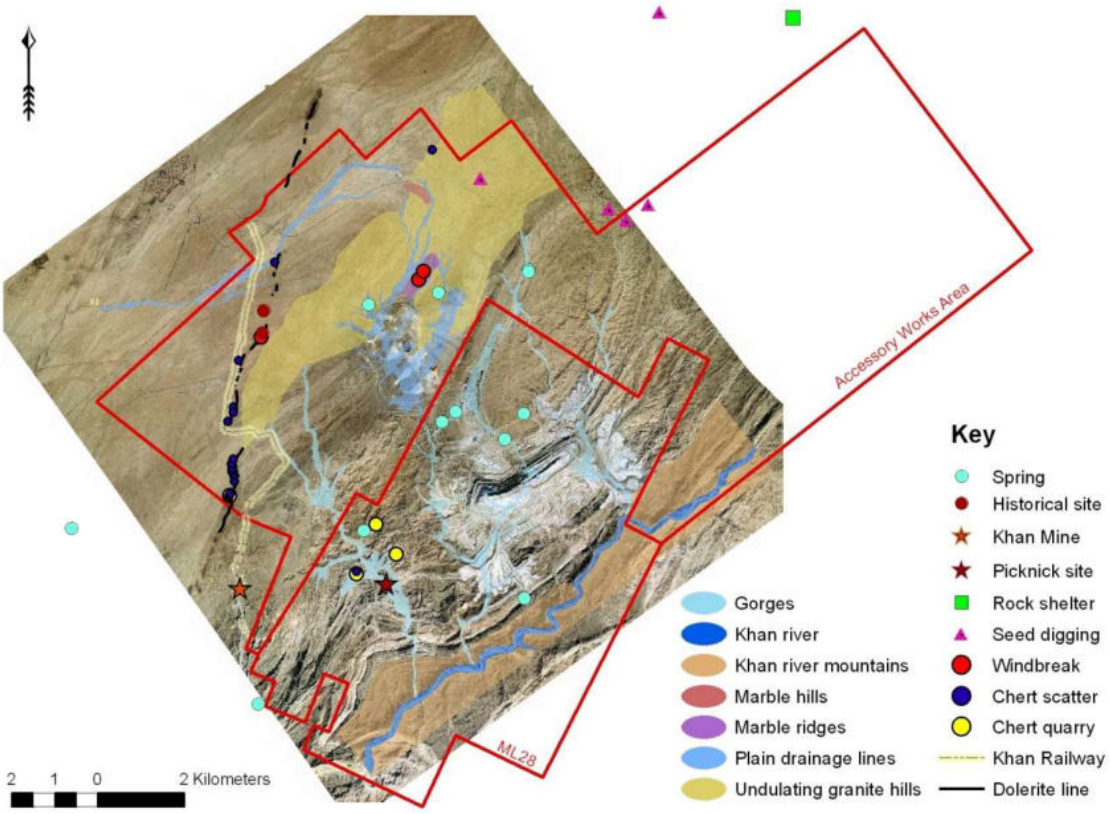


Figure 2.5: Archaeological and sensitive sites at Rössing

2.13 SENSITIVE LANDSCAPES[31]

Sensitive landscapes encompass a wide variety of site-specific points of interest as well as zonal areas, ranging from critical habitats or habitats occupied by threatened or endangered species to areas of historical (legacy), cultural and heritage importance. Sometimes the boundaries are well defined and the features clearly discernible (e.g. national parks), but sometimes the boundaries are uncertain, varying or vague (e.g. habitats). Sensitive features may also be located on adjoining land or include undefined aspects of a perceived value such as an ecosystem, landscape aesthetics or sense of place.

The Khan River and its associated rugged flanks are particularly scenic and have touristic potential. Places of archaeological and historical importance such as the former Khan Mine and the remnants of the old German railway line built in the early 1900s are part of this landscape (see also Figure 2.7). The naturalness, remoteness and cultural-historical importance of these landscapes are collectively known as their *sense of place*. Rössing highly respects sense of place and believes that maintaining this natural sense of place throughout the mine's life will result in a positive legacy after closure.

[31] Additional information is contained in the Rössing Land Use Management Plan, (2008)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

Access to the Khan River and its associated mountains is limited. Its northern bank is part of the Rössing Mining Licence and its southern bank is part of the Namib-Naukluft Park. Along the Khan River and within the gorges several ephemeral springs occur, mostly after local rainfalls. From all the studies done by Rössing and others, these parts have shown biodiversity of high significance, especially within the wider landscape context. Several scarce plant species occur here; many animal species, especially invertebrates, are confined to the rocky hillsides; and the availability of water in the drainage lines create important ecological corridors, providing water, food, shelter and migration routes. Although vulnerable, because the river is relative inaccessible, the Khan River and its associated mountains enjoy implicit protection. In combination, the inaccessibility of hilly and mountainous terrains, the tourism potential and the conservation status of the zone south of the Khan River qualifies the area clearly as a sensitive landscape that needs protection and wise management.

2.14 VISUAL ASPECTS

At Rössing the visual impacts of man-made landforms such as the tailings facility and the waste rock dumps can have an adverse effect on the landscape aesthetics. Moreover, the appearance of man-made landforms has a definite cumulative impact, often centred on visual contrast, which needs to be understood and managed. In addition to visual contrast, visual absorption capacity needs to be considered when determining impact significance. This refers to the capacity of the receiving environment to absorb the visual intrusion and typically relates to colour, shape, form and texture.

Objectives of minimising the visual impacts of the final heights and shapes of man-made landforms thus need to be set, requiring maintaining the characteristics and attractiveness of the surrounding, wider landscape. Although the design of mitigation measures and the evaluation of options need to take the visual aspects of surrounding landforms into consideration, the ultimate goal is to maintain or create a sense of place that is characteristic of the environment and valued.

Sense of place at Rössing has already been significantly impacted due to the long period the mine has been operating. To the contrary, the landscape character of some surrounding areas such as parts of the Khan River and the Welwitchia Plains remain intact due to the stark skylines constituted by the rugged terrain.

Higher levels of visual intrusion as a result of the vertical rise of the tailings facility are possible. Height of the tailings beyond 680 mamsl can have higher levels of contrast created by massing and scale. Waste rock dump heights have reached levels that are about the same elevation as the surrounding topography and visual impacts of these man-made landforms are restricted to a small number of viewing points outside the Mining Licence and accessory works areas.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

2.15 REGIONAL SOCIO-ECONOMIC STRUCTURE[32]

The Erongo Region, located in west-central Namibia and measuring nearly 64,000 km² in size, is sparsely populated. Just over 240,000 people, or about 9% of Namibia's total population, live in the region. More than 80% of these people live in the urban areas. Three of the region's eight towns are located along the coast and includes the major towns of Walvis Bay and Swakopmund with the latter as the capital of the region. In addition to mining-support businesses, tourism is regarded as an important economic activity for Swakopmund while Namibia's only deep-water harbour is located at Walvis Bay, which makes the town an important hub for the fishing, shipping, storage and transporting industries. Mining and Agricultural are key drivers for the micro and macro economy with agriculture limited to stock farming and mostly located in the more arable eastern parts of the region and operating mines delving for uranium, gold granite, marble, semi-precious stones and salt.

Erongo has a well-developed infrastructure, second to the Khomas Region. Mining, fishing, tourism, transportation and storage comprise the principal economic activities in Erongo, with most of these taking place in the western and coastal parts of the region.

Based on the National Census of 2023, the Region's population was pegged at 240,206 (from 150,809 in 2011). In the 12-year period from 2011 Erongo's population grew by 58%. Much of this occurred in the three constituencies of Swakopmund and Walvis Bay, which had a combined growth of 67%. The high growth figures are suggestive of high in-migration to the region and specifically to Walvis Bay and Swakopmund.

There are 96 schools in the region, which are made up of primary schools, combined and senior secondary schools and additional schools that are run privately. There are 24 public health facilities in the region comprising 4 public hospitals, 2 health centres and 18 clinics. Privately operated facilities also exist, but mainly cater for individuals with medical insurance and the wealthy.

2.16 INTERESTED AND AFFECTED PARTIES

The following stakeholder groups were identified as key interested and affected parties consulted in engagement processes, related to Environmental Impact Assessments, at Rössing:

- The Namibian State, specifically the following ministries:
    - Mines and Energy,
    - Health and Social Services,
    - Labour and Social Welfare,
    - Environment, Forestry and Tourism,
    - Agriculture, Water and Land Reform,
    - Education, Arts and Culture,
    - Urban And Rural Development, and
    - Ministry of Finance and Public Enterprises

[32] Additional information relevant to this section is contained in the Rössing Closure Management Plan, (2011), updated from the preliminary results of the 2011 Population and Housing Census by the National Planning Commission, (2012).

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

- Regional and local authorities:
    - Erongo Regional Council,
    - Swakopmund Municipality,
    - Walvis Bay Municipality, and
    - Arandis Town Council;
- Parastatal service providers
    - NamPort;
    - NamWater;
    - NamPower;
    - TransNamib;
    - Roads Authority;
- Other service providers
- The !Oe#Gan Traditional Authority;
- Other uranium mines in the Erongo Region;
- Rössing Uranium;
- The Rössing Foundation;
- Organised labour;
- The media;
- The farming community, both small-scale and commercial;
- Economic sectors which may be affected by mineral exploitation, e.g. tourism;
- Community groups and social institutions in Swakopmund, Walvis Bay and Arandis.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

3. DESCRIPTION OF THE CURRENT OPERATION

Although the extent of linear infrastructure at Rössing is comparable with that of a small Namibian town, it does not cover a large surface area. Including the linear infrastructure, the total surface area of land disturbance at Rössing according to man-made landforms, i.e. the direct footprint, is about 2,640 ha in 2024. This area represents about 20 % of the total land of 13,003 ha under Rössing auspices. The footprint did not increase substantially over time.

To portray the footprint better, the production and extraction process at Rössing is briefly described below. It is followed by a description of the main components of the mining activities that caused the direct footprint, followed by a brief description of components of the socio-economic footprint of the company.

3.1 PRODUCTION PROCESS

The current mining sequence is a conventional drill, blast and load operation on a large scale. Mining is done by blasting, loading and hauling from the main open pit, referred to as the *SJ Pit*, before the uranium-bearing rock is processed to produce uranium oxide.

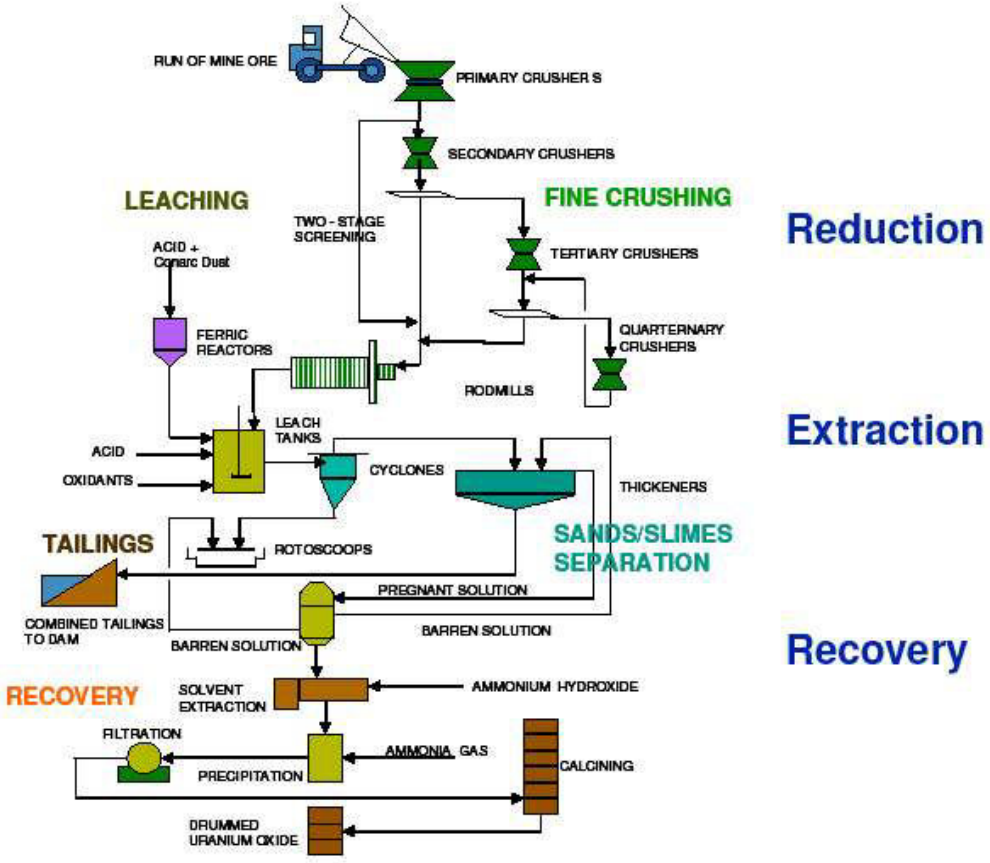


Figure 3.1: A simplified flow diagram of the production process at Rössing

The run of mine material from the open pit is fed through primary and secondary crushers to the processing plant. The metallurgical process is a conventional acid leach with ion exchange solution concentration and solvent extraction purification, followed by the precipitation of ammonium diuranate and roasting to produce uranium oxide. The final

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

product, U_3O_8 concentrate, is of a low radiation level and loaded into steel drums, containerised and dispatched via Walvis Bay for export to conversion and enrichment facilities in other parts of the world, to be processed as nuclear fuel for use in power plants. Figure 3.1 simplifies the production process at Rössing as a flow diagram.

The stages of processing and extraction are described in more detail in the following sections[33].

3.1.1 MINING

Ore is extracted from the hard rock by blasting. The explosive used is a mixture of 60% Emulsion (E6000HR) and 40% Ammonium Nitrate Prills (Expan 200), this explosive mixture is well known as High Energy Fuel (HEF) 260. Blasting takes place on average once a week, using approximately 200 tonnes of explosives per blast. A total of 10 000 tonnes of explosives is consumed per year.

3.1.2 CRUSHING

Ore from the open pit is delivered in 100, 140 and 180 tonne haul trucks to the primary crushers, where two gyratory crushers reduce the ore to less than 160 mm in size. A conveyor belts transports the crushed ore to a coarse ore stockpile with a live capacity of some 80,000 tonnes (see Figure 3.2).

Coarse ore is withdrawn from the stockpile by vibrating pan feeders, feeding directly onto a coarse ore reclaim conveyor. This conveyor discharges the ore to a pre-screening plant where all fines are removed and the coarse material returned to the surge bin ahead of the secondary crushers. The ore is further processed through secondary, tertiary and quaternary stages of crushing and screening, delivering a final product of less than 19 mm in size to the fine ore stockpile. The crushing circuit is equipped with an adequate system of dust extraction and collection into covered lugger bins. There are, in total, ten collection systems that provide extraction points from the reclaim tunnel to the fine ore storage bin.

[33] See Section 3.4 (open pit mining operations, p 46 – 53), Section 3.5 (processing operations, p 53 – 59), Section 3.6 (waste disposal, p 59 – 72) in Ashton, *et al.*, (1991). Recent information relevant to this section was also obtained from Rössing's Radiation Management Plan (2012)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

Figure 3.2: The coarse ore stock pile at Rössing

3.1.3 MILLING AND LEACHING

The final stage of size reduction employs four (4) Marcy rodmills operating in parallel. This milling stage comprises two modules that can be operated independently. Each module consists of two rodmills which feed into six leach tanks respectively. Grinding in the rodmills is a wet process, with feed water that can be any one or a combination of fresh water, return dam solution from the tailings impoundment and seepage water from the seepage dam. The final particle size leaving the rodmills is 1.1 mm in diameter on average.

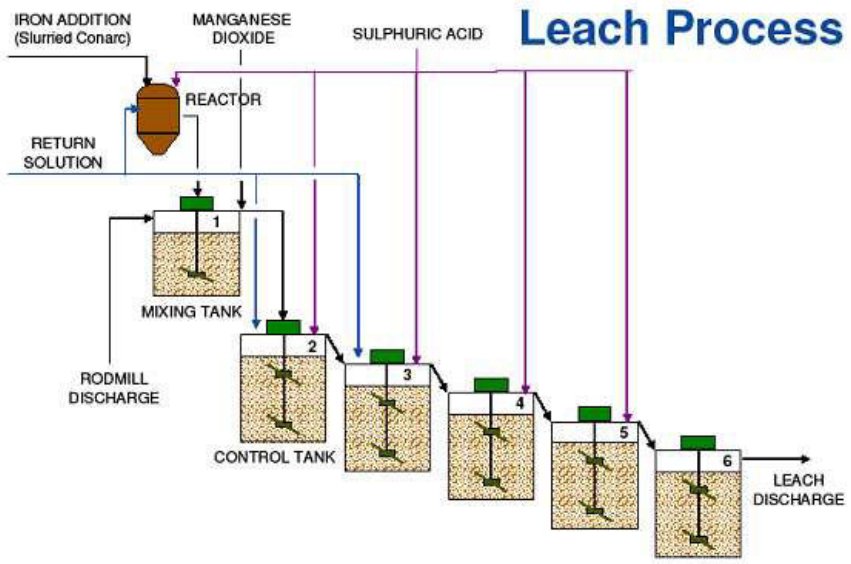


Figure 3.3: The leach process at Rössing

The resulting slurry is pumped from the rodmills to the leaching section where it is mixed with sulphuric acid, ferric iron and manganese dioxide in a series of six leach tanks (see Figure 3.3). The first tank in the series (290 m^3 capacity) is considerably smaller than the other five (1,450 m^3 capacity), thus ensuring adequate mixing of reagents and leach feed.

The steel leaching tanks are rubber-lined and mechanically agitated. Retention time in the leaching section is 8−9 hours at a temperature of 35°C, with uranium extraction of 85−90%. Gases and fumes generated during the leaching process are captured on top of the leach tanks by means of scrubbing units. The reagents used for leaching are:

- Ferric iron to oxidise the uranium from a tetravalent to a soluble hexavalent state. Ferric iron is obtained by reacting iron oxide with 93% sulphuric acid in special Rössing designed reactor vessels. Iron oxide (haematite) is brought in by truck in 1 m^3 mega bags.
- 93% sulphuric acid for extraction. Sulphuric acid is imported through the harbour in Walvis Bay, railed to site and stored in large acid tanks prior to being delivered to the leach tanks.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

- Manganese dioxide to oxidise ferric iron to ferric. Manganese dioxide ore is delivered to the harbour in Walvis Bay by ship and then railed to site and stored in a storage bunker. It is transported by front end loader to a crushing, grinding and thickening plant adjacent to the leach modules where a finely ground slurry is produced and delivered to the leach tanks as part of the extraction process.

3.1.4 THE SANDS / SLIMES SPLIT

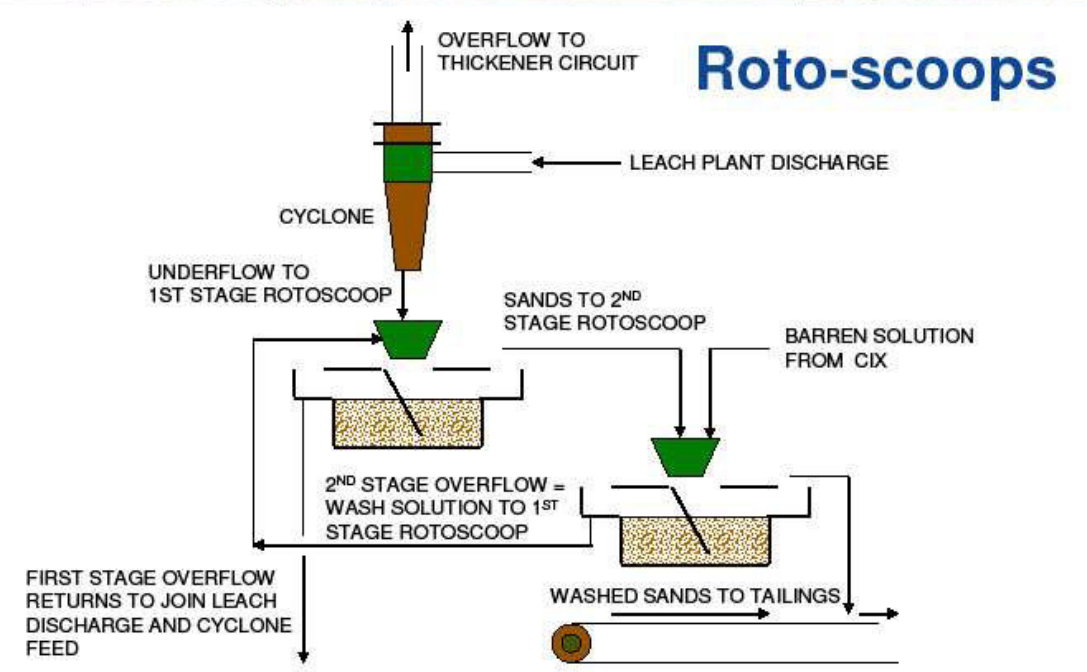


Figure 3.4: Washing circuits

Pulp leaving the final leach tanks flows into a ten-way motorised pulp distributor and thence to 10 hydro cyclones. A sand/slime split occurs here with the slime fraction (cyclone overflow) directed to a counter current decantation (CCD) thickener circuit (see Figure 3.4). The coarse sand fraction (cyclone underflow) reports to one of ten primary rotoscoops. There are 20 rotoscoops in each module arranged as 10 discrete pairs, a primary and secondary unit each, providing a two stage sands washing circuit. Barren solution from the continuous ion exchange plant is used as the wash medium on all second stage units. Washed sands are removed from the second stage rotoscoops by a conventional conveyor belt.

3.1.5 THE SLIMES WASHING – CCD THICKENERS

Slimes (cyclone overflow) washing is carried out using a five stage CCD thickener circuit (see Figure 3.5). The first stage consists of four identical thickeners with the slimes fraction distributed equally to two of them. The third and fourth thickeners are used as clarifiers. First stage thickener underflows are re-combined and progressively pumped through four further stages of thickening and re-pulping, thus five washing stages are achieved. Continuous ion exchange (CIX) barren solution is introduced into the fifth washing stage. This runs counter current to the slime flow, and provides the wash

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

medium taking up the uranium. First stage thickener overflow, called “pregnant solution”, contains uranium (uranyl sulphate), at a concentration of 0.180 g/L.

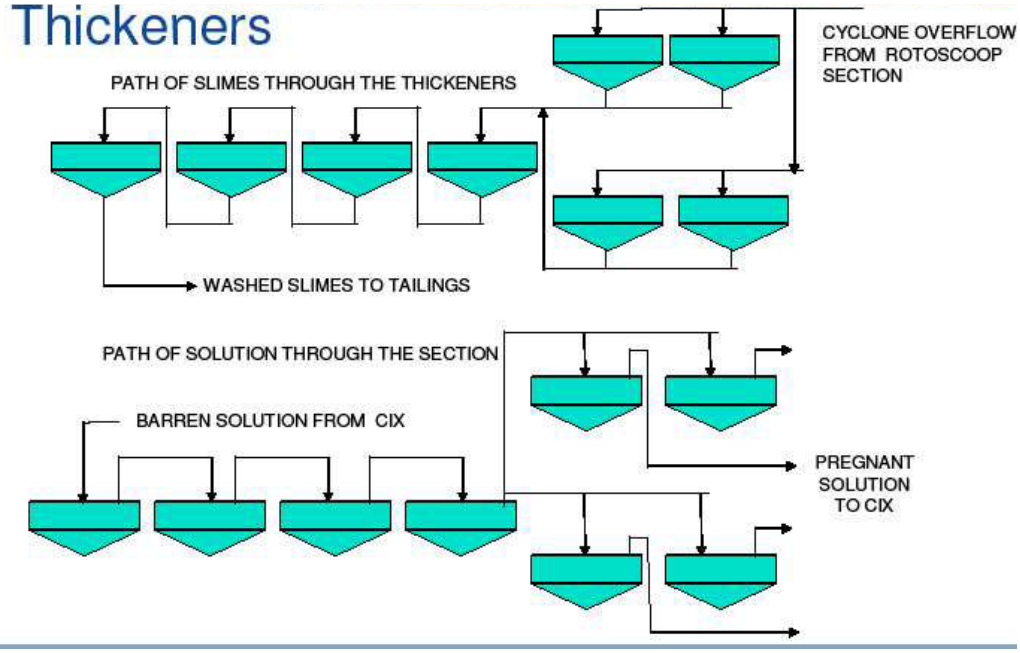


Figure 3.5: CCD Thickeners

3.1.6 TAILINGS DISPOSAL

The slimes from the fifth thickening stage are pumped to the tailings facility to the mixing and tailings pumping station at Paddy X via a pipeline, while sands and the coarse material from the second stage rotoscoops are sent to the station via the sands conveyor. The slimes and sands are re-combined prior to disposal. The solids settle out while the effluent (return dam solution) is pumped back to the processing plant for re-use at the rodmills.

3.1.7 CONTINUOUS ION EXCHANGE

First stage CCD thickener overflow (pregnant solution) is pumped to a pregnant solution storage tank situated near the CIX plant (see Figure 3.6). Tank discharge is by four pumps, each delivering to one line of the CIX contactors. The Rössing CIX plant is built on the Porter system, which uses the upward flow of pregnant solution to fluidise a bed of ionic resin beads in a series of six contactor chambers per line. The flow of pregnant solution is counter current to the resin movement. There are four lines of CIX contactors with six chambers in each line. Resin transfer from one contactor to the next is carried out by air lifter units of which there are six per contactor. Loaded resin from contactor 1 in each line is transferred to the elution columns. Three elution columns per line of contactors are provided; these take the form of fibreglass lined mild steel pressure vessels. Sulphuric acid (at 10% concentration) is passed through the resin bed, stripping the uranium from the resin beads during its passage. Stripped resin is then returned to the contactor line and the uranium rich concentrated eluate is pumped to solvent extraction. The eluate has a uranium concentration of 4 – 5 g/L.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

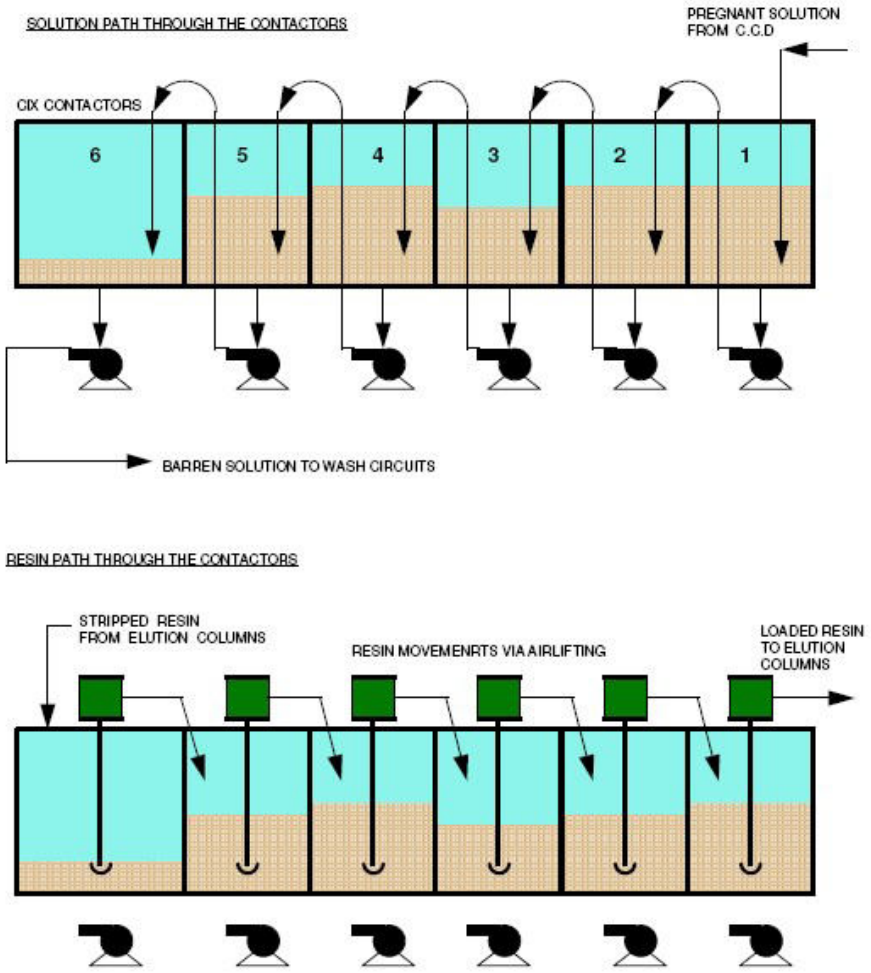


Figure 3.6: Continuous Ion Exchange (CIX)

3.1.8 SOLVENT EXTRACTION

Concentrated eluate containing 4 to 5 g/L uranium is pumped to solvent extraction as the aqueous phase of the extraction process (see Figure 3.7). The organic phase is Shellsol, containing alamine 336 and isodecanol. Extraction, i.e. transfer of uranium from the aqueous to the organic phase, is carried out in five stages of counter current contact using Davy Powergas mixer settler units. The loaded solvent is then passed through a two unit clean water scrubbing stage prior to a four unit stripping stage where the loaded solvent (organic) is mixed with a 7% ammonium sulphate (aqueous) solution under pH control with aqueous ammonium hydroxide. Uranium is stripped into an aqueous phase and is pumped to the final product recovery plant as OK liquor (concentrated uranium diuranate solution) containing 8 to 20 g/L uranium. The stripped solvent returns to the extract mixer settlers to repeat the process as described above.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

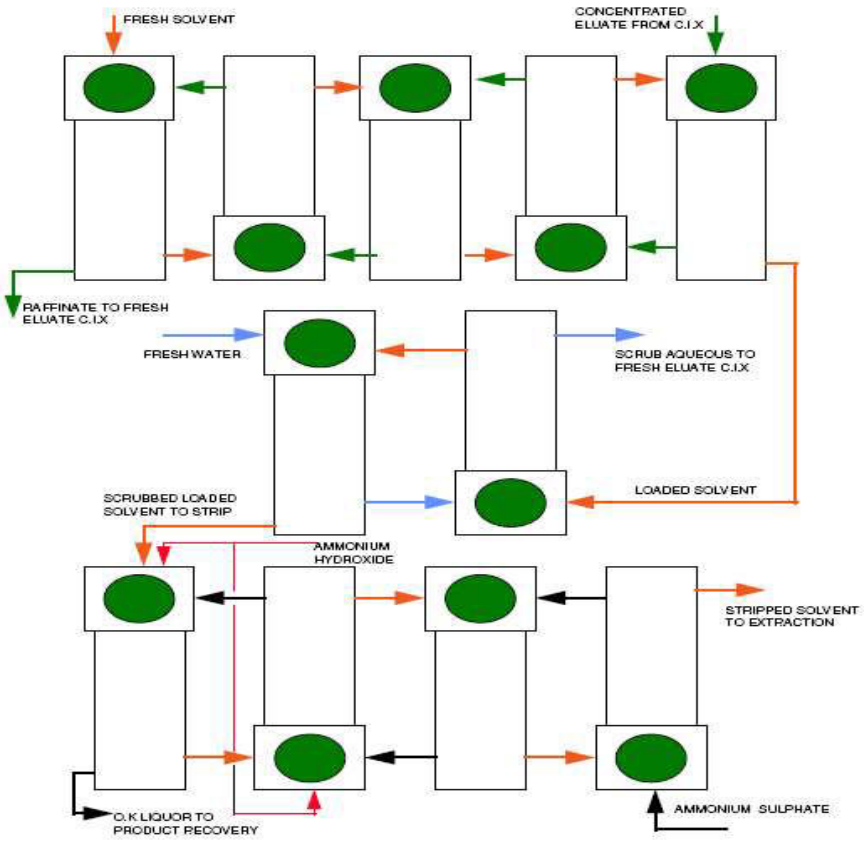


Figure 3.7: Solvent extraction

Strict fire protection procedures are in force at the Solvent Extraction (SX) plant. These include:

- Restricting access to area;
- Annual induction for all personnel who enter the SX area for any reason;
- Prohibition of matches, cigarette lighters or any other combustible material within the designated area.
- Regulation of hand tool types such that the possibility of creating a spark is minimised.
- A comprehensive fire protection system attached to and serving all mechanical equipment and storage tanks. This system comprises fixed water sprays on the outside of all mixer settler units and storage tanks.

Mixer settler units are also equipped with an internal foam injection system. The system is activated manually on receiving a signal from sensing devices located inside and outside the various items of equipment. Automatic initiation of the systems will activate the water sprays only.

3.1.9 FINAL PRODUCT RECOVERY

OK liquor, the chemical solution containing uranium trioxide, is pumped to the Final Product Recovery (FPR) building from the SX plant. The first stage of final recovery is

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

the precipitation of ammonium diuranate (yellowcake) from the OK liquor. This is carried out in an agitated precipitation tank. Gaseous ammonia is added to raise and maintain the pH of 7.3. Precipitation tank discharge gravitates to a yellowcake thickener. Thickener overflow (ammonium sulphate) is returned to the SX strip mixer settlers while underflow material is pumped to a two-stage washing section. Washing is carried out by two drum filters in series equipped with overhead water sprays. Filter cake from each stage of washing is re-pulped with process water. Re-pulped second stage filter cake is fed into one of the two multi-hearth calcining furnaces. Each furnace has six hearths and is heated to 700°C on the final hearth. The yellowcake feed is calcined to uranium oxide and is discharged via a hammer mill to an automatic drum filling plant. Final product at $\pm$ 98.5% U_3O_8 is dispatched in sealed drums, each drum automatically washed and dried and weighing $\pm$ 450 kg.

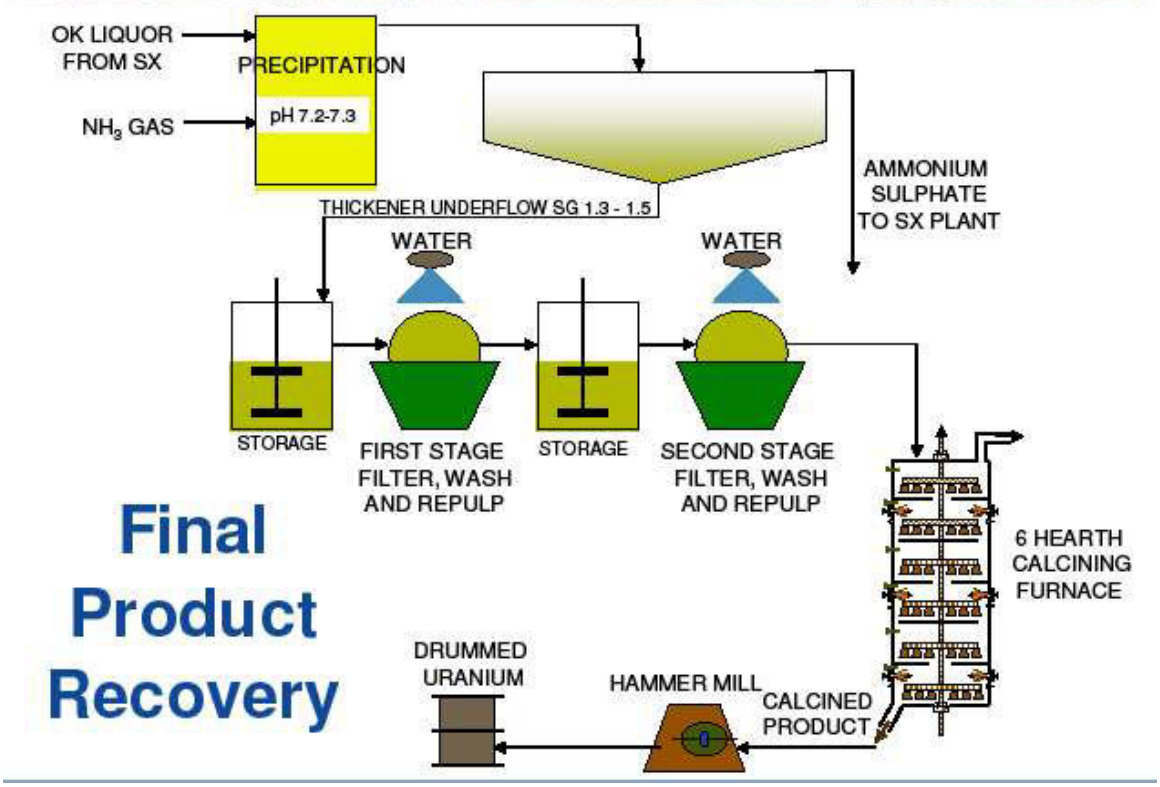


Figure 3.8: Processes of the Final Product Recovery

Gases and calcine particulates generated and emitted from the process are prevented from entering the atmosphere by means of an extraction and dust collection system and two wet venturi type scrubbers.

A summary of the processes at the FPR is shown in Figure 3.8.

3.2 COMPONENTS OF THE CURRENT LAND FOOTPRINT

As a large-scale open pit operation, the majority of Rössing's land footprint comprises of huge man-made landforms which include the open pit, the waste rock dumps, the tailings facility and the processing plant, offices and administrative buildings. These

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

man-made landforms are clearly visible from air (see Figure 3.9) and in combination with the linear infrastructure on site, account for almost 90% of Rössing's current land footprint. The linear infrastructure and man-made landforms are described below.

Figure 3.9: Aerial view of Rössing

3.2.1 LINEAR INFRASTRUCTURE

Linear infrastructure at Rössing is connected to buildings for workshops, laboratories, medical, personnel and administrative use, gardens, security facilities, a dormant landfill site, parking lots, domestic and industrial waste demarcated areas and storage facilities for fuel, consumables, explosives and chemicals. Linear infrastructure connections to Rössing are indicated in Figure 1.4.

Road and rail infrastructure

The D1911 district road branches off from the B2 national road between Swakopmund and Usakos to connect Arandis with the national road network. A 10 km-long double-

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

lane tarred road from the Arandis turn-off provides access to the mine. This latter road consists of the short D1905 and the private road section.

On-site, the infrastructure consists of a main tarred road with a network of various tarred and gravel access and haulage roads and tracks, with a total distance of around 30 km. From the B2, uncontrolled access to the site is possible on the gravel track via the Arandis Airport to the Khan River and, hence, the Welwitschia Plains in the Namib-Naukluft Park. This track is partly situated on the mine accessory works area.

A full-gauge railway line link connects the mine site to the main TransNamib railway line between Swakopmund and Usakos from the Arandis siding. On-site, the railway line has four branched sidings.

Water infrastructure

NamWater's Rössing terminal reservoirs (60 000m^3) are connected to the mine with a 600-mm pipeline. The water infrastructure on site exists furthermore of a network of water supply pipelines and storage reservoirs, a series of borehole pumping stations in and along the Khan River and a network of monitoring boreholes scattered over the mining tenement as well as an extensive system of sewerage and effluent pipes that drains to an activated sludge treatment plant near the open pit. In 2022, RUL commissioned six (6) additional water reservoirs to collective capacity of 60 000m^3.

As a result of the drive that began in the late 1980s to reduce water consumption at Rössing, today about 60% of plant solution utilised at the mine is recycled by means of a closed water system. An extensive water infrastructure network exists on site.

The Department of Water Affairs (DWA) of the Ministry of Agriculture, Water and Land Reform permits Rössing to extract brackish water from the Khan River aquifer for industrial use. Power lines and pipelines connect the abstraction system to the mine's water distribution network. Water from the Khan is mainly used for the suppression of dust in the open pit with minimal use routed to exploration drilling projects on ML28.

Power infrastructure

Power is supplied from the national grid by NamPower. Rössing itself has a switching substation, from where power is distributed to the mine, to Arandis, to the NamWater booster stations along the pipeline, and to the Arandis Airport. At Rössing the 220 kV power supply is stepped down to 11 kV into a network of overhead and underground cables. The power line supplying power to the external sites partly runs along the southern slope of the tailings facility.

Rössing's main 11 kV substation distributes power to the various areas via overhead and underground cabling. Furthermore, equipment is fed from 6.6 kV, 3.3 kV or 550 V lines, which are stepped down by transformers at various substations.

Trolley assist technology is utilised in the open pit to increase the energy efficiency of haul trucks. The haul trucks can be operated by diesel fuel or electricity. Overhead lines are erected on haul truck runs which are economically viable, upon which haul trucks engage trolley assist mode in order to operate on electrical power. Shovels in the open pit use power via portable 6.6kV transformers.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

In 2024, Rössing commenced construction of a 15MWe Photovoltaic Solar Power Plant. The plant is scheduled for commissioning towards end 2024 and envisaged to supply power to the mine via a 11 kV powerline.

Telecommunication infrastructure

A total of 624 landlines exist on-site. Rössing also makes use of a 20 Mbps Telecom Metro ethernet network to enable information technology (IT) network functioning on-site and at the Corporate Offices in Swakopmund.

On-site, the IT network consists of a fibre-optic backbone connecting four distribution points to two data centres. The fibre-optic cable is mostly trenched across the mine site, but several aerial fibre cable lines also exist. From the distribution points, fibre-optic cables branch out to the relevant buildings.

Off-site, the IT network consists of a fibre-optic backbone connecting the mine with the Swakopmund corporate office. The fibre-optic cable runs above surface along the railway line.

3.2.2 THE OPEN PIT[34]

The open pit at Rössing is the longest-running and one of the largest open pits in uranium mining in the world (see Figure 3.10), measuring about 3,5 km by 1,5 km. The depth from the pit rim, to the currently lowest operating bench is approximately 420 m, about 180 m below the level of the Khan River alluvial aquifer situated 3 km to the south.The pit is roughly rectangular in shape with the longest axis oriented approximately east–west, cross-cutting a north-easterly trending ridge which is bounded to the southwest by Pinnacle Gorge and the northwest by Dome Gorge.

The pit void is mined by a conventional truck-and-shovel operation, with mining being conducted in 15 m benches. Pit ramps are 40 m wide and established at a maximum 10% gradient. The central benches of the pit are generally in excellent condition – a result of good pre-split blasting techniques. The upper and lower benches are in poorer condition as a result of over-blasting, potentially affecting the stability of the pit rim. Nevertheless, the rocks making up the pit walls, despite being heavily jointed, have high strength values. There is also little seismic activity in the area. Sudden rockfalls and failures are thus rare.

Production at Rössing between 1980 and 2004 fluctuated in response to the volumes required by the long-term sales contract portfolio. Development of the open pit fluctuated accordingly. Mining had reached Bench 20 in 2004, when a decision had to be taken whether to close the mine in 2009 or extend operations to 2016. During 2005, RUL Board approvals were obtained for extending the life of the mine, by introducing the concepts of mining two separate pushbacks, named Phase 2 and Phase 3. The Phase 1 extension was completed in 2010, when mining in the centre of the pit was stopped at Bench 29 because of limited mining space and rockfall hazards. The piloting of Phase 2 mining started in the north-western part of the pit in 2006 while the Phase 3 push-back on the southern side of the pit commenced in 2007. The final depth of the open pit, within the

[34] Additional information relevant to this section is contained in the Rössing Closure Management Plan (2011)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

context of the currently approved Life-of-Mine plan, will be reached in 2026 at Bench 34, approximately 60 metres above mean sea-level (amsl).

Figure 3.10: The pit void at Rössing, looking northeast from the current viewpoint.

Mining activities in the lower part of the pit have been abandoned towards the end of 2010 and have been refocused on the higher lying benches of the next set of push-backs, located in the south, west and northwest of the existing excavation. As the new pit walls cut their way through severely folded geological domains, constant monitoring and assessment of pit limits and haul roads is taking place, in order to ensure that potential high wall failures won't put the business at risk.

Infrastructure in the pit consists of a trolley-assist with power cables and transformers, installed in 1986, as well as water distribution pipelines. Radiometric scanners are used to measure the grade of truckload material in order to direct allocation to the crusher or at the low-grade stockpiles and waste rock disposal areas. As the new ramps are starting to evolve, the existing trolley-assist infrastructure is being relocated. As such, trolley 13 has very recently been commissioned and will be the waste conduit for the next four years to the eastern stockpiles. Furthermore, Trolley 12 is in the process of being commissioned and will be the main ore conduit from the pit to the primary crushers and stockpiles, until end of the current mine life.
Due to the inaccessibility of the Khan Mountains and the steep slopes of the waste rock dumps, access to the pit void from the south, south-east and east is restricted, and can be regarded as impossible. Access from the west is restricted and the only permitted access is from the north, by coming from the main entrance of the mine.

Mining of the small satellite pit known as *SK4*, and situated 1,200 m to the east of the SJ Pit, commenced in 2010 and was completed in 2011. The 97.5 m-deep SK4 Pit void

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

has a final volume of 164,000 m³, a footprint of 4.03 ha, and a depth of 442.5 m above mean sea level at the bottom of the pit.

The Rössing Uranium LoME from 2027 to 2036 was approved by the Rössing Board in February 2023. One month later, a 13-year contract was signed with Beifang Mining to commence with a full contract mining service from 2024 to 2036. By the end of 2023, Beifang had mobilised a new fleet of heavy mining equipment ("HME") to site, together with an experienced workforce trained to operate this equipment. The first blast was taken in the new Phase 4 pushback, ahead of schedule, on 21 December 2023.

The upper benches of the Phase 4 pushback will be mined concurrently with the final benches of the Phase 2/3 pushback at the bottom of the pit. The latter will supply most of the ore until the end of 2026, while mining waste in Phase 4 to expose more ore from 2027 onwards. To enable this, funds were allocated for the execution of various infrastructure projects in the mining area. The largest of these is the construction of a high-energy rock-fall catch fence on Trolley 11 that will protect mining activities in the bottom of the pit from rockfalls arising from Phase 4 mining above. This project is still under construction and will be completed in 2024. Smaller infrastructure projects included the removal of power lines from the Phase 4 mining area, as well as the allocation of facilities to Beifang. While mining continues in both areas until the end of 2026, Rössing will continue to operate its remaining HME, after which Beifang will take over all mining from 2027 onwards.

Public access to the open pit from the northern directions is only possible through the main entrance of the mine. Otherwise the surrounding waste rock dumps and rugged terrains on the southern, eastern and south-eastern sides limit wildlife, and human, access to the open pit. From the west human access is not permitted.

The open pit cross-cuts the hydrogeological connection between the existing processing plant situated above the Boulder Gorge fracture system and the Khan River receiving environment. In this way the pit acts as a cut-off trench, and enables the interception and subsequent evaporation of water moving downstream from the plant area. The elevation of the bottom of the pit, furthermore, is substantially below the level of the Khan River – 3 km to the south – and the regional water table is about 20 m below ground. The direction of groundwater flow is towards the water table depression around the pit, and not away from the pit into the surroundings. The Khan River, in turn, is separated from the pit by a low-permeability rock mass, significantly reducing the possibility of water from the Khan entering the pit void.

3.2.3 THE WASTE ROCK DUMPS[35]

The total footprint of the waste rock dumps is about 760 ha, with 6,78 million tonnes mined and disposed in 2023, which results in 1,018.42 million tonnes of cumulative waste rock on the mine. The stockpiles have a combined footprint of more than 120 ha. In general, rock disposal sites are established as close to the major mining areas as possible (Figure 3.11). The current waste rock dumps and low-grade stockpiles consist of a mix of the abundant rock types in varying and random proportions. No deliberate efforts are made to segregate specific rocks when dumping, but minimising haul

[35] Additional information relevant to this section is contained in the Rössing Closure Management Plan, (2011)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

distances from the respective mining phases dictate that waste rock from the different formations are segregated. Typically, as mining deepens the pit, the dumps grow in height rather than width in terms of footprint area.

Waste and low-grade stockpile areas are mostly located around the western, southern and eastern margins of the pit void, in the former valleys of dry drainage lines that drain towards the Khan River. Dumps extend up to 2 km away from the pit.

The waste rock dumps and low-grade stockpiles consist of mineral waste and low- or high-grade, high calcium-carbonate-content (high-calc) material that is generally resistant to weathering. The waste material varies in size from large boulders more than 1 m in diameter, to gravel-sized particles and fine sand. The following cut-off grades are used to classify the material transferred to the rock dumps:

- Waste rock: <0.118 kg/t U_3O_8
- Low-calc material: >0.118 < 0.169 kg/t U_3O_8, at low-calc index values, and
- High-calc material: >0.194 kg/t U_3O_8, at high-calc index values.

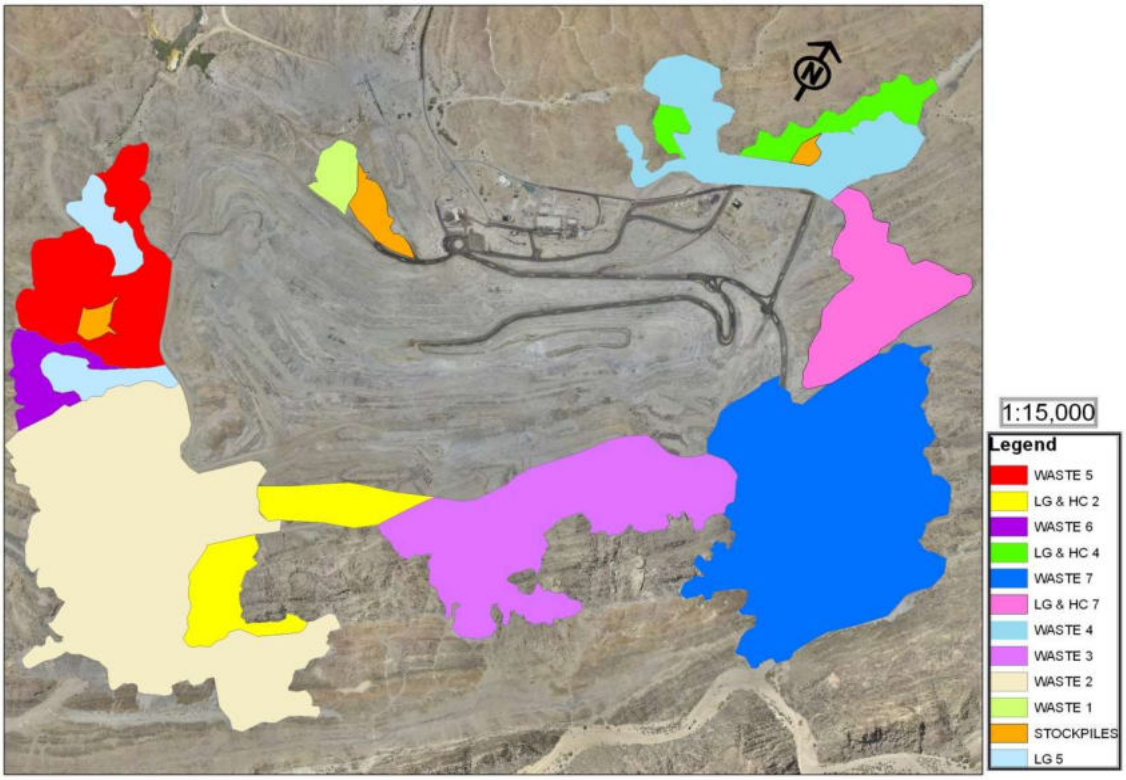


Figure 3.11: The location of waste rock dumps at Rössing

Dump heights have reached levels between 520 and 575 mamsl. This is at about the same elevation as the surrounding topography and, at this stage visual impacts of these man-made landforms are restricted to a small number of viewing points outside the Mining Licence and accessory works areas. Due to the sheer magnitude of the waste material to be dumped and stockpiled, it is inevitable that new land would be disturbed. About 70 ha would be eventually disturbed in addition to the current dumps, meaning

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

that the total footprint of the waste rock dumps and stockpiles would be more than 830 ha.

Secondary aquifers underlying the rock dumps consist of rock of different geological formations weathered on structural features like fractures and joints. Water moves slowly through these secondary features, following the down-gradient direction, with velocities and volumes of flow being much smaller than in the sand of the dry drainage lines, but showing a wide range of variability depending on rock type.

Positioning of the waste rock dumps has already permanently altered some of the surface drainage patterns that join the Khan River. The flow of surface water is directed either through or beneath the waste rock dumps, with the potential to increase the levels of heavy metals, salts and radio-nuclides in groundwater. Primary and secondary aquifers play an important role in transmitting groundwater to the Khan River. Groundwater flow is for this reason adequately monitored and controlled.

Since waste rock contains low or sub-economic concentrations of radioactive minerals, radioactive emanations have been determined. Radon exhalation rates average around 0.74 Bq/cm²s, ranging between 0.01 Bq/cm²s and 3.97 Bq/cm²s.

On occasion, foreign materials have been placed within the waste rock dumps. For example, high-grade ore from underground workings, which are contaminated by metal pieces, was stockpiled on the Waste Rock Dump 4 footprint. Over time, non-mineral waste was also placed on the waste rock dumps. The latter type of waste included contaminated waste from the FPR facility and the burnt-down SX facility, scrap metal, grease, vanadium pentoxide drums, tyres, and bags of jarosite. The placement of this form of waste on the waste rock dumps has been terminated as a practice, and over the years, the non-mineral waste has been covered with thick layers of waste rock.

3.2.4 THE TAILINGS FACILITY[36]

The tailings facility is the largest component of the combined Rössing footprint, covering a footprint of about 746 ha and containing about 500 million tonnes of tailings. It rises to an elevation of about 670 mamsl, more or less 100 m above the surrounding surface. The location and layout is shown in Figure 3.12.

All tailings from the uranium extraction process are conveyed and pumped to the facility situated to the north-west of the plant and separated from it by a north-east trending ridge and hills. Due to the low uranium content of the ore, the tailings consist of virtually the entire mass of input ore plus waste process liquids. The tailings material is coarse, by industry standards.

Originally designed as an upstream ring deposition facility, it was operated as an open surface tailings dam until the early 1980s. In this design, deposition was confined to a catchment, protected by a surface seepage collection dam situated in the main channel about 1,000 m downstream of the depositions. From 1976 to 1984, the process plant was operated on freshwater. Water pumped to the tailings dam as part of the tailings

[36] Additional information relevant to this section is contained in the Rössing Closure Management Plan, (2011)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

slurry, as well as all process plant run-off from the plant drainage sump known as the *snake pit*, was left on the dam to evaporate. By 1984 pumps were used to distribute the tailings around the crest of the tailings dam. It became clear that water savings measures became necessary and it was decided to change the circuit within the processing plant, to recover water stored on the tailings facility and to reduce the wetted surface of the facility. As part of these measures a paddock operation over the entire tailings facility was introduced in 1984. It proved so successful in saving water that the decision was taken to implement the paddock operation throughout the tailings facility.

Figure 3.12: Location and lay-out of the tailings facility at Rössing

In 2000, a number of pump stations were decommissioned, a conveyor installed to transport sands to the top of the tailings facility and two new pump stations had been commissioned. During 2008 and 2010, a number of studies were carried out to investigate the feasibility of alternative tailings deposition methodologies, including dry-stacking and high-density tailings deposition, using various footprint extension options. The preferred option was to continue with conventional slurry deposits in paddocks on the entire footprint of the existing facility.

A biodiversity study to assess the footprint impact of proposed extensions in 2005 indicated that, in the west, the tailings facility borders an important zone of *lithops* – not only a Red Listed plant species but also an endemic to Namibia. Since the study area is covered by about a quarter of the entire population, a decision was taken not to expand the tailings facility horizontally, but vertically.

To accommodate the maximum volume of tailings vertically, it is assumed that all existing but currently dormant paddocks, as well as paddocks to be re-established on existing tailings materials, will be brought back into service as part of routine operations, using the normal equipment. For this phase a new starter embankment, a seepage recovery sump and a seepage collection trench were introduced.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

The 300 million tons of coarse and fine tailings material contain radioactive minerals and have a specific activity of roughly 50 Bq/g. Radon emanations between 0.11 and 2.21 $Bq/m^2/s$ with a mean of 1.6 $Bq/m^2/s$ are characteristic. Four radioactive release pathways are discernible: from radon, airborne radio-nuclides in dust, water-borne radio-nuclides, and direct radiation.

Tailings material is also susceptible to wind erosion. Windblown tailings have been accumulated to the southwest of the facility over the years and heavy wind storms in the past have dispersed tailings to a distance of up to 8 km west of the facility.

Surface seepage from the tailings impoundment occurs through the filter drain in the embankment and the foundation materials. An extensive seepage control programme and monitoring system has been established to contain sub-surface seepage in Pinnacle and Panner Gorges.

A designated part of the tailings facility is used for disposal of contaminated waste, but it is covered by layers of tailings material.

3.2.5 THE PLANT, OFFICES AND ADMINISTRATIVE BUILDINGS[37]

The processing plant at Rössing covers a surface area of 195 ha and encompasses the primary crusher, the coarse ore stockpile and conveyer system; the secondary crushing plant; the fine crushing plant; the uranium extraction section, which includes the rod mills, the leaching section, sands washing, ten counter-current decantation thickeners; the tailings handling systems; CIX plant; the SX plant; the FPR plant; and the engineering workshops and offices.

The plant also includes the former pyrite stockpile area, the former acid plant area, the acid unloading facilities, the acid pipeline, and the acid storage tanks. Buildings are mostly of concrete and concrete block construction. The tanks for storing petrol are stored underground, while diesel is stored in a designated bunded area. Solvent, acid and ammonia storage are above ground.

The area comprising the processing plant is delineated in Figure 3.13. Elongated in shape, the south-eastern boundary of this area is the corridor formed by the main mine road and railway line, and in the north-west by the elevated slopes of a north-east-trending ridge, the Berning Range, which forms a natural buffer zone against the tailings facility. The total processing plant area is approximately 195 ha in size. The layout of the plant has remained virtually unchanged since the beginning of production in 1976 although some changes to facilities and infrastructure were made over the years.

With the height of the tailings facility rising continuously at the time, it became impractical to pump the tailings slurry from the level of the plant to the high level of the tailings facility. For this reason, an overland conveyor was commissioned in 2000 to transport tailings sand to a new mixing station on the dam and the pump system in the processing plant area altered accordingly.

[37] Additional information relevant to this section is contained in the Rössing Closure Management Plan, (2011)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

A pre-screening plant was added prior to 2000 as a way to save on ore-crushing costs. A pilot ore-sorting plant was constructed during 2000, and was operated from 2001 to 2007. It was then closed down because the operations were no longer considered feasible due to continuously high maintenance requirements. Slimes, mixed with the sands, were pumped to the dam.

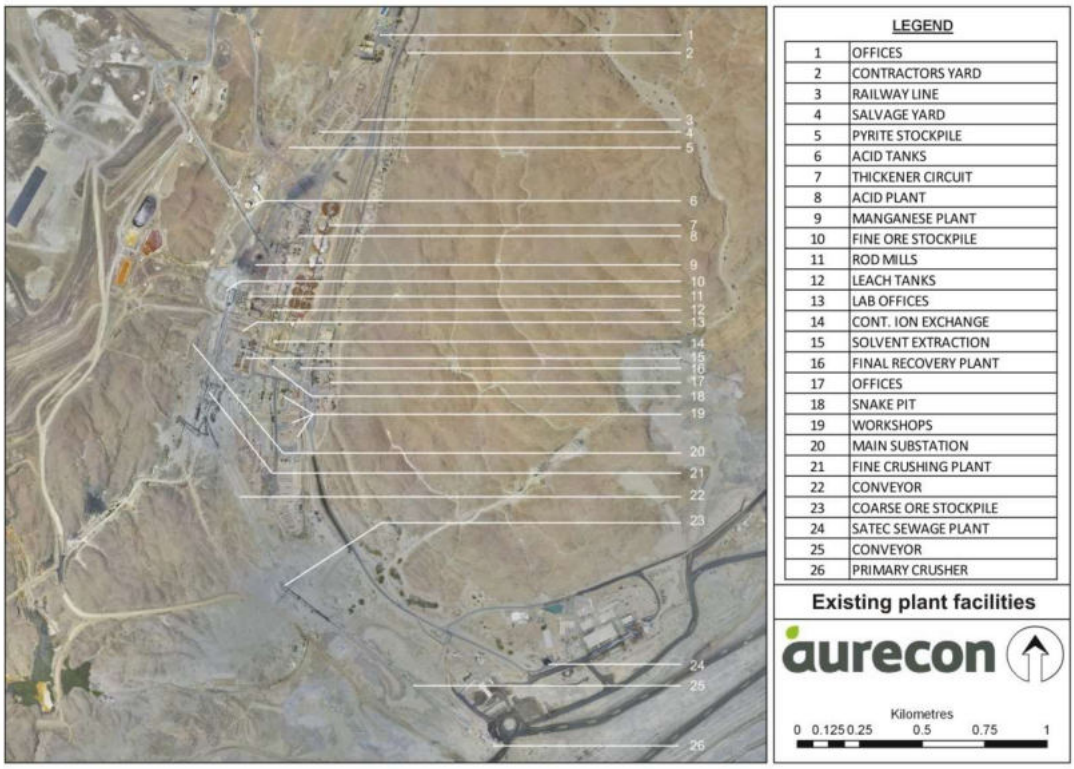


Figure 3.13: Lay-out of the processing plant at Rössing

In 2010 the former acid plant was demolished as part of the mine-wide progressive rehabilitation programme. The area was cleared of rubble but not decontaminated, because of the potential future use of the land as part of the processing plant. In order to provide more acid storage on-site, a third acid storage tank was built in 2010 and taken into service in 2011. A new set of emergency generators was built in 2010.

In the original area that became the processing plant, the top soil was originally thin, sandy and unconsolidated. Although the area had a low elevation, bedrock was exposed at a number of places. Fill materials from various sources have been used to make up the ground levels over most of the processing plant area. Tailings have been used as fill in some instances. Parts of the plant area were initially uncovered, but were later paved with concrete. Most of the roads in the area are tar-sealed.

The entire area where the processing plant is located dips gently towards the east, and surface drainage aims towards Boulder Gorge situated on the eastern side of the administrative buildings and offices, along the main road that runs from the main gate towards the pit. In turn, this drainage line aims towards the Khan River, but is intersected by the open pit. In the southern part of the processing plant area, run-off is divided between the Boulder and Pinnacle Gorges.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

Underneath the surface of the processing plant bedrock fractures provide the pathway for water-borne contamination from some parts of the plant. A number of potentially hazardous chemicals and materials are present on the surface and in the subsurface at the site. These residues have accumulated over many years, and may be concentrated or diffused where they occur. Most of these contaminated sites have been verified to identify management requirements. The list of potential residues is summarised in Table 3.1.

A removal programme for asbestos has been in place for some years. The last significant quantity of asbestos was removed from the demolished acid plant area in 2011. It is company policy not to use chemicals containing polychlorinated biphenyl (PCB). None have been identified in inspections since an exchange campaign was put in place in the late 1980s.

Table 3.1: Potential hazardous chemicals and materials present in the processing plant area

Chemical/material	Location
Uranium concentrate	FPR/Laboratories
Uranium-containing aqueous solutions	Laboratories/Plant (rod mills to FPR)/Tailings facility
Resin	CIX/Fibreglass workshop
Uranium-bearing organic solutions	SX
Sulphuric acid	Acid tanks/Leaching plant/CIX/SX
Pyrite	Former acid plant
Manganese	Leaching/Manganese plants
Caustic soda	CIX
Sodium hydroxide	SX
Isodecanol	SX/Tailings facility
Alamine	SX/Tailings facility
Shellsol	SX/Tailings facility
Flocculants	Thickener area
Ammonia	Ammonia tanks/SX/FPR
Explosive chemicals, e.g. ammonium nitrate	HEF plant/Ammonium nitrate store
Laboratory chemicals	Laboratories/Leaching plant/CIX
Compressed gases, e.g. oxygen and acetylene	Workshops/Compressor room and plant
Degreasers, descalers, etc.	Workshops and plant
Cleaning chemicals	Plant, offices, workshops
Other chemicals such as paints and adhesives	Paint shop, plant, rubber lining workshop
Soil stabilisers	Open pit and tailings facility
Water treatment chemicals	Acid plant, CIX, SX and Satec plants
Petrol and diesel	Workshops and service stations

The mine’s progressive rehabilitation programme was implemented in 1995. Within the ambit of this programme, a number of smaller buildings, redundant plant sections and waste sites were rehabilitated over a three-year period. The programme was

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

resuscitated in 2010 upon the demolition of the acid plant and, in 2011, saw the removal of redundant infrastructure and a number of salvaging and waste site clean-up projects. Since 2011 all historical waste disposal sites are identified and assessed in terms of remediation requirements.

3.2.6 EXPLORATION ACTIVITIES

Exploration activities at Rössing re-commenced during the mid-2000s in response to improvements in uranium prices and demand. Prior to this, there were numerous exploration campaigns between 1955 and 1978, following discovery of uranium mineralisation in the Rössing area in 1928. During the mid-2000s exploration program, a number of areas on the mining lease were targeted for drilling to verify and potentially upscale the extent of uranium mineralisation identified from previous exploration programs, and for assessing potentially new deposits from a 2005 airborne radiometric survey. Work involved geological mapping and exploration drilling by percussion and diamond core drilling to establish three-dimensional pictures of the occurring ore bodies. Land disturbance during exploration is inevitable, because the drill platforms and access tracks can only be shifted in a limited way.

Specific archaeological and vegetation surveys have been carried out to identify areas of sensitivity and vulnerability. The findings of these surveys were incorporated into a social and environmental management plan that were part of the exploration programs, signed off by the national authority and internally within Rössing Uranium. Transport of samples for assay and final storage at Rössing's sample storage facilities and transport of mineral waste generated during the drilling process to be disposed at the contaminated waste storage facility on the tailings facility was officially permitted.

Exploration area rehabilitation at Rössing generally includes the removal of drilling samples and all waste material types from the drilling sites, clearing of spillages, raking of vehicle or rig tracks, and covering of open drill holes with concrete cones or wooden blocks. For example, drilling in the SH area was completed in 2007 and the area was rehabilitated, inclusive of sample and waste removal, some restoration of the chert quarry and road areas. The exploration work in the Z19/Z20 anomalies were conducted between 2010 and 2012. Since these anomalies are located inside the Namib-Naukluft Park (NNP), an environmental management plan (EMP) for exploration was developed. Approval was obtained from the Department of Parks and Wildlife Management of the Ministry of Environment, Forestry and Tourism (MEFT) and had a special emphasis on the rehabilitation part of the plan. Following completion of the Z19/Z20 exploration activities, a rehabilitation contractor experienced in working in the NNNP was contracted to implement the rehabilitation commitments which were signed off by the MEFT in mid-2012 after completion.

In 2024, Rössing consulted MEFT (Department of Parks and Wildlife and Environmental Commissioner) with plans to commence with exploration activities in the Z20 area. A consultation meeting was held, with the Executive Director, Environmental Commissioner and Director of National Parks and Wildlife, in which RUL informed the regulator of plans to reinitiate exploration activities in Z20. Subsequently, preparations for exploration activities commence for exploration drilling to commence within the year.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

3.3 COMPONENTS OF THE SOCIO-ECONOMIC FOOTPRINT

Rössing is Namibia's first uranium mine, and the only one for about three decades. As an employer and contributor to various levels of the economy, the mine played a significant social and economic role in the Erongo Region since the 1970s, and has since become well integrated into the socio-economic fabric of the region and of Namibia. When operations commenced at Rössing, it triggered multiple developments in the Erongo Region and among the communities in the immediate vicinity of the mine. A great number of people were drawn from inside and outside Namibia into the Erongo Region and significantly enriched its social fabric. An increasing need for housing employees saw the establishment of the town of Arandis, while an obvious socio-economic influence on Swakopmund arose with the need to accommodate the majority of Rössing employees, besides seeing the development of a range of related supporting services, facilities and infrastructure.

Rössing always aims to ensure that its contribution to social, economic and environmental improvements in the Erongo Region in particular and to Namibia in general will be sustainable over time, an aspiration that is based on a firm stakeholder engagement approach. Given the socio-economic context of Namibia as a developing country, stakeholders recognized Rössing as a major employer and an indirect contributor to various levels of the economy. Rössing contributes significantly to Namibia's revenue from taxes on income and profits. In 2023, 74% of Rössing's total procurement expenditure was allocated to Namibian registered suppliers. Rössing's exports also contribute a significant amount to foreign exchange for the country.

To comprehend Rössing's socio-economic footprint, it is important to understand the characteristics of its workforce. Rössing's influence on the socio-economic fabric of Namibia and the Erongo Region is manifested in many ways, but mostly in the hosting communities and through the Rössing Foundation.

3.3.1 THE WORKFORCE[38]

At the end of 2023, Rössing Uranium had a workforce totalling 871 employees. This comprised 775 permanent employees and 96 employees with fixed-term contracts. Rössing's recruitment strategy is primarily aligned to its overall business strategy while providing equal employment opportunities for the job applicants. A key measure in the process is its compliance with the Namibia Affirmative Action Act (Act 29 of 1998) in ensuring equal employment opportunities for applicants and that they are equitably represented in the workforce. The company has made significant progress in achieving the country's Affirmative Action objectives. The reduction in workforce of the historically disadvantaged Namibian men is attributed to the voluntary separation packages offered to the employees as part of the LoME strategy.

The ratio of men and women employed in the company was 80:20. Measures have been put in place through talent management to increase the employment of women through focus groups, succession planning, targeted recruitment strategies, job attachments and graduate development programmes. A key enabler is the designated platforms and workplace committees in place that, from time to time, engage in addressing key

[38] Information relevant to this section was obtained from the Rössing Closure Management Plan, (2011)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

environmental, social, and governance ("ESG") HR issues with a strong focus on a culture incorporating inclusion and diversity, pay and equality.

The 2023 statistical information on our workforce profile, indicates 98.74% (860) Namibians with permanent employment and fixed-term employment contracts and 1.26% (11) Non-Namibians, including fixed term contract. Female representation among employees is about 19.74% (172).

Primary benefits of Rössing employees include a salary, medical aid contribution, retirement provision, cash in lieu, housing, and risk cover (death, accidental and disability). Medical coverage is likely to be beyond the reach of most employees when they are not employed by Rössing, meaning that employees may depend on the State's provision of health care when not working for Rössing. For those employees with chronic medical conditions other than HIV/AIDS, the termination of medical aid may result in having to rely on State facilities for chronic care. State facilities began providing anti-retroviral treatment (ART) in 2004.

Rössing has been participating in the Vocational Education and Training Levy submission since inception and has contributed N$8,483,662.37 to the 2023 Training Levy cycle. Nineteen job attachments from Namibia Institute of Mining and Technology ("NIMT") vocational training centre were provided an opportunity to work alongside skilled artisans to gain valuable practical technical skills and knowledge. The cost of external training interventions for 2023 amounted to N$6 million, with overal training and development cost amounting to N$28 million.

3.3.2 THE HOSTING COMMUNITIES[39]

Information gathered in 2011 concerned with the multiplier impacts of the uranium sector estimated that about three jobs are created downstream for every two direct jobs[41]. At end 2023, Rössing employed 871 employees and an equal amount of contractors.

As a major employer and purchaser of goods and services, Rössing made a significant annual contribution to economic development in the Erongo Region and to Namibia at large. Rössing's total spend for goods and services for our operations was N$3.88 billion during 2023 (2022: N$3.42 billion). As during the previous reporting years, most of the procurement expenditure was on Namibian-registered suppliers. Rössing's spend with local suppliers amounted to N$2.86 billion during 2023 (2022: N$2.54 billion), accounting for 74% of our total procurement expenditure. The continued high percentage of local spend reflects the company's confidence in procuring locally. N$487 million was spent with South African suppliers, representing 12% of our procurement expenditure, while we spent N$531 million with international suppliers, representing 14% of our total expenditure. Rössing remains committed to supporting local suppliers, including spend on developing small and medium-sized enterprises ("SMEs"). The bulk of the Namibian spend remains in the Erongo (41%) and Khomas (50%) Regions. Spend in other regions of Namibia amounted to 9%, with the highest spend in the northern region due to the current Supply of Sulphuric Acid agreement with Dundee Precious Metals in Tsumeb.

Arandis was established in the late 1970s as a resettlement town for Rössing's largely semi-skilled employees. Later, in 1994, Arandis was handed over to the State and

[39] Information relevant to this section was obtained from the Rössing Closure Management Plan, (2011)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

proclaimed as an independent town. The Updated Baseline study that was conducted in 2017/18 showed that Arandis is 43% dependent on the mine for its income.

3.3.3 THE RÖSSING FOUNDATION

The company has established the Rössing Foundation, a special purpose vehicle which is managed independently from Rössing by its own set of trustees on which Rössing's Board members are represented. The Rössing Foundation was established in 1978 by Rössing Uranium Limited through a Deed of Trust to implement and facilitate its corporate social responsibility activities within the communities of Namibia.

Honouring our corporate social responsibilities, Rössing Uranium supported the Rössing Foundation and other community initiatives with an investment of over N$41 million in 2023 compared to N$29.4 million during 2022. Of this amount, N$38 million went to the Rössing Foundation, and about N$3 million was in-kind and cash contributions to worthy community initiatives.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

4 DESCRIPTION OF ENVIRONMENTAL IMPACT ASSESSMENTS AT RÖSSING

Rössing has a long history in proactive management and over its 48 years of existence various environmental strategies were applied. Wherever possible Rössing prevented, or otherwise minimise, mitigate and remediate, adverse impacts of operations on the environment. Compliance with all environmental laws, regulations and standards is the foundation on which environmental performance is build.

4.1 FROM PRE-MINING AND CONSTRUCTION TO NAMIBIA'S INDEPENDENCE

During the late 1960s, the Rio Tinto Zinc Corporation (RTZ) acquired the exploration rights to the Rössing deposit and reinvestigated the resource intensively. This included airborne and ground radiometric surveys, detailed topographical and geological mapping, drilling, bulk sampling and metallurgical testing in a 100 t per day pilot plant to determine the feasibility of establishing a mine. A period of exploration, which included the construction of exploration camps and development of basic infrastructure, followed.

Actual development of the mine commenced in 1974 when the open pit was started. The plant was commissioned thereafter. By 1976 the first uranium from the new mine was produced with the intention to reach full capacity by 1977. However, certain design weaknesses in the plant emerged, and the ore proved to be highly abrasive. The SX-part of the plant was also destroyed by fire in 1978. As a result a great deal of the plant was extensively modified and one of the two solvent extraction sections totally reconstructed. Full production was reached in 1979 and in 1980 most of the construction work was completed.

Although no environmental assessment was required at the time of construction, the early mine operations commenced with due cognisance of the sensitive environment in which Rössing is situated. Since 1974 several investigations into specific aspects were conducted and documented. The initial investigations focused on changes of dust levels, water use, seepage and groundwater flows. An air quality monitoring program was established to address the early air quality concerns, and although no pre-operational radiation safety assessment was carried out, due care and attention was given to possible influences of radioactivity on both the human and the environment as from the late 1970s. At the end of the 1970's, the Environmental Department at Rössing was set up – something that was not mandated by law and considered as a unnecessary expense by many other mines.

Initial work on the environmental transfer of radio-nuclide discharges through the air and groundwater pathways started in 1979. In September 1982, Rössing contracted consultants to conduct the initial radon exhalation measurements on the tailings impoundment and other areas of the mine. A further study on the reclamation of the Rössing Tailings Impoundment was completed in 1984. One of the conclusions was that radon exhalation from this source could be reduced by applying a specified thickness of alluvium or waste rock[40].

[40] The bulk of the consultancy work at Rössing between 1979 and 1984 was done by Dames and Moore. See Ashton, *et al.*, (1991).

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

Focus on water and seepage remained strong during the 1980s, but the focus increasingly included air quality and employee health. Investigations with a biodiversity focus were conducted since the second half of the 1980s, but investigations and reports with an integrative approach were still rare.

Early commitment with regard to responsible environmental management was shown with the transplanting of *Aloe dichotoma* (quiver trees) from the area that was to become the open pit to the national botanical gardens in Windhoek. In the 1980s this commitment was strengthened when Rössing supported the former State Museum in an ambitious program to catalogue key elements of biodiversity on site. Monitoring of vegetation in the Khan River to examine the impacts of water extraction by the mine started in the early 1980s and became routine monitoring in 1988. It has been carried out ever since and contributed to the Tree Atlas of Namibia published in 2005[41].

Three important studies on radioactivity at Rössing were conducted by the Atomic Energy Corporation of South Africa between 1988 and 1990: Doses in the open pit was assessed and adaptation of the monitoring programme was suggested[42]; environmental radon concentrations were measured and a dispersion modelling was carried out[43]; and radon exhalation rates from identified sources were identified[44]. These studies assisted to model environmental radon concentrations associated with mining activities at Rössing[45] and to estimate the average radiation dose to the people of Arandis from radioactivity originating from natural and mining-related sources[46].

4.2 OPERATING IN INDEPENDENT NAMIBIA – THE FIRST 20 YEARS

Since Namibia gained independence from South Africa in 1990, a new legislative environment began to evolve. Shortly after independence, Namibia's Green Plan was drafted. Rooted in Article 91 (c) and Article 95 (l) of the Namibian constitution, the Green Plan was developed on a framework to promote sustainable development and described and identified actions to address the main environmental challenges facing Namibia. Following the Green Plan a lengthy, but pioneering stakeholder engagement process began to establish Namibia's 12-point Plan for Integrated and Sustainable Environmental Management and the Environmental Assessment Policy of Namibia. The latter was approved by the cabinet of the Namibian government in 1994.

Soon after independence, and before the Environmental Assessment Policy was approved, Rössing reiterated that one of its up-front, recorded goals (embedded in the business plan) is environmental improvement. The proactive pursuit of this philosophy moved Rössing management beyond the compliance focus to a focus of continual improvement in environmental performance.

In this spirit Rössing committed itself to responsible environmental management in an independent Namibia by conducting an Environmental Impact Statement, completed in

[41] Curtis and Mannheimer, (2005)
[42] De Beer and Leuschner, (1988)
[43] Grundling and Leuschner, (1988)
[44] Strydom *et al.*, (1989)
[45] Grundling and Leuschner, (1990)
[46] De Beer, (1990)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

1991[47]. A first of its kind, the purpose of the project was to provide a scientific base of the possible pre-mining environmental conditions describing location, topography, geological and mineral reserves, radioactivity, soils, hydrology and surface water quality, geo-hydrology and groundwater quality, ecological and biodiversity features, demographics, socio-economy, patterns of land use and communications and infrastructure.

The study comprehensively describes the mining operations of then, including waste disposal, dust and radiation control measures, workforce and environmental health and safety and interpolate from adjacent and similar, but undisturbed areas to set a reference document against which the impacts of both current and future developments, as well as the effectiveness of environmental protection and reclamation measures, could be assessed. Possible impacts as a result of projected future mining operations are assessed, and decommissioning plans are also proposed, but an Environmental Management Plan was not included.

Closure Planning at Rössing began in 1991 to accommodate anticipated operational changes for the remaining life of the mine, as well as the vision for closure. In support of the continuous planning process, several social and technical closure studies were done and have been updated. Since 1991 various studies were conducted to increase the knowledge base regarding mine closure.

In search for a long term solution for water supply to Rössing, an impoundment of the Khan River was suggested and investigated during the second half of the 1990s. The idea was to create an aquifer recharge scheme whereby a portion of the occasional floodwaters in the river would be captured, silt to settle out and then channel clear water into the downstream alluvial aquifer. Several technical and design investigations were made and assessment of the potential environmental impacts of the proposed aquifer recharge scheme was conducted during 1997[48].

The final document contains comprehensive information about water supply along the coast of Namibia; extensive baseline information about the Khan and Swakop Rivers; describes the methodology to evaluate the magnitude and importance of impacts associated with the proposed project; describes the main findings and lists the key issues and concerns; assesses the identified and possible impacts of the proposed project and summarizes recommendations and monitoring requirements. The report also contains consideration of mitigatory actions and finally concludes that there are no “fatal flaws” which would prevent the proposed project from proceeding. Despite this conclusion, the report recognizes the importance of negative public discernment about perceived undesirable detrimental effects of the project. Finally the report made firm recommendations about the removal of invasive plant species along the two rivers; monitoring of water tables and sharing of this information with the public; improved recharge and irrigation methods and the long term need for routine monitoring of sand, sand mining and the dynamics of sandy beaches north of the Swakop River mouth.

Although the project did not go ahead, the assessment of potential impacts was one of the most comprehensive conducted in Namibia at the time. The final documented report contains extensive baseline and technical information about water management as well

[47] Ashton, *et al.*, (1991)
[48] CSIR, (1997)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

as a number of specialist reports organized as appendices. Even though the assessment did not include an Environmental Management Plan, the final report contains a summary of impacts, mitigatory actions and further recommendations. As such the final report is still regarded as an important reference document to many of the more recent studies, assessments and investigations conducted at Rössing.

In 1997 an assessment of the radiological impacts associated with the use of Rössing tailings for maintenance of haulage roads in and around the open pit was conducted by the Atomic Energy Corporation of South Africa[49]. Before, Rössing was using alluvial sand from nearby drainage lines for cover of the roads inside and around the open pit. Due to a possible long term adverse impacts on the drainage lines and groundwater, the replacement of the alluvium with Rössing tailings material was contemplated. It was concluded that the average airborne activity concentration from and gamma dose rate on haulage roads should decrease or stay similar to the levels determined.

A similar study was conducted to assess the impacts of using seepage water for dust suppression in the open pit[50]. Rössing was using water from the open pit sump, from seepage collection trenches in the Pinnacle and Panner Gorges and from an aquifer in the Khan River for dust suppression in the open pit. Due to a reduction in the water available from the Khan River aquifer, the need arose to find an alternative – seepage water from the tailings facility. Possible radiological impacts from this source were assessed and the conclusion was that it is unlikely to cause any significant increase in radiation doses because of limited increase in radioactivity concentrations and a small fraction of seepage water involved[51].

A wildlife survey was carried out in 1998 to determine wildlife migration routes and the influence of fences (specifically around the tailings facility) on wildlife. Two reports and a map of migration corridors of wildlife as well as watering points were produced[52]. BirdLife International was instrumental in carrying out a number of bird surveys at Rössing to update the inventory produced during the 1980s[53].

Since its inception the Environment Department at Rössing was responsible to ensure that environmental impacts of operations are controlled and managed. In 1996 the International Organization for Standardization (ISO) published standard 14001 Environmental Management Systems (EMS) – Requirements with Guidance for Use and Rössing immediately started to develop its EMS in line with this international standard. Rössing was awarded certification the first time in February 2001 and became the second Namibian land-based mining operation to achieve certification. When ISO14001:2004 was published, Rössing incorporated the change into the existing EMS and received certification to ISO14001:2004 in early 2006.

Until the late 1990s Rössing produced acid for the extraction process in the metallurgic plant. Initially the acid plant used pyrite ore that was obtained from the Otjihase Mine near Windhoek, but after the closure of Otjihase in 1997, the pyrite ore was substituted with sulphur to produce sulphuric acid. From time to time acid stocks were supplemented by importing sulphuric acid from overseas, via the port of Walvis Bay. The imported acid

[49] De Beer, (1997a)
[50] De Beer, 1997(b)
[51] Rössing's Radiation Management Plan, (2012)
[52] Campbell, (1998)
[53] Stacey, (2006)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

was pumped to storage tanks on shore and then railed to the mine where it was stored for further use. In 2000 the acid plant was mothballed because it became more economical to import acid than to produce it on-site. The decision was taken to import the entire acid requirements via Walvis Bay and to expand the storage facilities thus. The new arrangement also implied more frequent and larger quantities of acid to be railed to Rössing.

Due to the nature and scale of the proposed expansions and the potential hazards sulphuric acid pose to human health and the environment in the event of a spillage, a team of specialists was commissioned to conduct an environmental impact assessment of the envisaged expansion to the importation, storage and transfer of acid to Rössing and evaluation of alternative processes, recommendation of best options, mitigation measures and management plans for the preferred options. It was made clear that the assessment should exclude responsibilities of non-Rössing organizations (such as aspects related to transport). The terms of reference included also formal communication with regulatory authorities and interested and affected parties[54].

The final report has been preceded by a comprehensive scoping report. The scoping report was used to answer the majority of concerns and issues raised by stakeholders and highlighted those concerns that were addressed through the actual impact assessment. The information compiled for assessing potential impacts is documented in the final report, issues of concern were listed and grouped into a logical sequence to provide the scope and scale of concerns as well as appropriate mitigatory measures that could enhance positive benefits and minimize potential adverse effects. Criteria to evaluate the impacts include anticipated scale, duration, severity, certainty and significance. Moreover, the assessment process brought issues to the fore in an open debate, improved public awareness about Rössing's operational practices, enabled wide and constructive stakeholder engagement and underlined the importance of maintaining a high "state of readiness" to deal with possible disaster events such as sulphuric acid spills. Organized as appendices the report contains also a specialist study on acid handling; design specifications on storage facilities; transport logistics and scheduling; handling, training and emergency responses; medical preparedness; and public awareness about sulphuric acid.

Radiation remains a challenging priority at Rössing and in 2001 the company invited Rio Tinto Technical Services to conduct a study on post-closure radiological exposures and mitigation options, in particular to evaluate the tailings facility cover options, by calculating doses for the various options of the 1997 Closure Plan. In the study, post closure doses were estimated to be well below the dose limit for members of the public, both during and after decommissioning. All doses in the Rössing environment for the offsite maximally exposed persons were found to be less than 0.25 mSv/a. It was concluded that radiation from Rössing, and the tailings facility in particular, would not have a significant radiological impact at Arandis[55].

A number of radiation-related studies followed during the 2000s: On radon exhalation values, radon sources and dose attributable to radon at receptor locations surrounding Rössing[56]; assessment of airborne and deposited dust levels[57]; and background radon

[54] Ashton, *et al.*, (2000)
[55] Isaack, (2001)
[56] Everett, (2001)
[57] PARC Scientific and EnviroSolutions, (2001)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

concentrations for determining pre-mining conditions[58]; a screening assessment of the post-closure radiological impacts of Rössing[59]; post-closure public dose assessment for proposed expansions at Rössing[60]; an investigation into the possible increase in external radiation doses at the FPR[61]; atmospheric dispersion calculations to assess radiological impacts of radon and long-lived radioactive dust at selected locations to assess current, extension and post-closure scenarios[62]; and a dose assessment to compare current radiological impacts of the mine on members of the public compared to the life-of-mine-extensions and after mine closure[63].

The sustainability assessment for Rössing in 2003 included an environmental impact assessment conducted, which considers social, environmental and biophysical impacts of proposed mine extensions. The assessment aims to ensure appropriate remedial action where needed, and to identify actions that will create positive socio-economic outcomes for stakeholders beyond the physical and time dimensions of the present mine[64]. The proposed changes to the mine are described, which included a pushback of the then existing open pit to the west (referred to as Phase II) and a subsequent pushback of the pit to the south (referred to as Phase III).

The study includes a public stakeholder participation programme, and assesses socio-economic impacts on the towns of Arandis, Swakopmund and the Erongo Region elsewhere, and on- and off-site biophysical impacts. The environmental assessment showed that there are no environmental impacts that cannot be addressed or minimised and the highest environmental risk is associated with the expansion of the tailings facility. Assessment of the radiation levels indicated to remain well below occupational and public dose limits. Some of the proposed operational changes indicated possible improved environmental performance, such as reduced water usage, reduced dust emissions and reduced groundwater pollution.

The first complete closure management plan for Rössing, according to the Rio Tinto Closure Standard, was conducted in 2005. The plan covered two closure alternatives: closure in 2009 or 2016. The plan was the first to document detailed discussions of

- Impact and risk identification;
- Stakeholder consultation;
- The development of a vision for closure;
- The development of closure objectives and targets;
- A description of preferred mitigation alternatives;
- An identification of knowledge gaps and further work required;
- An estimation of closure cost and accounting provision.

The expansion activities proposed in the mid 2000s required authorisation and clearance and consequently a multiphase Social and Environmental Impact Assessment (SEIA) has been commissioned by Rössing for the proposed expansion project in

[58] EnviroSolutions, (2002)
[59] De Beer, Ramlakan and Schneeweiss, (2002)
[60] De Beer and Ramlakan, (2003)
[61] Abrahams and Anderson, (2004)
[62] Strydom, (2006)
[63] De Beer and Liebenberg, (2008)
[64] Rössing Closure Management Plan, (2005)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

accordance with these requirements, as well as the internal standards and guidelines prescribed by Rio Tinto[65].

The entire extent of the envisaged expansion of the Rössing comprised a number of components, dealt with in two phases. Phase 1 of the SEIA process entails a sulphuric acid manufacturing plant; associated sulphur storage on the mine; transport of sulphur from the port of Walvis Bay; a radiometric ore sorter plant and the mining of an ore body known as SK4. Phase 2a entails the sulphur handling facility in the port of Walvis Bay whereas Phase 2b entails the extension of the current mining activities in the existing SJ open pit; increased waste rock disposal capacity; establishment of a new crushing plant; increased tailings disposal capacity; establishing of an acid heap leaching facility; establishing of a ripios disposal area and additional plant associated with the above.

The assessment of the proposed expansions entails an outline of legal and policy frameworks regarding the environment within which Rössing operates; a description of the proposed expansion project components, their alternatives and potential impacts; a description of the public participation process; a description of the methodology; and, most importantly, an assessment of the significance and possible mitigation of the potential impacts that were identified, and management recommendations.

The proposed expansions were announced in the media in 2007, followed by public and key stakeholder meetings with a wide array of interest groups and organisations. Public meetings were again held in early 2008 in Arandis, Swakopmund and Walvis Bay. The purpose of this series of meetings was the release of the Phase 1 Draft SEIA Report, as well as the introduction of the Phase 2 Scoping Report of the SEIA process.

An SEIA for the construction of a sulphur handling facility in the port of Walvis Bay was completed in 2009. In the interest of time and to allow for an earlier clearance, it was decided to separate the sulphur handling component in the port from the remainder of Phase 2 of the SEIA process, meaning that this component was subjected to an individual SEIA process (referred to as the Phase 2a process).

Phase 1 of the SEIA process has been approved by the Directorate of Environmental Affairs at the Ministry of Environment and Tourism by 2008 and Phase 2a in 2009.

A number of specialist studies have been undertaken to properly understand the most significant impacts of the further proposed developments and to ensure an acceptable level of confidence in the assessment of such impacts. Impacts were evaluated according to a tabulated rating system, where each impact is described according to its extent (spatial scale), magnitude (size or degree scale) and duration (time scale), with and without mitigation. After mitigation, no risks remain that are high or critical.

Engagement with the public and stakeholders interested in, or affected by, the proposed development formed an integral component of the assessment process. Public and stakeholders have had several opportunities at various stages throughout the SEIA process to gain more knowledge about the proposed components, to provide input and to voice any issues of concern. The general low attendance of public meetings and the lack of comments on the draft Phase 2 Scoping Report caused concern that the public was not accessing information about the expansion project, and that the concerns and

[65] Ninham Shand, (2008) and Aurecon, (2011a)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

recommendations were not being articulated and recorded. It was hoped that a new approach would reach a broader audience than before and result in a better and more detailed understanding. This would, in turn, lead to more comprehensive input. Difficulties in engaging with marginalised groups were also identified as a need to be addressed. A decision was therefore taken to change the format of the public participation process for Phase 2b of the SEIA process, by moving away from large open house public meetings to specific focus groups based on stakeholder categories.

During August 2010 focus group meetings were held with the interest groups, preceded by a tour of the mine and a visit to the site of the proposed expansion project components. This contextualised the discussions at the meetings, and facilitated more informed and in-depth questions and comments. Meetings focused on issues which had been identified as of interest to each particular group and presentations and specialist attendance were arranged to match.

The new format proved to be extremely productive. All focus groups were involved in the consultation process, and the inclusion of marginalised groups was particularly successful. Participants freely voiced their concerns, questions and recommendations, captured and included in the final assessment. Participants also showed great interest in the technical details of the proposed new acid heap leaching process.

A key component of any thorough SEIA is the consideration of alternatives (strategic or project level; site, arrangement of facilities and layout; technology or process) during assessment. A two year process of refining the decision criteria and technical information was used to inform the decision on the preferred layout with the following main objectives:

- Minimise the physical footprint of the proposed expansion
- Optimise the use of areas where the sustainable development impacts are minimised
- Find the best practical site for each of the facilities
- Make the best use of newly impacted sites, and
- Ensure that the expansion follows a strategic Life of Mine approach.

Key decisions had to be taken about facility locations and overall site layout during the ‘order of magnitude’ stage. Two workshops were held to identify the most appropriate areas for new processing and waste disposal facilities by using multi-criteria decision making methodologies. The land use database (developed in 2008) was an essential tool in the subsequent process used to identify the most appropriate layout. Rössing determined a list of criteria comprising four main categories for land use optimisation during the assessment. The objective was to ensure that proposed extensions are in line with a sustainable development approach, which emphasises economic viability, environmental sustainability, and social acceptability. Criteria were sorted as technical, environmental, socio-economic and strategic categories.

The series of documents that support Phase 2b of the SEIA process, and culminate in the final SEIA Report, comprise:

- A Public Information Document (PID) released in August 2007
- A Scoping Report released in April 2008
- A Background Information Document (BID) released in October 2008
- A summary of specialist study findings released in August 2010 and

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

- The eventual SEIA Phase 2 Report (3 volumes)

The final SEIA Report provide a wide range of sufficient and reliable information to make an informed decision on whether or not the proposed components of Rössing's expansions were acceptable from a social and environmental perspective. Outcomes include confirmation of the social and environmental acceptability of preferred or indicated sites; identification or confirmation of the environmentally preferred process and technology alternatives; identification of possible mitigation measures to reduce the significance of potential impacts; and documentation of the identified mitigation measures in a Social and Environmental Management Plan (SEMP). The SEMP has been developed to guide the design, construction, operational and closure phases of the proposed expansions. The final SEIA report was submitted to the Directorate of Environmental Affairs by the end of 2011 and approved in 2012.

Exploration activities at Rössing commenced during the mid-2000s, causing a number of areas on the mining lease to be drilled in search of new uranium ore bodies. Rössing has decided to proactively follow best practice to manage these activities. Specific archaeological and vegetation surveys have been carried out to identify areas of sensitivity and vulnerability. The findings of these surveys were incorporated into a social and environmental management plan that became part of the exploration program rolled out in the Z-area since 2010, signed off by the national authority and internally within Rio Tinto.[66] Part of this management plan is to rehabilitate the areas disturbed by exploration activities.

4.3 STRATEGIC ASSESSMENTS

Ideally, cumulative environmental impacts should be taken into account in all environmental assessment processes. Environmental impact assessments have traditionally, however, failed to come to terms with cumulative impacts, largely as a result of the following reasons:

- Cumulative effects may be local, regional or global in scale and dealing with such impacts requires co-ordinated institutional arrangements; and
- Environmental assessments are typically carried out on specific developments, whereas cumulative impacts result from broader biophysical, social and economic considerations, which typically cannot be addressed at the project level.

In 2009, an initiative was launched to provide a guiding framework for sustainable uranium mining development specific to the Erongo Region, including aspects of mine closures and early planning for desired post-closure conditions. Consequently, the Southern African Institute for Environmental Assessment (SAIEA) was contracted by the Ministry of Mines and Energy to undertake a strategic environmental assessment (SEA) of the so-called uranium rush in the central Namib[67].
The SEA was expected to provide direction to the uranium industry, government and other stakeholders in the central Namib. Exploration for and mining of uranium is a collection of projects, each being conducted by individual companies that are not related to each other and, in many cases, undertaken in isolation of each other. However, they collectively combine to produce potentially cumulative impacts including the loss of a

[66] Aurecon, (2011b).
[67] Rössing Closure Management Plan, (2011)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

sense of place; the over-abstraction and pollution of groundwater; short- and long-term exposure to radiation by workers and the public; stress on physical and social infrastructure; and opportunity costs on other, more sustainable industries. But the uranium rush could also offer substantial opportunities for synergies, and the industry could stimulate critically needed development.

One of the objectives of the SEA was to outline a Strategic Environmental Management Plan. The latter offers a set of environmental quality objectives, expressed as a set of desired future environmental conditions elicited through a stakeholder consultation process. The Plan sets targets as regards how best to achieve the desired objectives, suggests indicators that could be used to map progress towards those targets, and lists the parties responsible for the Plan's implementation.

Implementation of the Plan is the most critical part of the SEA and the extent to which it is implemented will determine its ultimate success in guiding the uranium rush towards a sustainable future. The planning for closure is addressed in a number of environmental quality objectives contained in the Plan, and provides specific guidance for the Erongo Region in this respect. Recognising the opportunities and constraints presented by the uranium rush, the Chamber of Mines of Namibia established the Uranium Stewardship Council as a 'spokesperson' for the Namibian uranium industry, both nationally and internationally[68].

In 2008, a significant milestone was achieved when the Namibian Stock Exchange (NSX) agreed that uranium exploration and mining companies could not be listed on the NSX unless they were members of good standing with the Uranium Stewardship Council. All Council members are bound by the Chamber's Constitution that commits them to upholding the Namibian uranium 'brand', and ensuring the highest standards in environmental and radiation safety management.

[68] Chamber of Mines of Namibia, (2009)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

5 IMPACT MANAGEMENT AT RÖSSING

5.1 THE IMPACT MANAGEMENT SYSTEM IN EFFECT AT RÖSSING

All operational activities at Rössing are managed to ensure that the impact on both the biophysical and socio-economic environment are reduced to acceptable limits. This management is implemented in a number of ways, at all stages of mine operations, namely planning, construction, operation and decommissioning of facilities. For this purpose Rössing implemented an integrated Health, Safety and Environment Management System (HSE MS) in 2008.

The management system is a tool designed to assist in achieving Rössing's goals, including its legal obligations. This systematic approach to management performance promotes the efficient use of resources and offers the prospect of financial gains to the company – generating a win-win outcome in terms of environmental and business performance.

Health	**Safety**	**Environment**
H1 – General principles **H2** - Fitness for duty **H3** - Noise, vibration and manual handling **H4** - Hazardous substances management **H5** - Airborne contaminants **H6** – Radiation **H7** - Carcinogenic substances **H8** - Travel and remote health	**C1** – Isolation **C2** – Electrical safety **C3** – Vehicles and driving **C4** – Working at heights **C5** – Confined spaces **C6** – Cranes and lifting equipment	**E1** - Air quality, noise control and Greenhouse gases (GHG) **E2** - Hazardous materials and non-mineral waste control and minimisation **E3** - Biodiversity, rehabilitation and Land use management **E4** - Mineral waste, acidic and other impacted drainage control **E5** - Water usage and quality management
Major Hazards **D1** – Rail Safety **D2** – Fire Safety Management **D3** – Management of Pit Slopes, Stockpile spoil & Waste Dump spoil. **D4** – Explosives Management **D5** – Management of Tailing and Water Storage Facilities. **D6** – Process Safety **D7** – Communities and Social Performance		

Figure 5.1: The RUL HSE Performance Standards

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

In addition to the HSE MS Rössing developed internal Health, Safety and Environmental Performance Standards. The intent of the standards is to gain commitment of employees on an annual basis to improvement in impact management performance. Figure 5.1 displays the new set of standards that was introduced in 2019 and being successfully audited for compliance on annual basis.
The International Standard for environmental management systems, ISO 14001, through its design encourages continual improvement. ISO 14001 is embedded in the HSE MS at Rössing. The system not only helps to ensure that major health, safety and environmental risks and liabilities are identified and managed, it also establishes a framework for tracking, evaluating and communicating the performance in these aspects. Adoption of ISO 14001 therefore implies a constant commitment to improving Rössing's environmental monitoring and environmental performance efficiency.

Figure 5.2 provides an overview of the integrated HSE MS in effect at Rössing. The structure of the management system follows the layout of common international standards such as ISO 14001:2015, (Environment); ISO 45001:2018 (Health and Safety); ISO 9001:2015 (Quality). The system is based on the principles of continuous improvement and adopts the methodology of Plan, Do, Check and Review.

Figure 5.2: Overview of the HSE management system in effect at Rössing

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

The use of a formalised, integrative HSE MS is essential in allowing Rössing to optimise, coordinate and manage the various operations, personnel, plant and equipment and their interactions in a manner that demonstrates consistent application of best practice in environmental management. Matters of planning, implementation and operation, checking and corrective action, and management review, are embodied in the system. This approach assists in identification of key environmental aspects and serves to guide Rössing in continued formulation of suitable Standard Operating Procedures (SOPs) and in attaining continual improvement objectives. Through the system Rössing can efficiently detect and minimise the potential adverse impacts of its activities on the receiving environment.

Codes of Practice have been developed as part of the HSE MS design to ensure a process of continual improvement in the HSE management and performance. The HSE MS Code of Practice (JA05/COP/003) provides a set of management steps, focussing on the organisation's achievement of its HSE goals that form part of the wider management of the organisation's operations. The Code of Practice considers all aspects of Rössing's operations in order to manage any potential HSE impacts and it contains references to the HSE MS procedures.

The HSE MS is furthermore divided into seventeen elements. Each element sets out to achieve a specific objective that enables the business to best identify and manage its various HSE threats and opportunities. Many of the elements are inter-related. The four core elements of the HSE MS are:

- The Environmental Policy
- The Legal and other requirements register
- The HSE risk register
- HSE improvement plan/s

5.1.1 PLANNING

HSE Policy

The HSE Policy is the overarching and guiding document that informs the manner in which Rössing conducts its business activities and manages impacts on the environment and the health and safety of its employees and on the public at large.

Rössing's Managing Director (MD) is accountable to the Rössing Board for all HSE matters and the MD is the custodian of the HSE Policy.

Legal and other requirements

The management of all identified HSE hazards / aspects must comply with the relevant Namibian legal requirements and relevant standards and guidelines to ensure that good international practices are applied to the HSE MS. The term "other requirements" refers to non-regulatory requirements to which Rössing has voluntarily subscribed, and / or CNNC has formally committed Rössing to meet. A Legal Register that contains all applicable legal and other legislative requirements is maintained and annually updated.

Appendix 1 summarizes some of the legal requirements relevant to Rössing's operations.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

Hazard identification and risk management

The policy and goals of the HSE MS are based on an understanding of all the HSE hazards / aspects of operations, products or services related to Rössing. This means that every hazard / aspect in which operational activities may affect health, safety and the environment must be investigated so that the most important HSE impacts (HSE hazards / aspects with significant impact) are identified.

A description of the potential or known HSE impact as a result of each identified HSE hazard / aspect is listed on the HSE risk register. Where mitigating measures are already in place to reduce the severity of any potential impact to the health, safety and environment, these measures are also described. The HSE hazards / aspects that potentially result from any particular input or output are classified according to their impact category, for example: Employee health; employee safety; pollution to air, water or soils; fauna and flora; hazardous and non-hazardous wastes; radioactive material, etc.

Appendix 2 summarizes environmental impacts according to their spheric dimension, hazard, outcome, operational phase, risk management control mechanisms and way that the impact is managed.

Risk assessment framework

In accordance with the HSE MS, the Rössing risk management framework is based on a three-tiered model (Figure 5.3) that allows the appropriate level of risk assessment to be selected to match the nature, context and scale of the hazard being considered.

Figure 5.3: The three-tier risk assessment model

Qualitative risk matrix

The HSE Risk Matrix (Table 5.1) and associated Consequence (Table 5.2) and Likelihood (Table 5.3) descriptors are used to assess risk levels.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

Table 5.1: Qualitative risk matrix

	Most serious consequence				
	Very Low	Low	Moderate	High	Very High
Almost Certain	Class II	Class III	Class IV	Class IV	Class IV
Likely	Class II	Class III	Class III	Class IV	Class IV
Possible	Class I	Class II	Class III	Class IV	Class IV
Unlikely	Class I	Class I	Class II	Class III	Class IV
Rare	Class I	Class I	Class II	Class III	Class III

Table 5.2: Descriptors for the consequence of an impact occurring

Consequence Type	Consequences				
	Very Low	Low	Moderate	High	Very High
Health & Safety	Negligible health impact	Low level short term inconvenience or symptoms. Typically a first aid case with no medical treatment.	Injury or illness requiring medical treatment, that does not lead to restricted duties or lost time. Typically a medical treatment case injury or illness. Also includes diagnosed occupational illnesses that do not require medical treatment E.g., Dermatitis, laceration requiring suturing, NIHL, pneumoconiosis or other diagnosis without significant impairment or disability.	Injury / illness with moderate damage or impairment (<30% on impairment scale) to one or more persons. Typically a restricted duties or lost time injury/illness. E.g., Loss of finger, broken leg, injury requiring in-patient care, severe asthma attack, mental illness (with lost time), NIHL, pneumoconiosis or other diagnosis with significant impairment or disability.	Single fatality or severe permanent impairment to a person (>30%) e.g. loss of hand or lower limb (at knee), paraplegia
Environment	Transient, minor impact to environment.	An unplanned or unpermitted or unintended event; or a series of chronic or cumulative events results in: Harm to the environment that is localized, of short-duration, effects no sensitive receptors and is quickly and easily rectified (eg, within a shift). (For impacts to groundwater – a few days to weeks of natural recovery.)	An unplanned or unpermitted or unintended event; or a series of chronic or cumulative events results in: Harm on the environment that is localized, effects no sensitive receptors and is rectified or reversed within a few days to weeks of work effort, or a few days to weeks of natural recovery. (For impacts to groundwater – weeks to months of natural recovery.)	An unplanned or unpermitted or unintended event; or a series of chronic or cumulative events results in: Harm on the environment that is largely localized but starts to be unconfined, effects sensitive receptors and is rectified or reversed within weeks to months of work effort, or weeks to months of natural recovery. (For impacts to groundwater – months to years of natural recovery.)	An unplanned or unpermitted or unintended event; or a series of chronic or cumulative events results in: Harm on the environment that is unconfined, effects sensitive receptors and is rectified or reversed within months to years of work effort, or months to years of natural recovery. (For impacts to groundwater – years to decades of natural recovery.)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

Table 5.3: Descriptors for the likelihood of an impact occurring

Likelihood	Likelihood description	Frequency	Substance Exposure
ALMOST CERTAIN	Recurring event during the life-time of an operation/project.	Occurs more than twice per year.	Frequent (daily) exposure at > 10 x OEL.
LIKELY	Event that may occur frequently during the life-time of an operation/ project.	Typically occurs once or twice per year.	Frequent (daily) exposure at > OEL.
POSSIBLE	Event that may occur during the life-time of an operation/project.	Typically occurs in 1-10 years.	Frequent (daily) exposure at > 50% of OEL. Infrequent exposure at > OEL.
UNLIKELY	Event that is unlikely to occur during the life-time of an operation/project.	Typically occurs in 10-100 years.	Frequent (daily) exposure at > 10% of OEL. Infrequent exposure at > 50% of OEL.
RARE	Event that is very unlikely to occur very during the life-time of an operation/project.	Greater than 100 year event.	Frequent (daily) exposure at < 10% of OEL. Infrequent exposure at > 10% of OEL.

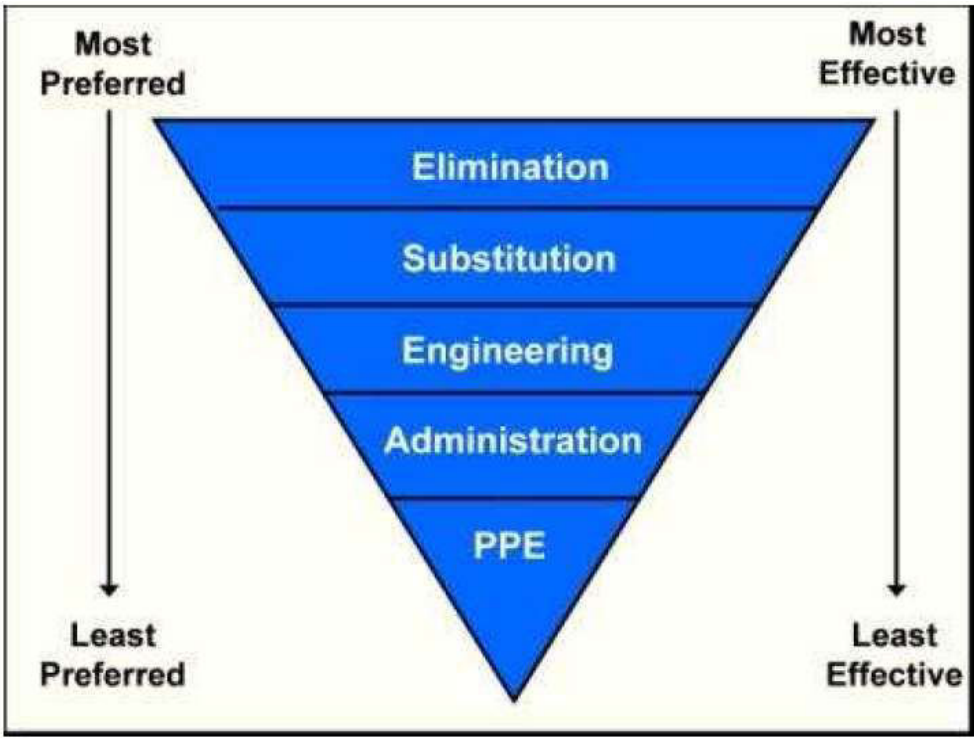


Figure 5.4: Hierarchy of controls

The potential impact resulting from each identified HSE hazard / aspect is prioritised into a HSE impact, as follows:

- Critical priority impact, and particularly all risks identified with a 'major' or 'catastrophic' consequence significantly exceed the risk acceptance threshold and require urgent and immediate action.
- A high priority impact is a risk that exceeds the risk acceptance threshold and requires proactive managements. This includes risks for which proactive actions have been taken, but further risk reduction is impracticable. Active monitoring is required.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

- A moderate priority impact is a risk that lies on the risk acceptance threshold and require active monitoring. The implementation of additional measures could be used to reduce the risk further.
- A low priority impact is a risk that is below the risk acceptance threshold and do not require active management and requires only periodic review to test its status.

This HSE risk register is updated by Rössing employees and HSE advisors annually.

Hierarchy of controls
Operational controls are measures undertaken to mitigate risk and these are classified in accordance with HSE MS hierarchy, and preference given as follows (ordered from most to least effective): Elimination, Substitution, Engineering Controls, Administrative Controls and Personal Protective Equipment (PPE) (Figure 5.4).

HSE management improvement planning
HSE improvement plans are the cornerstone of the Rössing's HSE MS. An improvement plan describes the activities or tasks to achieve the set HSE objectives and targets in terms of timetables, resources, responsibilities and reporting frequencies for the various tasks and actions required.

Information for the HSE annual policy and policy strategies review, which is used to revise objectives and targets, is based on the following:
- Results of HSE MS audits
- Feedback from annual reviews
- Relevant incidents or emergencies
- HSE performance – monthly monitoring reports from the Health, Safety and Environmental Sections
- Legal compliance and new requirements
- Results of benchmarking to ensure that Rössing operates its HSE programmes in line with international trends, as defined by RUL
- Decommissioning requirements

HSE management improvement plans are set for each high and critical priority hazard / aspect, while monitoring programmes are set for medium and serious priority hazards / aspects to ensure that these remain well managed. There is ongoing monitoring of moderate and low priority hazards / aspects to ensure they remain well managed and do not become high priority hazards / aspects.

The results of the improvement plans are reviewed annually. During the operational review process, new activities, processes and HSE hazards / aspects are identified and incorporated into the database. New hazards / aspects are prioritised and programmed where required.

The following methodology is used to set up the improvement plans:
- The mine is subdivided into work areas with responsibilities
- Activities pertinent to each work area are identified and HSE hazards / aspects arising from each activity are identified
- A description of the impact resulting from each hazard / aspect is noted for each hazard / aspect, together with a priority ranking (Low, Moderate, High and Critical)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

- Actions are identified for each high and critical priority HSE hazard / aspect to minimise the impact of that hazard / aspect on health, safety and / or the environment.
- A programme of implementation for each action is developed for incorporation into the HSE risk database, to include the following data:
    - Objective to achieve
    - The target for improvement (measurable outcomes)
    - A list of actions, to indicate the person responsible, the completion date and / or the frequency of monitoring and
    - Monitoring of progress, in accordance with the required reporting frequency

5.1.2 IMPLEMENTATION AND OPERATION

Organizational resources, accountabilities and responsibilities
The objective of this element is to ensure HSE responsibilities are allocated and accountability for the maintenance and continual improvement of HSE management is established at every level of the business.

The various appointments and their associated roles and responsibilities are central to the adoption and implementation of an efficient HSE MS.
General Managers are responsible for ensuring that the HSE Policy is implemented, that annual targets are met and that the necessary reporting procedures and structures are in place.

The HSE Manager is custodian of the HSE MS and is responsible for the implementation of health, safety and environmental strategies. The implementation of the operational HSE MS in each work area is the responsibility of the individual departmental managers. They work according to the guidelines maintained by the HSE Manager.

The HSE superintendents are the appointed management representatives of the HSE MS. As such they are responsible for the overall implementation of Rössing's HSE MS and so must co-ordinate implementation efforts throughout all departments. They liaise closely with the departmental managers, superintendents and the HSE specialists to ensure the programme is correctly managed and maintained, and facilitate and co-ordinate specialist HSE projects, should it be required. They are also responsible for reporting on the performance of the HSE MS to senior management for review.

The sectional superintendents are responsible for all HSE hazards / aspects in his / her work area and for ensuring that the objectives and targets as stipulated for each HSE hazard / aspect in his / her area are met within target dates stipulated in the relevant HSE improvement plans.

The HSE advisors *a*re responsible for monitoring the hazards / aspects and impacts of Rössing's operations to the HSE Department. They assist departmental managers and superintendents with the implementation of the HSE MS in their respective work areas. The HSE advisors facilitate the internal communication on HSE issues within Rössing, collate and interpret monitoring results, set up and update the HSE improvement plans, based on annual HSE MS reviews as aligned with the operational HSE MS, and identify training requirements.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

The HSE officers are responsible for the monitoring of those aspects within the department that are stipulated in the monitoring programme.

Training, competency and awareness

All Rössing employees and contractors have a responsibility to work in accordance with the foundations of the HSE MS. They should also possess the necessary knowledge and competence to carry out delegated tasks in compliance with the HSE MS, especially those activities that have the potential to have significant impacts. Accordingly training requirements for the various departments and work areas are undertaken.

A generic HSE induction training course is delivered to all new employees or contract workers, which deals with overarching health, safety, and environmental issues at Rössing. Task-specific training can take place in the various departments and sections on an ad hoc basis. Records of all training courses are kept on the HSE MS register.

HSE advisors raise awareness and train employees about HSE hazards / aspects, as relevant to the employee's particular work area. Follow-up awareness training is scheduled where internal audits show HSE awareness is lacking. Records of HSE training and awareness programmes are maintained in the dedicated HSE folder on the Rössing Intranet.

Supplier and contractor management

Suppliers

The Rössing HSE MS includes procedures to ensure that the procurement of equipment, materials, chemicals and services (including labour) fall within the acceptable HSE risk to the operation, as follows:

- Potential suppliers of products or services are assessed on their ability to meet HSE requirements, appropriate to the assessed risk to the operation
- Suppliers must provide Material Safety Data Sheets (MSDS) to Rössing as far as possible, prior to the delivery of such products
- Equipment, materials and chemicals are received, stored and dispatched to and within the operation in accordance with HSE requirements and
- A Procurement Standard is in place to control any liability regarding the disposal of surplus, used materials, chemicals, equipment, and hazardous waste.

Contractors

Contractors are categorised and managed according to identified HSE risks, as assessed for each contract. Where risks are identified as unacceptable, agreements are made for the contractor to manage these risks, according to the Rössing HSE standards and procedures. Each contractor must designate an on-site works manager and contract owner responsible implementing the HSE MS in relation to that contract. All contractor personnel are given appropriate orientation and induction training, including emergency response procedures, by the Rössing HSE trainers, prior to commencing work.

Documentation and document control

A procedure for document control is in place for the HSE MS to ensure that appropriate procedures are available as required, implemented and maintained. The HSE Compliance Section is responsible for the distribution, control, storage and collection of all such documents and records, which includes process information, organograms of

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

responsible personnel, internal standards and operational procedures. All HSE controlled documents are managed and disseminated via the HSE portal of the Rössing intranet. Systems and compliance audits are undertaken to verify the document control procedure.

Communication and consultation
Successful management of HSE hazards / aspects of concern are largely based on the effective communication of HSE monitoring results. The HSE MS ensures sound and effective communication and reporting structures so that hazards / aspects of concern are reported correctly, accurately and to the correct personnel. This allows for an appropriate response and the continual improvement of each of these aspects. The communication process in place also allows for changing requirements to be internalised and acted on, by way of the annual review process and by changes to the HSE policy and the HSE MS, as relevant.

Operational control
Operational controls are essential for the management of HSE risks associated with Rössing's work activities. This is achieved through the RUL Performance Standards (Figure 5.1), as well as other mandated or necessary risk treatment processes to control the risk to *as low as reasonably achievable* (ALARA). Procedural documents for specific operations and activities are developed on which management and mitigation measures are based. Performance against the operational procedures is monitored and non-conformances are reported so that area owners can rectify non-conformances by means of corrective actions.

Appendix 3 tabularises all procedures in operation at August 2024.

Management of change
Change is regarded as any alteration to the facilities, equipment, procedures or operating conditions outside the intent of current established parameters. The HSE MS includes a Management of Change procedure. The goal is to ensure that proposed temporary or permanent changes will not result in increased risk to health, safety, environment, financial systems and operations processes.

The Management of Change procedure requires that:

- all affected personnel are notified of any intended or actual change that poses a potential risk
- all affected personnel are fully aware of any possible dangers associated with the proposed and actual changes
- all affected personnel are informed of how to handle any adverse situations that may arise and
- required paper work is completed to record any temporary or permanent change.

The change owner, as the individual assigned to implement the change, is responsible for ensuring that a change is co-ordinated and all affected personnel are fully informed. Change is then implemented throughout the relevant area and line managers as appropriate, with required documentation to record measures for auditing purposes.

Business resilience and recovery
Through the Business Resilience and Recovery Programme (BRRP) Rössing ensures that the appropriate level of resources (plans, procedures, facilities, equipment and

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

trained personnel) are available for an effective response to control and recover from disaster and emergency situations.

Rössing has procedures in place for responding to emergencies and unexpected and uncontrollable situations. Business resilience and recovery procedures are developed on an ongoing basis, based on a comprehensive risk assessment of the operations. Emergency procedures are practised regularly across the mine, as initiated by the Fire and Emergency Response Section.

5.1.3 CHECKING AND CORRECTIVE ACTION

Measuring and monitoring

HSE monitoring programmes are implemented to track workplace occupational hygiene and environmental performance. Monitoring of HSE hazards / aspects is undertaken by the HSE advisors, who have the following responsibilities:

- Collect and maintain all HSE records
- Develop techniques and procedures for monitoring
- Define standards
- Determine monitoring equipment, instrument control and calibration and
- Communicate results of all monitoring to HSE Superintendents, who reports performance on a monthly basis
- Compile monthly, quarterly and annual Health, Safety, Environment and Communities reports.

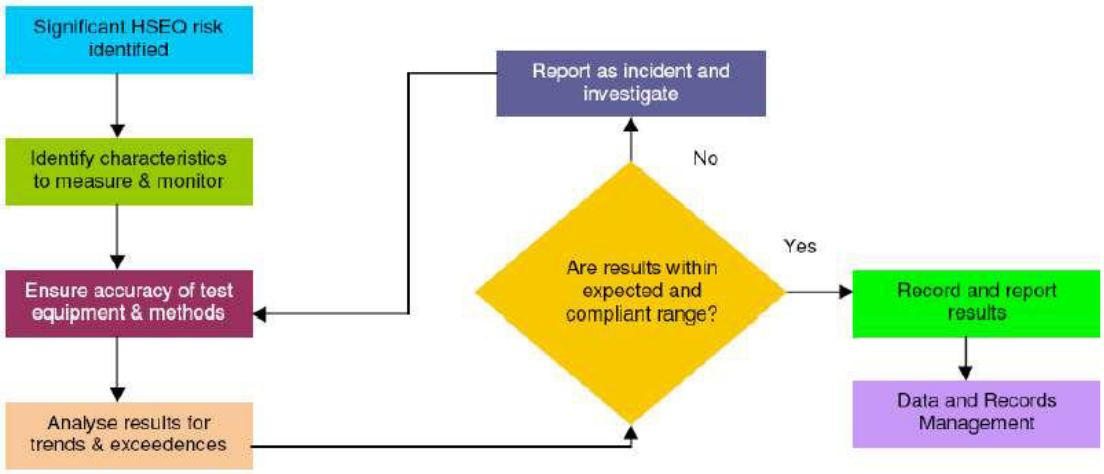


Figure 5.5: HSE monitoring work flow

Results from monitoring (Figure 5.5) are analysed on a regular basis to:

- Outline trends and potential exceedances of operating criteria (e.g. legal exposure, emission standards)
- Assess control designs and their success
- Identify the needs for corrective actions and improvement opportunities
- Reflect the level of achievement of objectives and targets, and
- Record, report and investigate exceedances.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

Non-conformances, incidents and action management
The departmental managers are responsible for non-compliance reporting and investigation, allocation of resources for corrective action, and for ensuring the success of the corrective actions. Action is required when one of the following occurs:

- An HSE incident is reported;
- Monitoring (or auditing) has identified negative impacts;
- Non-compliance with Rössing standards and / or legal requirements occurs;
- Deviations from objectives and targets occur, and
- A complaint is received from a member of the public concerning any HSE hazard / aspect.

While HSE advisors can assist and facilitate implementation of corrective and/or preventive actions to minimise or prevent any HSE impact, the responsibility for the investigation and remedial actions rest with line management.

Reporting on HSE issues is integrated with existing reporting on operational issues, at monthly intervals. The HSE advisors attend departmental meetings to report on any non-conformance and corrective actions that were carried out or which are still outstanding.

Data and records management
Data relating to HSE management monitoring surveys conducted around the mine by the HSE advisors are stored in the HSE system. HSE records include:

- Collected HSE monitoring data
- Instrument calibration certificates
- Audit findings reports, and
- Corrective actions stemming from HSE incidents and non-conformances

Audit findings, HSE incidents, HSE non-conformance reports, as well as any other relevant correspondence (e-mails, photographs etc.) are stored either electronically or as hardcopies in the HSE filing system. The HSE improvement plans are documented in the electronic support system Business Solution and actions stipulated under an HSE improvement plan in the Business Solution as a result of an HSE incident are cross-referenced to the incident number or audit report number.

Performance assessment and auditing
The Rössing Audit Programme which allows for periodic evaluation has the following objectives:

- Determine / verify compliance with Namibian and other relevant international legislative frameworks
- Determine / verify compliance with HSE policies and standards
- Identify HSE hazards / risks
- Minimise potential liabilities by identifying areas where corrective action is required
- Assess the HSE MS, and
- Assess HSE performance against predetermined goals and targets.

HSE audits, as well as internal system compliance and technical audits are conducted according to prescribed procedures. The audit finding reports are stored in the relevant HSE sections. The HSE Manager ensures that audits occur within a year cycle and that

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

all audit findings detailed in the audit reports are addressed. The HSE advisors sign off audit findings once audit deviations noted in the relevant audit report are satisfactorily addressed.

Rossing appointed global certification provider audits against ISO14001, ISO 45001 and the HSE MS standard and issues certificates relevant to the defined scope of Rössing's business or management system.

Rössing has received ISO14001 certification the first time in February 2001. Appendix 4 provides a summary of the various assurance approaches followed at Rössing.

5.1.4 REVIEW

Management review
The objective of the management review is to ensure the effectiveness of the HSE MS through evaluating the need for changes and establish actions to improve the system, audits and resources.

The management review is undertaken annually to ensure the effectiveness of the system and evaluates the need for changes and establishes actions to improve the system.

5.2 HSE MANAGEMENT PROGRAMMES

Because of their complexity, the management of some HSE aspects requires a multi-dimensional, multi-year approach. The risks and liabilities of these aspects cross-cut over many terrains, involving many departments and operational activities, and require strategic and specialized management programmes. Examples include radioactivity, air quality, water, biodiversity, rehabilitation, mineral waste and non-mineral waste management. These management programmes are discussed below.

5.2.1 MANAGEMENT OF RADIATION[69]

Sources of radiation in uranium mining
The mining and processing of ores containing uranium and thorium can give rise to exposure to ionising radiation in various forms to both employees and to members of the general public living in the vicinity of the mine. In order to control the exposure to ionising radiation, all aspects of radiation protection and monitoring need to be addressed.

Radiation levels at Rössing are low compared with some other uranium mining operations in the world. This is due to the low-grade ore, and to a lesser extent due to the favourable uranium: thorium ratio of the ore; the ratio of uranium to thorium in the ore is about 6 to 1. Rössing ore contains an average of 360 g/t of uranium and environmental radioactivity is therefore low. The total radioactivity per gram of ore is typically 60 Bq, originating from uranium and thorium and their radioactive decay

[69] Information relevant to this section was obtained from the Rössing Closure Management Plan (2011) and Rössing Radiation Management Plan (2012)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

products. Uranium is extracted from the ore using an open-pit mining, crushing, milling and metallurgical extraction process.

After milling, the radioactivity is concentrated by the metallurgical extraction process. Radioactivity levels along the production process range from 60 Bq/g in the ore to 380 Bq/g in OK liquor. The majority of the radioactivity entering the processing plant ultimately ends up in Rössing's commercial product – U_3O_8 – at levels of about 21,000 Bq/g. The remaining radioactivity from the ore, which is associated with the rest of the daughter radio-nuclides in the uranium decay chain and those in the thorium series, is deposited to the tailings impoundment, along with other mineral waste. The radioactivity level in the tailings is typically 50 Bq/g.

The processing of bulk uranium containing materials also leads to the formation of radioactive scale on equipment within vessels and pipes. The radioactivity level of this scale can reach up to 40,000 Bq/g. Radioactivity from the above materials and process chemicals can lead to exposure to workers, and/or the contamination of the soil, air or water in the vicinity, and will require remedial measures during operation and at closure. Radioactivity also occurs in dust generated by the mining and milling process which is dispersed by wind. Finally, the extraction and size reduction of ore results in an increase of radon concentrations in the environment, both within the borders of the mine site and beyond.

Most of the radiation occurring at the Rössing mine originates from the uranium, actinium and thorium decay chains. Because of the low ore grades, radiation levels in most areas of the mine are low, except for the areas in the plant where concentration of uranium takes place. Figure 5.6 shows mining related sources of radioactivity in purple colour.

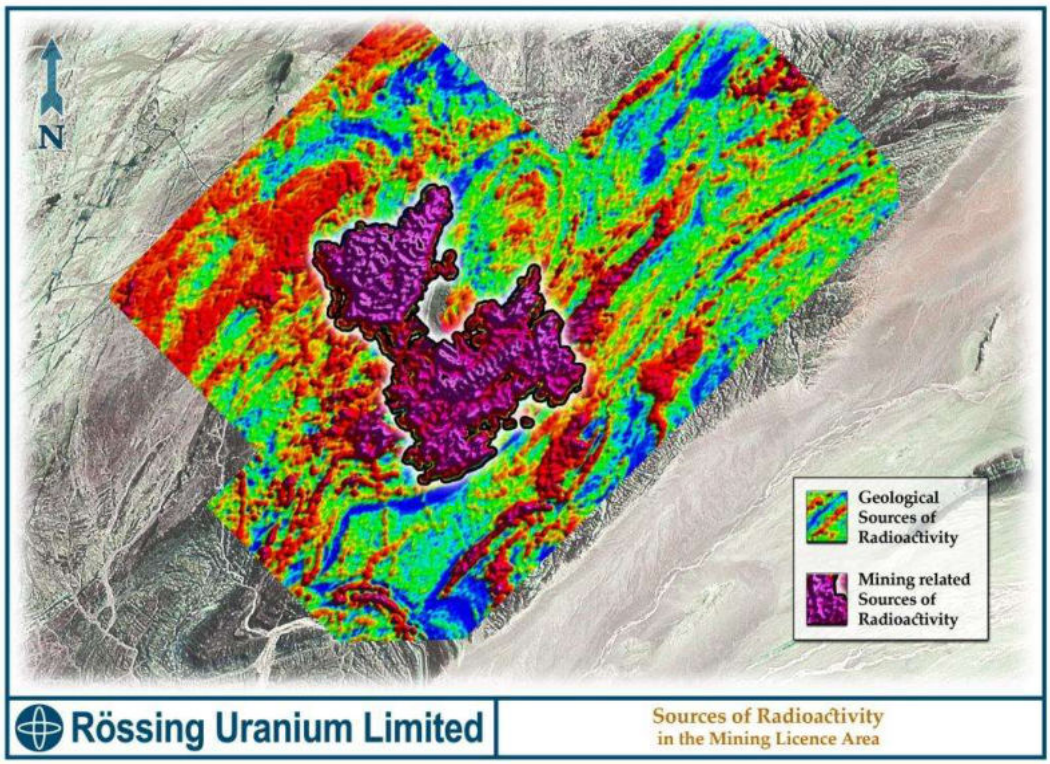


Figure 5.6: Sources of radioactivity at Rössing

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

Radioactivity in excess of the natural background radiation specific to the area enters the environment through the redistribution of rock materials by mining out the open pit, placing material on rock dumps and placing tailings into the tailings repository.

Long-lived radioactive dust comprises the inhalable portion of dust containing the long-lived radio-nuclides of the uranium, thorium and actinium decay chains. Sources at Rössing include

- The open pit and mining and blasting activities therein (ore dust)
- Dust roads, especially when covered with tailings sand (ore or tailings dust)
- The rock dumps, coarse ore and fine ore crusher dust plumes (ore dust)
- Areas of coarse and medium grained tailings on the tailings facility, the tailings dust plume, areas of silt and precipitated salts on the tailings facility and areas of seepage precipitate between the toe of the tailings facility and the seepage dam (tailings dust)
- Stack emissions from the FPR, if not adequately controlled, and the FPR area itself (uranium dust)

Radon-222 is a radioactive gas which is a member of the uranium decay chain. Sources of radon at Rössing include

- Ore body (open pit)
- Ore stockpiles (coarse ore stockpile, fine ore stockpile)
- Waste dumps and low grade ore stockpiles
- Tailings area
- Empty tanks and pipes with radon scales (jarosite)
- Crushing circuit

Since 1989, Rössing has measured radon exhalation rates from various radon sources. A comprehensive data set of radon flux measurements has been developed. The radon sources measured include:

- The open pit shell;
- The waste rock and low grade ore stockpiles;
- The crushing circuit, including the coarse and fine ore stockpiles;
- The tailings impoundment;
- Contaminated areas around the plant; and
- Background locations in the surrounding environment, including localized areas containing enhanced natural radioactivity levels.

Measured radon concentrations across the mine site range from background (50 Bq/m^3) to 350 Bq/m^3 in some areas of the pit and tailings.

Radiation exposure pathways

The path followed by radio-nuclides from their source via air, soil, water, and food, to humans, animals, or the environment is called the exposure pathway. The exposure of humans to radiation can occur directly from the outside (external), or internally through ingestion or inhalation. The most relevant pathways for the exposure to ionising radiation as a result of mining activities are as follows:

- Direct exposure to external gamma radiation
- Atmospheric pathway: The inhalation of dust containing radio-nuclides
- Atmospheric pathway: The inhalation of radon and radon progeny

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

- Aquatic pathway: Radioactivity can enter the environment via the aquatic pathway, in the form of seepage water that contains dissolved radio-nuclide salts. Seepage emanates from the tailings facility as surface water flow and groundwater flow in fractured rock aquifers and alluvial aquifers. If uncontrolled, the seepage could enter the Khan River and reach downstream users in the lower Swakop River. Active seepage control measures are in place to prevent this from happening.
- Ingestion: Radio-nuclides can be ingested directly, or swallowed after inhalation of dust.

Legal requirements

In terms of the Atomic Energy and Radiation Act, 2005 (No. 5 of 2005) in Namibia, regulation of radiation exposure falls under the jurisdiction of the National Radiation Protection Authority (NRPA). The NRPA is currently situated within the Ministry of Health and Social Services, but it may eventually be an independent body. In addition, the Atomic Energy Board advises the Minister and the NRPA on radiation protection matters. The Act is implemented in the form of the *Regulations for Protection against Ionising Radiation and for the Safety of Radiation Sources*, which were gazetted in November 2011. The NRPA was established in 2009. Since then, mines have been required to compile and implement a Radiation Management Plan according to guidelines supplied by the NRPA. The Radiation Management Plan is approved by the NRPA and compliance with the Regulations is audited annually. In addition, each operation is mandated to report its uranium exports, transport of radioactive materials, disposal of radioactive waste and worker exposures to the NRPA on a six-monthly basis. Furthermore, the transport, storage and/or possession of radioactive materials, as defined in the Regulations, are subject to regulatory control from the NRPA.

The national radiation protection legislation is based on the internationally accepted principles recommended by the International Commission on Radiological Protection (ICRP), which are implemented in the form of Regulations by the International Atomic Energy Agency (IAEA). The ICRP guidelines include the principles of optimisation[70], limitation[71] and justification[72], which form the basis for the discipline of radiation protection. The Rio Tinto Health Standard B5, which deals with radiation protection, sets additional goals for optimising radiation protection in the workplace and for the public.

In addition to national legislation, Rössing follows the IAEA approach to radiation protection, which aims to reduce exposure to maximally exposed members of the public ('critical groups') to below the recommended and internationally accepted International Commission on Radiological Protection (ICRP) public dose limit and constraint. The public dose limit is set at 1 mSv per annum, with all exposures kept ALARA. In addition, the public dose constraint is used to ensure that exposure from all operations in the area combined, and to any specific critical group, is limited to a total of 1 mSv per annum. A reasonable starting point, therefore, is a public dose constraint of 0.3 mSv per annum, which would assume the unlikely situation of three operations contributing radiation exposures to a common critical group. A public dose assessment performed in 2020 has demonstrated that public exposure from the mine's radioactive emissions is well below

[70] Radiation doses and risks should be kept as low as reasonably achievable (ALARA), economic and social factors being taken into account.
[71] The exposure of individuals should be subject to dose or risk limits, above which the radiation risk would be deemed unacceptable.
[72] No practice involving exposure to radiation should be adopted unless it produces a net benefit to those exposed or to society generally.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

applicable limits, i.e. below both the public dose limit (1 mSv per annum) and also below the public dose constraint (set at 0.3 mSv per annum).[73]

Radiation Management Plan

The objective of Rössing's Radiation Management Plan (JK20/MMP/001) is to ensure that exposures to ionising radiation will not give rise to unacceptable levels of risk, and that the sources of such exposures are identified, quantified, controlled and minimised.

The plan describes the occupational radiation protection programme, details the public exposure monitoring programme, the waste management programme and emergency preparedness and response programme, and provides a product transport plan. It also gives a comprehensive summary of the risk-assessments done, including all impact assessments, public dose assessments and closure management plans.

Occupational Radiation Protection

Measures for limiting and mitigating occupational radiation exposures include

- Radioprotection zoning (areas with a potential exposure exceeding 5 mSv are zoned controlled radiation areas, are fenced and access restricted, and workers in this area are monitored continuously)
- Occupancy limitation (in areas with a dose rate potentially exceeding 10 µSv per hour, occupancy limitation is applied to limit the maximum daily dose to below 80 µSv).
- Ventilation (ventilation is an effective measure to reduce the concentration of radon decay products in air, hence reducing the potential internal exposure from radon decay products)
- Dust or fume control measures (dust control measures include wetting or stabilisation of roads, covering of dust generating processes such as crushing and ore storage areas)
- Personal hygiene facilities (clean change rooms and lunch areas are provided, care is taken to avoid contamination of areas outside the mine by laundering contaminated clothing on site)
- Contamination control (items leaving site undergo a comprehensive contamination inspection routine before they are cleared to leave site. This prevents contaminated materials, such as scrap and tools, from leaving site and contributing to the spread of contamination)
- Administrative controls (safe work procedures)
- Training (awareness raising and skills improvement initiatives are offered to employees and to identified public stakeholders such as police officers, teachers, municipal workers, journalists, emergency responders and many more)
- Personal protection (PPE, in particular respiratory protection where needed) together with clean shaven policy.
- Emergency plan and drills

The effectiveness of employee radiation protection controls are monitored by way of personal and area radiation monitoring programmes:

- Continuous personal sampling of external radiation for all radiation workers. Thermo luminescent dosimeters (TLD) are used for this purpose. The wearing period is 12 weeks and TLD's are analysed and serviced by the South African Bureau of Standards (SABS).

[73] Aurecon, (2011)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

- Random personal sampling of external radiation for all exposure groups. Electronic personal dosimeters are used for this purpose. Two models are presently in use, the Thermo Scientific EPD-G and the Tracerco PED.
- Random personal sampling of internal exposure from radon progeny. The SARAD DosemanPro is used for this purpose, a highly effective and user friendly direct-reading progeny measuring device.
- Random personal sampling of internal exposure from the inhalation of radioactive dust. The SARAD MyRIAM is used for this purpose, a direct reading instrument which uses in internal pump to collect dust on a filter, which is subsequently analysed for its radioactive content. A dose can be read directly from the instrument.
- Monthly urine bioassays are taken for all designated radiation workers to exclude any potential internal contamination or workers with uranium.
- Monthly pregnancy testing in female plant workers ensures timely removal of pregnant employees from areas with annual radiation exposures exceeding 1 mSv per annum.
- Air quality on site is monitored by using high-volume samplers and PM10 air samplers. Dust samples are regularly submitted for radionuclide analysis.
- Air quality in the FPR area is monitored continuously by using an Trolex Air XD Real-time Dust Monitor with real time reporting to the Central Processing Control (CPC) room.
- Comprehensive radiation clearance procedures for tools and equipment ensure any cross-contamination between contaminated and uncontaminated areas occurs on site.

Public Radiation Protection

The public dose limit is 1 mSv per annum. However, the maximum public dose assessed is significantly below this, at a maximum of less than 0.3 mSv per annum and down to very low exposures. It is therefore not possible to directly measure public exposure by issuing dosimeters to members of a critical group, as the measurement signal (the dose due to mining activities) will be swamped by the much larger measurement noise (natural background radiation, at approximately 2 mSv per annum).

The public dose assessment therefore builds on the principle of (see Figure 5.7)

1. Identification of radiation source
2. Identification of exposure pathway
3. Identification of critical group for this exposure pathway
4. Assessment of maximum exposure from identified source to identified critical group along pathway
5. Combination of all relevant pathways for each critical group

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

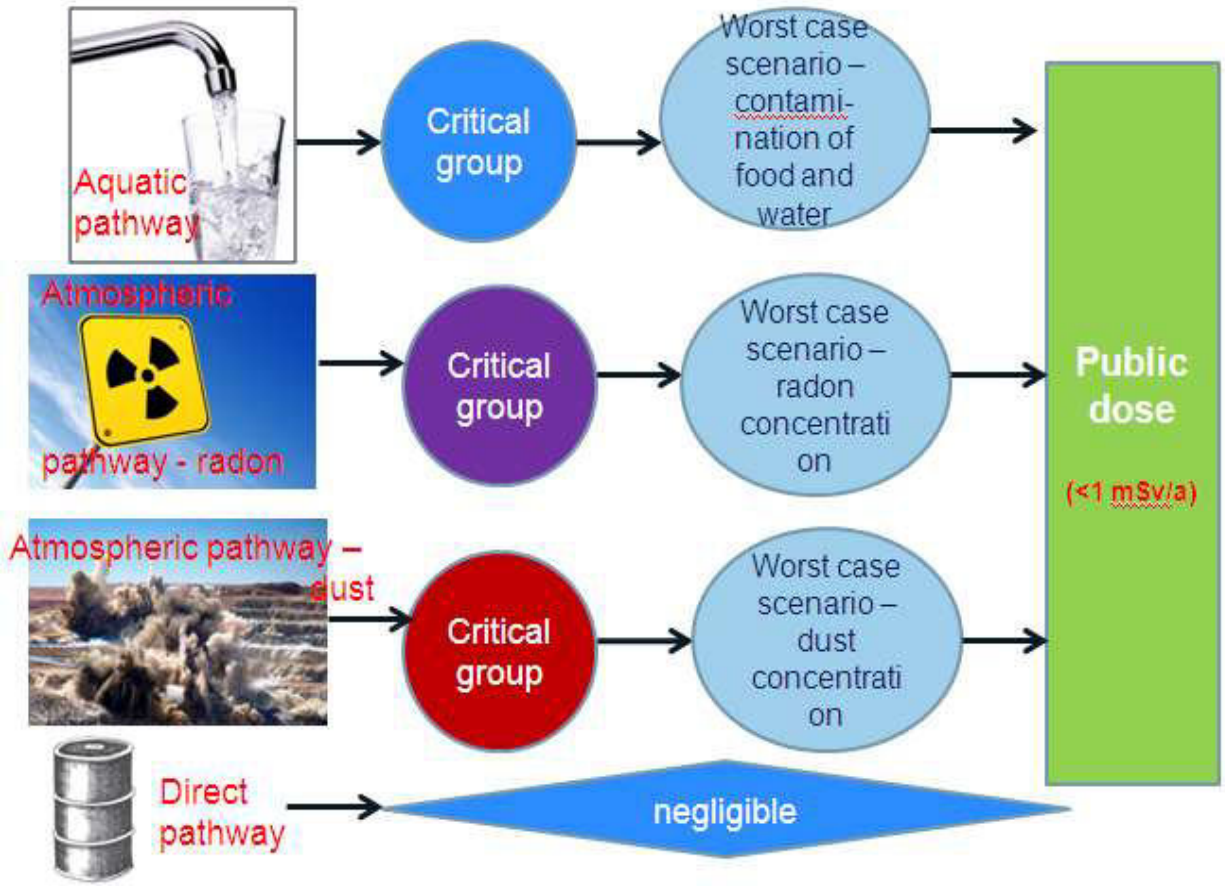


Figure 5.7: Exposure pathways and critical groups for public dose assessments

Aquatic pathway

Pollution of groundwater can occur through

- Dissolution and leaching into groundwater of radionuclides in tailings, ore and waste dumps
- Underground migration of seepage from tailings
- Deposit of radioactive materials on soil surfaces and subsequent dissolution in groundwater.

Radionuclides in groundwater can lead to the uptake of radioactive material through direct water consumption, or through the consumption of crops which have been irrigated with the groundwater, or by the ingestion of animal products from animals using the groundwater as drinking water. Assuming a groundwater concentration of radionuclides, the following processes are relevant:

- Irrigation of crops, subsequent crop ingestion by humans
- Irrigation of crops, ingestion of crops by animals, subsequent ingestion of animal products by humans
- Water ingestion by humans
- Irrigation of soil, soil uptake by humans and animals
- Irrigation of soil, direct irradiation of humans from soil.

A part of the tailings solution discharged to the tailings dam infiltrates into the tailings pile and either remains entrained around the particles or percolates through and

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

emerges at the toe of the dam. The toe seepage is mostly collected in trenches, pumped to Lake Geoff. Overflow from the trenches is channelled on surface to the seepage dam from where it is recycled. Water that seeps into the bedrock under the dam is recovered by a collection of seepage control systems. Seepage recovered is re-entered into the plant process as a water saving measure. Monitoring of seepage control installations on the tailings facility is carried out daily.

Water quality is monitored by using a collection of monitoring boreholes located around the site and in the Khan aquifer, the aspect is discussed in section 5.2.3.

Atmospheric pathway – radon
For an assessment of public dose as a result of radon emissions from mine sites, the following information is required:

- Radon exhalation rates at various sources
- Meteorological data (wind speeds and directions)
- Local topology in the area surrounding the radon exhalation

Detailed atmospheric dispersion modelling is required to fully evaluate the distribution of radon from its sources to areas of concern, such as towns and villages, and also for impacts of dust containing long-lived radioactive nuclides.

The modelling exercise is supplemented with an extensive radon measuring programme, covering a 16 by 16 km grid across the mine site. This grid covers both areas affected by mining and background and hence serves as a confirmation and check of the radon dispersion models.

Atmospheric pathway – dust
For an assessment of the dose to humans resulting from fugitive dust, the following factors have to be considered:

- Sources of dust
- Chemical composition and particle size distribution of dust
- Radionuclide content of dust
- Meteorological conditions
- Age distribution of critical groups
- Rate of uptake of radionuclides by different crops from deposited dust
- Percentage of use of own grown crops versus crops imported from elsewhere
- Percentage of animals and animal products consumed versus animal products imported
- Percentage of milk and milk products produced by own cattle, versus imported products

Dust collected at the locations for critical groups is analysed for radionuclide concentration, in Bq/g. Dust samples are sent regularly to an accredited laboratory for an analysis of the radionuclide content in the inhalable portion of the dust.

Records
All records relevant to the employee and public exposure monitoring programme are kept indefinitely, in a format that allows the presentation of yearly statistical information about the monitoring processes.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

Industrial radiation sources
All sealed radioactive sources (industrial gauges) previously stored in secure bunkers were removed for offsite disposal in RSA by NECSA with approval from the NRPA. Safety and security of sealed sources is detailed in the Radiation Management Plan.

Emergency preparedness and response
Actions taken in an event of a uranium oxide spill are detailed as part of Rössing's BRRP procedure. Valid emergency information sheets accompany the consignment throughout the duration of the voyage which provides correct emergency actions to the relevant parties. Formal and legal regulations are in place in the countries through which Rössing's product containers are transported and clearly address responsibilities and accountabilities regarding emergency response and clean-up. A drill on the action to be taken during an emergency is practiced at least once a year.

Transport
Rössing's final product, U_3O_8 is listed as a Class 7 hazardous material, with a United Nations hazardous material number of 2912 (radioactive material, low specific activity LSA-1 non-fissile or fissile excepted). The hazardous properties of U_3O_8 are relatively low compared to other radioactive materials and most hazardous materials in general. Transportation of U_3O_8 is governed by the IAEA Regulations for the Safe Transport of Radioactive Material[74] as well as national and international standards and regulations. These standards and regulations stipulate the responsibilities of shippers and carriers. In many jurisdictions, carriers must be licensed to carry nuclear material.

U_3O_8 is packed in drums steel drums and sealed. All cleaning, marking, labelling and monitoring of product drums and containers are done following the IAEA Regulations for the Safe Transport of Radioactive Material[75]. Employees working with the drums and close to the drums during packing, cleaning and monitoring, are monitored for external radiation dose.

Uranium ore samples are sometimes transported to laboratories off site, either within Namibia or across its borders.

Ore samples containing uranium, with an activity of 1 Bq/g (from uranium alone when ore grade is > 40 ppm), or with a total activity of 1,000 Bq or more, may only be transported if permitted by the National Nuclear Regulatory Authority. Packaging and disposal of ore is furthermore accompanied by required documents and subjected to internal control measures.

5.2.1. MANAGEMENT OF AIR QUALITY

Air quality management at Rössing is guided by an Air Quality Management Plan (JE20/MMP/004). All air emissions are listed in an inventory (JE65/STD/002) and all air quality standards applied at Rössing are documented (JE65/STD/001).

The current air quality monitoring program is based on the original one established during the pioneering years at Rössing. In the meantime the **E1 (**Air quality, noise control

[74] IAEA, (2005)
[75] Ibid

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

and Greenhouse gases (GHG)) guides the current operations. Concerns about air quality – then and now – are based on two uncertainties: The relationship between air quality and employees' health; and concerns about impacts on the ambient environment[76].

Measurements are taken in order to ensure that exposure levels of employees do not exceed prescribed occupational limits and to ensure that existing and newly introduced controls efficiently detect differentiations as a result of process changes. Informed risk-based decisions, related to the level of control, are introduced for the various exposure levels thus, and the objective is to optimise performance in terms of emission reduction and control measures.

Since its inception meteorological data is collected at Rössing in order to characterise the ambient environment and to determine the dilution and dispersion of atmospheric contaminants. There are four weather stations that are in operation, located at Point Bill, Hill Jim (open pit) and the tailings facility on site, and in Arandis at the valve house.
The Rössing air quality hazard assessment was initially conducted during a series of workshops in March 1993. During the workshops the nature of the airborne emissions, the mechanisms that result in the release of the airborne contaminants and the control systems to limit these releases were identified.

An air quality risk assessment for Rössing was conducted in 1998. It was identified that SO_2 (from the former acid plant), total dust and lodged silica from tailing dust were the air-borne contaminants with the most significant impacts. A study, which assessed hazards, exposure, pathway, intake and toxicity, was completed in 1998[77]. The study also applied the background and philosophy of risk in setting environmental control thresholds for use at Rössing. More recently an air emission risk screening was conducted and the risks at Rössing were classified as low. Although air quality risks are thus characterized, there is a need to update the risks to reflect current operations.

Rössing's documented dust inventory is based on the air quality risk assessment of 1998. Models such as the US-EPA recommended Fugitive Dust Model, AirDos EPA, Industrial Source Complex Long Term Model and Industrial Source Complex Short Term Model were used in the past to determine fugitive dust inventory sources at Rössing according to area, type and dust generating activity. The inventory was amended with calculated PM10 and Total Particulate Matter (TPM) emissions from the Air Quality Impact Assessment conducted in 2007 as part of the proposed Rössing expansions. Fugitive dust emissions were quantified during this assessment using the most recently United States Environmental Protection Agency's approved regulatory model, the AERMET/AERMOD suite of models.

[76] The ambient environment, which may be adversely affected by radiation, dust and gases emanating from Rössing and its related activities, is defined as general public, visitors to Rössing, the residents of Arandis and the fauna and flora surrounding the mine. It is not only human health that can be adversely affected by impurities in the air: the fall-out of heavy metals onto soil and foliage of plants also results in adverse impacts. The metals are either taken up directly from the deposits on the foliage, or it is taken up by plants and concentrated in the leaves of the plants. This can result in the bio-accumulation of heavy metals and radio-nuclides in the food chain, with severe adverse impacts in some cases. On the other hand, greenhouse gases have a knock-on effect on (global) atmospheric processes.
[77] Metago Environmental Engineers, (1998)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

It is acknowledged that the operations at Rössing can result in the generation of dust, and in combination with natural occurring background dust levels, dust can have adverse impacts on the surroundings. The Rössing Dust Management Plan intends to provide a consistent approach for dust management at the mine, with the aim to continuously reduce levels of fugitive dust. Specifically, the plan contains information about dust inventories, risk assessment measures and practices to minimize the generation of dust, monitoring, plumes, performance criteria, communication and reporting.

Detailed sources of dust and particulate emissions at Rössing are identified and documented. The main sources and activities that contribute to dust emissions are drilling and blasting; loading and hauling; transfer, crushing, conveying and storage of ore; operations (including vehicle movement) and exposure to wind[78]. Currently comprehensive air quality monitoring activities take place at various locations on the mine site. Monitoring includes measuring PM10 dust, for example (Dust fallout sampling procedures JE50/PIN/003; PM10 monitoring JE50/PIN/007; Multi-vertical dust sampling JE50/PIN/006).

The impact of the fugitive dust emissions on the quality of the air is determined from dust fall out depositions measurements (including multi-vertical samplers) and monthly estimates. Multi-vertical dust samplers at the edge of the tailings facility collect dust and sand particles that are blown westwards off the tailings facility. Readings from the multi-vertical sampler around the tailings facility during Bergwind conditions is estimated annually. The PM10 dust sampler is situated at four (4) places around the mine, at the Arandis residential area, mine Boundary on the South westerly side of the mine, Tailings west and at the Contractor Management Centre (CMC). PM10 dust samplers are used to determine the level of dust in the air. The primary concern is to test to see how much dust under 10 microns in size is airborne, as dust particles this size or smaller can cause damage to human health.

Rössing is using the ambient air quality standards based on Schedule 2 of the South African National Environmental Management Act: Air Quality Act (Act No.39 of 2004), as a reference to set criteria. In keeping with the current best practise, Rössing will also adopt the new South African ambient air quality standards as provided by the South African Government Notice (No.32816 Vol. 534). Details are set (see Table 5.4 and 5.5).

Table 5.4: Particulate matter (PM10)

Type	24 hours average	Annual average	Comment
Ambient air concentration	75 µg/m^3	40 µg/m^3	Frequency of exceedance for a 24-hrs average not more than 4 times

For fall-out dust depositions, Rössing adopted the South African method of evaluation as given in Table 5.6. The1,200 mg/m²/day threshold level is used as an action level and in the event that on-site dust fall-out exceeds this threshold, the specific causes of high dust fall-out should be investigated and remedial steps taken. In Arandis a 600 mg/m²/ day will trigger an investigation and remedial steps.

[78] Aurecon, (2011)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

Dust at Rössing is managed in various ways. Water is used to suppress dust on gravel roads. In addition, ligno-sulphonate, a chemical binder, is sprayed onto some road surfaces. A mobile road sweeper is used on tarred surfaces to remove dust and air-borne debris. At the crushers dust control entails preventative maintenance and frequent wash downs. Engineering controls such as dust extractors (at the crushers), scrubbers and baghouses (at FPR) are also in place.

Table 5.5: Dust fall-out range

Restriction Area	**Dust Fall Rate (D) ($mg/m^2/day$, 30-day average**	**Permitted frequency of exceeding Dust Fall Rate**
RESIDENTIAL	D<600	Two within a year, not sequential months
INDUSTRIAL	600<D<1200	Two within a year, not sequential months

Dust fall-out is monitored and recorded internally - monthly on site and annually to CNNC - to reduce dust through innovative controls. The impacts of blast dust are reduced by considering wind direction, prior to blast events, in order to limit dispersal and deposition. In addition, the blast areas are soaked with water before blasting. At the tailings facility, windrows are created to break prevalent air flow over the paddies. Table 5.6 shows some of the dust control measures that are applied at Rössing.

Dried-out tailings and seepage deposits may represent a major source of wind-blown dust. As a remediation option for fugitive dust from the tailings facility after mine closure, covering the entire tailings facility by a layer of rock is presented. Seepage areas, which also present a dust hazard after drying up, can be covered with rocks after mine closure too.

It was observed that biological soil crusts at Rössing are present in a somewhat reduced form compared to their occurrence in nearby habitats[79]. The suggestion is that the reduced form of biological soil crusts found at Rössing may be the result of fine layers of dust coating rocks and stones reducing the natural flow of condensed moisture to the hypolithic environment, resulting in a drier microclimate non-conducive to biological soil crust formation. A reduction in biological soil crusts could reduce the productivity of the desert habitats - biological soil crusts are known to be very active in fixing and remobilising carbon and nitrogen in desert soils[80]. Further research and monitoring is required to fully understand the likelihood and consequence of the impact of dust on the formation of biological soil crusts.

[79] EEAN, (2008)
[80] Belnap, (2001); Evans and Lange,(2001)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

Table 5.6: Dust control measures at Rössing

Source	Dust control measures
	Open pit
Haul and other roads	Spray with seepage water Spray with ligno-sulphonate Dust-A-Side Restricted speed limit (40 km/h)
Muck piles	Spray with water
	Waste rock dumps
Tops	Spray with water
	Blasting
Large blast	Wet drilling Consider wind direction
Small blast	Wet drilling
	Plant
Primary crusher	Spray at tipping point and dust collectors
Coarse ore stockpile	Spray at tipping point
Conveyors	Partially covered
Fine crushing	Regular wash-downs Dust collectors
	Tailings facility
Paddocks	Wind-breaks, e.g. wind rows
Roads	Spray with seepage water Spray with lingo-sulphonate Regular maintenance (road grading) Restricted speed limit (40km/h)
	Mine-wide
Roads	Road sweeper, Restricted speed limit (60 km/h)

It was also observed that the abundance and diversity of solifuges is exceptionally low at Rössing and the abundance and diversity of spiders is relatively lower than expected[81]. The Central Namib is a global hotspot of solifuge diversity so this paucity of solifuges and arachnids is likely to have a causal link. Dust attributable to operations at Rössing may reduce the availability of shelter and refuge for invertebrates. Coupled with dust related reduction in plant productivity, the reduced form of biological soil crusts and a reduction in moisture in the hypolithic environment, dust generation attributable to Rössing may have an impact on solifuge and arachnid mortality outside of the area of direct disturbance.

Invertebrate data collected from Rössing is restricted in terms of comparisons and identifying landscape-based patterns and some taxa are known only from one specimen trapped during survey work by the State Museum in the 1980s. To fully understand the likelihood and consequence of the impact of dust on solifuges and arachnids, quantified research and monitoring is required to a) establish a baseline of invertebrate abundance and diversity and b) fully understand the impact that dust has on invertebrate mortality.

[81] EEAN, (2008)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

Efforts to stabilise global atmospheric concentrations of greenhouse gas (GHG) at lower levels is a priority, as a result, Rössing measures GHG emissions too which requires Rössing to:

- Develop and maintain detailed knowledge of energy use, GHG emissions and saving / abatement opportunities at its operations;
- Identify and assess GHG related risks and opportunities for the business;
- Develop a plan and targets that drive improvements in energy efficiency and GHG emissions.
- Implement programmes that maintain energy efficiency and GHG emission reductions

Current measuring of impacts that can contribute to climate change includes the monitoring of GHG emissions and the monitoring of energy use at Rössing.

The intensity of emissions is reported per unit of product target, according to an operation procedure (JE65/PRC/001). Sources of GHG emissions include electricity and fuel consumption transport of reagents and uranium, blasting (explosives), waste (sewage, rubbish disposal and landfill) extraction and processing.

GHG emissions intensity per unit of product target, the so called Tier 1 target, is reported monthly and annually. The Tier 2 target is an internal target that calculates energy use per unit of "*work done*". To calculate the GHG equivalent of the amount of energy used, the total energy consumed is converted to CO_2 per tonne of U_3O_8 produced. The figures are used to drive energy efficiency and emission reductions on site, and are reported monthly and annually.

Electricity at Rössing is supplied by NamPower. It is a mix of 58% hydro (from the Ruacana plant in Namibia) and 42% Eskom (mainly from coal power stations in South Africa) power. Taking into consideration the electricity makeup, factors were developed for conversion of electricity to energy and GHG and these are 3.6 (GJ/MWH) and 0.529 (t CO_2-e/MWH) respectively. These factors need to be verified from time to time. Sub-metering of electricity is done on all working areas at Rössing in order to calculate the contribution of each component to the total energy consumption. The electrical feed to the various working areas are monitored by an online monitoring system which is used as inputs to an energy efficiency analysis and to track improvements.

Fuel, mainly diesel, is consumed by drilling, hauling, blasting and support equipment and vehicles. Diesel is also used for roasting purposes in the FPR. Default factors used in conversion of diesel to energy and greenhouse gas and these are 0.0382 (GJ/L) and 0.00269 (t CO_2-e/L). For petrol these figures are 0.0345 (GJ/L) and 0.00227 (t CO_2-e/L).

For the conversion of explosives, the default factor is 0.1778 (t CO_2-e/t explosives). For sodium carbonate it is 0.434 (t CO_2-e/t), but at Rössing the factor becomes 0.434 * 0.05 = 0.0217 tonne of CO_2 for every tonne of Na_2CO_3 (as only 5% of the carbonate is used up). The factor used for conversion of ore processed to GHG is 0.0022 (t CO_2-e/t ore milled). GHG emissions (CO_2-e) from domestic waste dumped at the landfill are determined using the methodology provided by Rio Tinto specifically for Rössing's landfill site.

The transport of uranium to converters and the transport of major reagents from suppliers to the mine are also reported annually only.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

Constant improvement in GHG management is guided by the documented plan (JE20/MMP/003). Accordingly targets to reduce energy consumption and emissions are set and reporting of performance against these targets are done monthly and annually (Monitoring and reporting procedures JE65/PRC/001).

Annual stack emissions monitoring are done at FPR to assess the efficiency of the stack filters. Chlorine detectors with an alarm system, for safety purposes, are in place at the sewage plant. Outcomes on several specialist studies (e.g. Volatile Organic Compounds) were done at various areas and indicated that the risk at Rössing is low.

Noise and vibration is monitored at Rössing through a network of various points and studies. Information is used to assess compliance and to address concerns, as well as to provide feedback to the Geotechnical Section, which utilized the information in investigating the impact of blast vibrations on the stability of the pit. The management of noise and vibration is guided by the Standard E1(Air quality, noise control and Greenhouse gases (GHG)) on which the Noise and Vibration Management Plan (JE20/MMP/008) is based. Environmental noise is monitored according to a procedure (JE65/STD/003). Noise is monitored and monthly reported to minimize noise to threshold levels and to identify exceedances. Engineering solutions and continuous business improvements attempt to mitigate the impacts of noise. Regular inspections and audits are conducted. Best practices are shared.

In conclusion, improvements of the air quality management practice at Rössing aim at

- a refined understanding of Rössing's dust pollution footprint, as expressed by the current dust plume in correlation to the wind regime
- a better understanding of the correlation between blasting and its impacts – dust, noise and vibration
- a review of the existing sources of emissions from mining operations
- characterising ambient air quality
- a better comprehension of the impacts of air quality on biodiversity
- review of control measures to recommend additional measures if needed, and mitigation to manage air quality better.

5.2.2. MANAGEMENT OF WATER

Water management at Rössing is guided by a formal water strategy, Water Management Plan and a Rössing specific-specific environmental standard on water usage and quality management. The Standard covers all activities connected to water abstraction, dewatering, transport, storage, usage (potable and process), and direct / indirect discharge, involving surface water (including run-off), impounded water and groundwater. The intent of the Standard is to ensure efficient, safe and sustainable use and protection of water resources and ecosystems. An understanding of water resources, their spatial and temporal interrelationships, ownership and the needs of key catchment stakeholders is thus required to provide the basis for the development of an integrated and strategic approach to water management that promotes the maintenance or improvement of water quality, upstream and downstream, minimisation of fresh water use and the maximisation of reuse and recycling.

Water supply at Rössing dates back to the late 1960s when two wells in the Khan River were permitted to provide water to exploration activities. In 1971 a third borehole was drilled to serve the pilot plant. More boreholes were drilled between 1973 and 1976, some of which were washed away in the 1985-flood and had to be re-drilled in 1986. In

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

1993 two more boreholes were drilled. Power lines and pipelines connect the abstraction system to the mine's water distribution network.

In December 2004, The Water Resource Management Act, 2004 (Act No. 24 of 2004) was gazetted and enforced. Subsequently in 2013, the Water Resources Management Act 11 of 2013 was gazetted and it came into operation on the 29 August 2023.

The government agency controlling Rössing's water management programmes is the Department of Water Affairs (DWA) in the Ministry of Agriculture, Water and Land Reform.

From the early years of Rössing's existence the DWA permitted Rössing to extract 870,000 m^3 per annum (2,384 m^3 a day) of brackish water from the Khan River aquifer for industrial use, mainly to suppress dust in the open pit. Power lines and pipelines of Rössing connect the abstraction system to the mine's water distribution network. As a proactive measure to concerns about a dropping water table, the DWA granted Rössing permission to extract water on the condition that vegetation along the river is monitored. Since 1988, the monitoring results have been submitted to the DWA to provide basis for revising water abstraction rates, should abstraction be identified to have an impact on vegetation. As of 1995, the sustainable yield of the Khan River aquifer has been determined every year after the rainy season and the extraction target set accordingly. Volumes and water levels are monitored monthly and used to update the water reserve estimation according to a documented operational procedure, JE65/OWM/001.

Hydrogeological studies indicated that, as a result of abstraction, the water table would be lowered to 10 metres below the surface but groundwater reserves at a depth of 10-20 metres below surface would still be available to sustain vegetation and dependent biodiversity. Monitoring results have shown that water levels measured upstream of the aquifer have a natural range of variation extending from approximately 1-10 m below the surface.

Extraction of brackish water from the Khan aquifer was voluntarily suspended between 31 December 2009 and 3 August 2011 in line with a drive to promote water savings. The monitoring and measuring of the vegetation and water levels in the river continued during the same time[82]. Abstraction of water resumed because of an increase in the need to suppress dust in the open pit as a result of the present extensions. The current rate of 600 m^3 a day is a target that Rössing set internally and is below the safe allowable abstraction. Rössing continues to adhere to another permit condition which is the monitoring of the ground water and the biannual vegetation in the Khan aquifer as described in procedures JE65/OWM/002.

About 40 million cubic meters of effluent is contained in the tailings facility at Rössing. This is a potential source of contamination that needs to be controlled. By law Rössing is obliged to ensure that no seepage from the tailings facility flows into the Khan River and other downstream receiving environments and to prevent residual contamination by metals, salts or radio-nuclides. Thus, impacts on water quality will fall within the range of natural variability for the receiving environment. Subsequently, water management at Rössing puts a strong emphasis on the tailings facility, and is regulated by various operational manuals and standard operational procedures that form part of the overall Water Management Plan (JA10/MMP/001).

[82] Rössing Closure Management Plan, (2011)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

Most of the surface seepage from the tailings facility flows down Pinnacle Gorge and is contained in the seepage dam below the facility. Two cut-off trenches further downstream were constructed during in the early 1980s by digging ditches across the riverbed into the weathered bedrock and removing any loose material. One or two concrete wells were placed in the deepest parts of the trenches before the latter were backfilled with permeable sand and gravel. The wells are installed with electrical submersible pumps which are operated by a fully automated system & monitored live on the Central Processing Control (CPC).

The purpose of the trenches is to remove groundwater flowing in the alluvium and thus cut-off the major flow paths of potentially contaminated water towards the Khan River (see Figure 5.8). A groundwater flow model of the tailings facility exists[83], which assists in the assessment of ongoing operations at the tailings facility and the consequent predictions of impacts of various long-term options. There is no diversion of storm water around the tailings facility in place. Due to the low rainfall in the area, there is minimal possibility of storm water damming up.

The buffering capacity of the rock types that surround the tailings facility, as well as the tailings sand itself, significantly inhibits the leaching of contaminants from the facility. However, small volumes of water from the tailings facility infiltrate into underlying bedrock where fractures allow some movement of groundwater from the western side of the dam towards Panner Gorge. Seepage of these contaminants into the alluvial aquifers of the Pinnacle, Panner and Dome Gorges is curbed by cut-off trenches and dewatering boreholes which are arranged in a double line on and along the western side of the tailings facility, in addition to the surface seepage collection dam in Pinnacle Gorge (Figure 5.8). Geophysical surveys were carried out to ensure that boreholes were placed on all major fractures. A cut-off trench is placed across the lower Panner Gorge to prevent inflow to the Khan River.

[83] Aquaterra, (2005)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

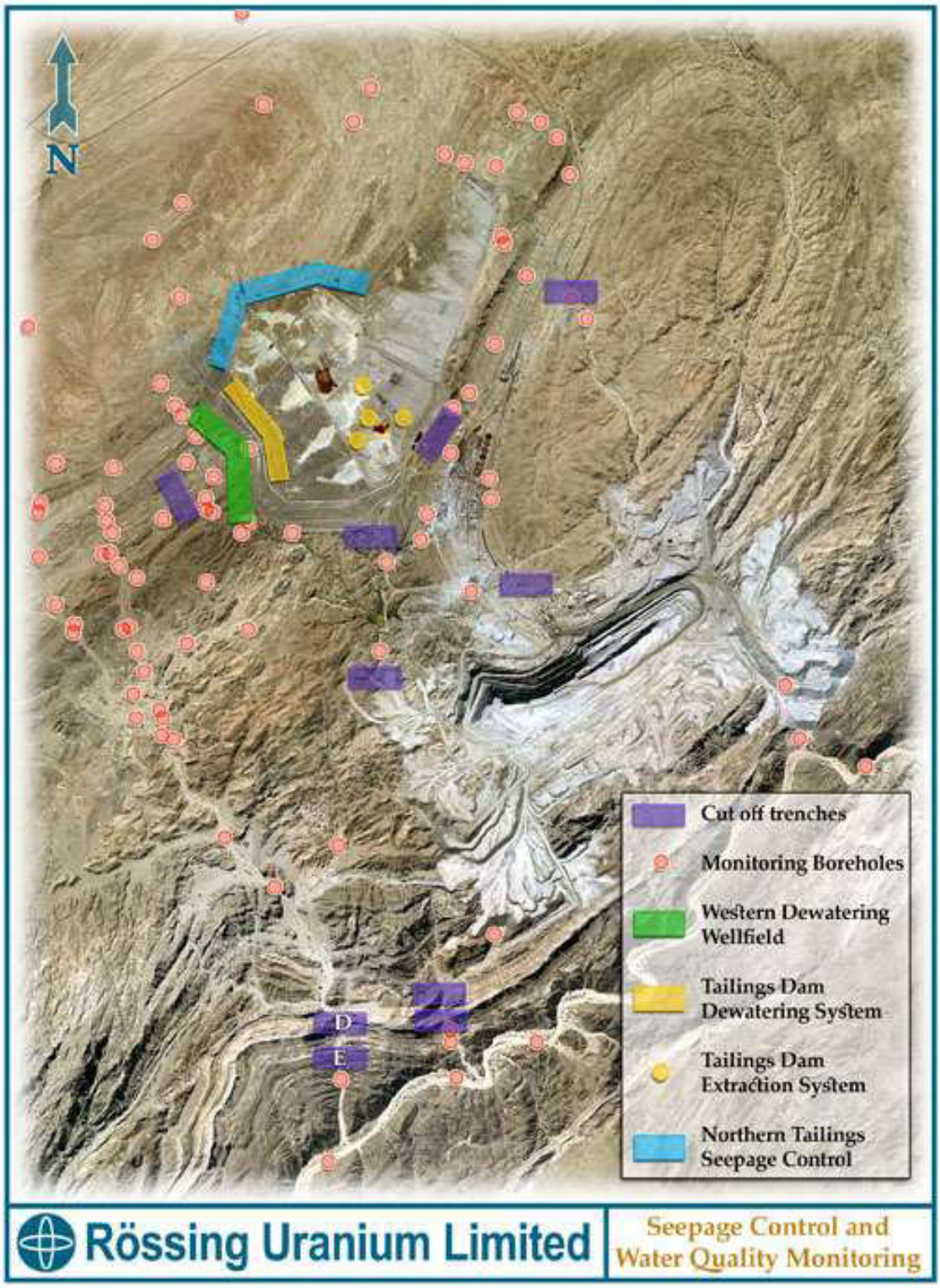


Figure 5.8: Water monitoring and seepage control at Rössing

Many former dewatering wells are currently not in operation because their yield has declined to less than 1 m^3/day, additional 20 boreholes were drilled in the in the area. This project was realised in 2023 and contribute increased dewatering in the area.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

The efficiency of the measures to control contamination of the Khan River is confirmed with regular borehole water monitoring in Pinnacle and Panner Gorges. The tailings facility is continuously monitored over 24 hours, generally completing a circuit every 2 hours. Groundwater flows and water quality are monitored at various other points and the seepage control installations are monitored daily. Monitoring includes checks on the available capacity at each operational open end as well as the water levels and shift log sheets are completed for evaluation. Flow meter readings are taken once per week and entered in a dedicated database to compile water balances and other reports. Water samples from the boreholes is analysed for radio-nuclide concentration, in Bq/L. Of the roughly 150 monitoring boreholes, monitoring is done against a schedule agreed upon between the mine & MAWLR under the Waste Water and Effluent Disposal Exemption Permit 674. Water samples are sent to accredited laboratories for analysis as per the agreed upon schedule.

Water storage in the tailings facility is minimised through a system of abstraction boreholes on and around the tailings facility. Away from the tailings facility the de-watering system exists of trenches and boreholes located in Pinnacle, Dome and Panner Gorges. The trenches and boreholes are pumped continuously to lower the water table and to reduce the advancement of groundwater contamination into the Khan aquifer. Detailed operational procedures include the Operation and monitoring of the seepage control systems (JE50/OWM/002); Water quality monitoring (JE65/OWM/004); Water quality management (JE50/MSP/001); Water recycling and re-use (JE50/OWM/003); Seepage recycling on the tailings dam (JE50/OWM/009) and Treatment of TDX boreholes (JE50/OWM/007). AutoCAD drawings of the seepage control systems and monitoring sites are annually updated (Water Control Plan 1002A) and filed at the Survey section. The location of the trenches and well fields can be seen in Figure 5.8.

Rössing uses steel pipelines of various diameters for the freshwater reticulation system. There are four main separate pipeline systems: 1) domestic water supply, 2) process water feed to the plant, 3) supply to the crushers and open pit and 4) supply to the fire tank and lakes. The purpose of having separate pipelines for domestic and process fresh water is to reduce the risk of potable water contamination. Drawings of the reticulation systems for fresh and recycled water are filed at the Engineering Drawing Offices. Pipes are colour-coded to indicate the type of solution.

The current water management system ensures that practically all process effluent is recycled, either directly from the paddy pond or from the seepage dam and seepage control systems. Only a small volume of seepage reaches the underlying bedrock and dissipates into fractured bedrock whose permeability is too low for effective dewatering. Hydrogeological modelling has shown this volume to be in the order of 100 m^3 per day. It is included in the site water balance as “seepage loss”.

The environmental impact of seepage is reduced by chemical reactions inside the tailings facility, which remove most of the acid and chemicals contained in the tailings solution. Tailings contain an average of 0.5% carbonate, which neutralizes sulfuric acid to gypsum and carbon dioxide. Other chemical reactions lead to the precipitation of iron hydroxides and co-precipitation of heavy metals and radionuclides. For instance, the TDS concentration of tailings solution is above 30 000 mg/L, but the seepage emanating from the facility is below 20 000 mg/L TDS.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

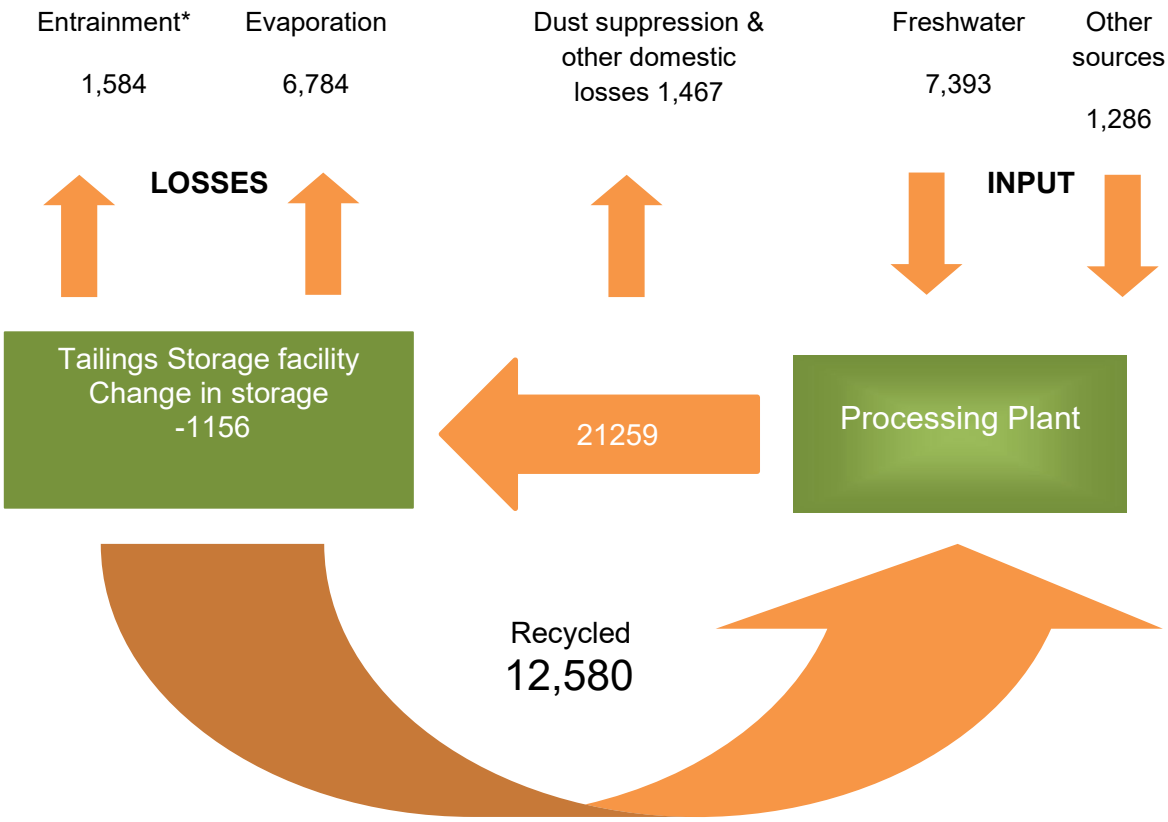


Figure 5.9: Schematic water balance for Rössing in cubic meters per day, 2023

Seepage is mainly characterized by increased sulfate, nitrate and magnesium concentrations, while chloride and sodium predominate in natural groundwater. The "seepage plume" around the tailings facility is defined at Rössing by the 3000 mg/L sulfate contour, while natural groundwater usually contains less than 2900 mg/L sulfate. The objective of water quality management in the mining area is to prevent as far as possible any expansion of the seepage plume beyond the area it occupied in 1999. Monitoring results since 2000 confirm that the plume did not spread outwards, but rather retreated in some places.

The Rössing water circuit is closed under normal operating conditions and no effluent is discharged. The water input balances the losses, so that the required volume of re-circulating process solution can be maintained. Water input to the mine (Figure 5.9) includes fresh water supplied by NamWater, brackish Khan River groundwater and recycled water from the seepage control systems, as well as moisture in ore and water in sulfuric acid.

Water losses occur due to evaporation from open water, e.g. tailings pools, lakes, tanks, wash-down and from entrainment of solution that will remain adsorbed to the tailings material. Other losses include water sprayed for dust suppression in the open pit, garden irrigation and seepage that bypasses the seepage control system. Evaporation loss is estimated at 6,784 m^3 per day.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

In 2023, Rössing used a total of 2 698 292 m³ of fresh water. The ratio of fresh water versus total water use was 0.290; meaning that 59% of the total water usage was obtained from reclamation. In essence fresh water is needed to counter evaporative losses and for drinking (household) purposes. Water input balances the losses (mainly through evaporation), so that the required volume of re-circulating process solution can be maintained. The Water Balance Procedure (JE65/OWM/001) and Fresh Water Supply Management (JE50/OWM/005) regulate operational activities.

Table 5.5: Water management procedures relevant to the effluence disposal exemption permit

Paragraph of permit	Subject	Procedure	Responsible section at Rössing
1.2.ii), 1.8.2	Seepage control systems	JE50/SOP/002	Water Management
1.2.i),ii) 1.6.2 1.9.1.6	Water recycling	JE50/OWM/009	Water Management
1.7.6	Fresh water supply management	JE50/OWM/005	Water Management
1.9.1.2	Waste rock dumping	MIN/WRD/001	Mine Planning
1.9.1.5	Disposal of hydrocarbons	JE50/WMP/002 ENV/WMP/003	Environmental Management
1.9.1.5	Disposal of chemicals	JE50/WMP/001	Environmental Management
1.7.3, 1.7.4, 1.7.9, 1.8.2	Water quality monitoring	JE65/OWM/004	Water Management
1.2.i),iii),iv) 1.4, 1.8.2	Monitoring of sewage plants	JE65/OWM/003	Water Management
1.7.1 1.7.2	Supervision of flow meters	JE50/MSP/001 JE50/MSP/002 JE50/SOP/002	Water Management
1.7.9	Monitor acid neutralization	JE65/OWM/004	Water Management

Rössing has standard operating procedures for water quality management and several related procedures to ensure compliance with the permit conditions. These are listed in Table 5.9 with reference to paragraph numbers in effluence disposal exemption permit.

There are currently no state regulations specifying water quality requirements for industrial water in Namibia. For this reason Rössing is using its own water quality criteria,

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

formalised as JE65/OWM/004 (Water quality monitoring) and JE50/MSP/001 (Water quality management) with the Water quality monitoring schedule agreed upon with MAWLR in 2018. To supplement the monitoring of water quality, the monitoring of several other aspects are documented as operational procedures. See Table 5.10.

Table 5.6: Water monitoring procedures at Rössing

Water aspect monitored	Procedure
Water quality (including fresh water, seepage, hydrocarbons)	JE65/OWM/004
Water levels	JE65/OWM/004
Seepage control systems	JE50/SOP/002
Fresh water supply	JE50/MSP/002
Water recycling	JE50/OWM/008
Seepage recycling on the tailings facility	JE50/OWM/009
Sewage water quality	JE50/OWM/003
Septic tanks	JE50/SOP/004
Khan river vegetation	JE65/OWM/002

Water is a scarce resource in the Namib Desert, where Rössing is located and as a management measure, Rössing continuously aims to reduce its water consumption per tonne of U_3O_8.

Two major permits of the DWA have been issued to Rössing – the industrial and domestic effluent disposal exemption permit (current number 674) and the abstraction permit 10200 for the Khan River well field. The objectives of the industrial and domestic effluent disposal exemption permit as stated by the DWA are to regulate the disposal of effluents produced by the mine and to prevent the spread of groundwater pollution from effluent or waste disposal sites into the receiving environment.

5.2.3. MANAGEMENT OF BIODIVERSITY AND REHABILITATION[84]

In 2004 Rossing launched its Biodiversity Strategy at the International Union for the Conservation of Nature (IUCN) World Congress in Bangkok. The strategy outlines the goal to have a 'Net Positive Impact' (NPI) on biodiversity on losses (impacts) and gains (offsets and restoration) by minimising the impacts of its businesses and contributing to biodiversity conservation to ensure that a region ultimately benefits as a result of its presence. By 2015, every site listed as High or Very High under the Global Biodiversity Values Assessment will have planned, costed, and commenced implementation of its NPI strategy. Rössing is listed as Very High.

[84] Smit, (2012)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

Rössing's Environment Standard E3 (Biodiversity, rehabilitation and Land use management) prescribes the implementation of an overall land management direction for each site. Accordingly, concepts such as avoidance and mitigation are well embedded in decisions with land use implications. In addition to the E3 Standard , the Biodiversity Action Plan (BAP) was developed to manage biodiversity aspects.

Rössing's BAP provides a mechanism to assess, prioritise and develop actions to address biodiversity risks and opportunities. Biodiversity management at Rössing is closely coupled to many other internal assurance processes such as community baseline assessments, Five Year Communities plans and SEIAs.
As custodian over ML 28, Rössing subscribes to minimising impacts of its operations and the maintenance and progression of biodiversity (through concrete as well as inferred conservation measures) on the land belonging to Rössing and in recognition and close cooperation with the neighbouring #Gaingu Conservancy, Namib-Naukluft and Dorob National Parks. Rössing is furthermore committed to enhance biodiversity protection by assessing and considering ecological values and land use aspects in investment, operational and closure initiatives.

Current biodiversity management at Rössing aims at achieving NPI before mine closure. The following outcomes need to be met:

- Continuous improvement of the biodiversity knowledge base
- Adverse impacts are constantly avoided and minimized
- Rehabilitation tasks are part of operational activities
- Additional conservation actions are supported to ensure sustainable landscape- and region-wide biodiversity benefits.
- Residual impacts are accurately calculated and compensatory offsets are implemented and are sustainable.

Biodiversity management activities at Rössing currently focus on the following:

- Monitoring, recording and reporting of biodiversity (including collection and identification) and making biodiversity information of Rössing and the central Namib more accessible
- Stakeholder engagement and awareness building, including the annual Birdwatching Day,
- Continuous updating, refinement and re-alignment of ongoing work identified in the BAP, and
- In cooperation with land use management and closure planning, investigate and plan rehabilitation at Rössing.

In 2011 it was decided to conduct an in-depth floral survey of under-collected biotopes at Rössing and a re-analysis of previously collected data plant data[85]. A total of 133 sample points was used and a total of 21 biotopes were identified at Rössing (Figure 5.10). Four biotopes were identified as Critical: the *Euphorbia virosa* belt (in which the open pit and waste rock dumps are located); the Khan River Mountains; the south-east gneiss hills and the undulating granite hills. Seven biotopes are rated as Rare and all others have a General rating.

[85] Burke, (2011)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

Initially only two plant species occurring at Rössing are thought to be of particular concern. The charismatic 'elephant's foot' *Adenia pechuelli*, occurs in relatively high concentrations on rocky hillsides. Formerly classified as near-threatened, it is now realized that the plant has a wide distribution in the Namib Desert and escarpment of Namibia and was down-listed in 2009 as a result. Thus, only *Lithops ruschiorum* remained as a species of concern from the earlier data. This *Lithops* species is believed to have a very restricted range in Namibia and is sought-after by collectors. Rössing possibly has the largest population of this plant in Namibia (around 25%). The species is the focus of continuous attention and research worldwide[86].

Following the 2011-survey, however, the number of recorded plant species in the Mining Licence area increased by over 100 species from 140 in 2005 to 253. A total of 68 plant species of conservation importance are now considered for the rating of biotopes.

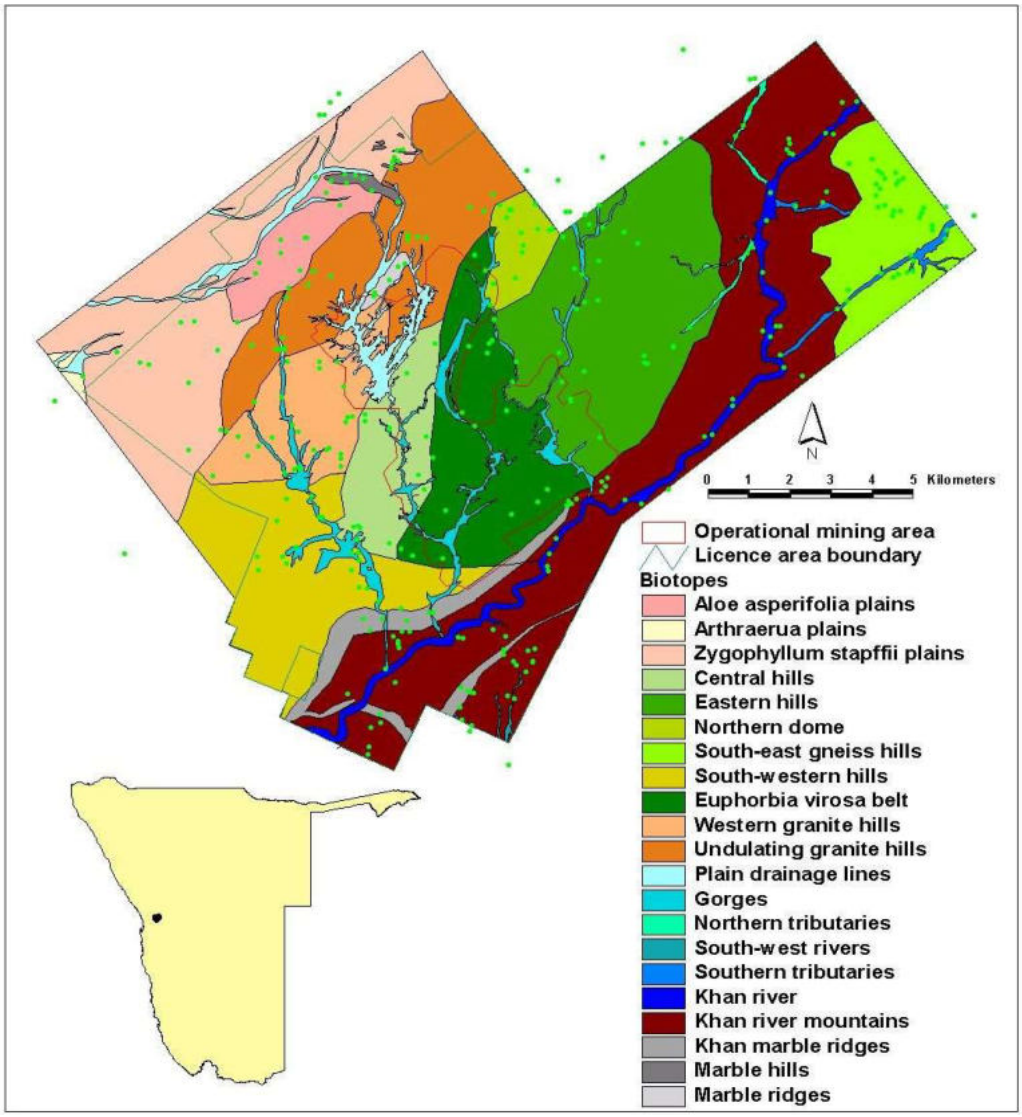


Figure 5.10: Biotopes at Rössing

[86] Loots, (2011)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

Invertebrate monitoring is ongoing at Rössing. Specialist identification of some species is challenging due to limited taxonomic capacity globally. As a solution a network of specialists in Namibia, South Africa and elsewhere is requested to do the identification. Since 2010 invertebrate monitoring at Rössing focused specifically on representation within the wider landscape. Reasoning for this is to specifically collect and / or re-discover the eighteen invertebrate species within the Critical, Endangered or Vulnerable categories identified in the earlier surveys since the 1980s. Occurrence of some of the target species is presumably limited to rocky hillside habitats. To determine the habitat compatibility the positioning of the sites identified in the 1980s was correlated and amended accordingly.

Biodiversity at Rössing is well studied over more than three decades – in fact, some regard it as over-studied when compared to the surroundings, including the Namib-Naukluft Park[87]. From the knowledge based built up over the three decades, there emerged also a need for better understanding the bigger picture, the entire landscape, in particular connections, patterns and processes. Categorisation of biodiversity is further hampered by the low level of biodiversity sampling outside the boundaries of Rössing. As a worst-case example, some invertebrates are known only from one specimen trapped during field surveys undertaken in the 1980s[88].

Improved understanding of biodiversity at Rössing provides important insights into rehabilitation requirements. Because about 90% of the disturbed area at Rössing is in operational use, rehabilitation interventions are limited to demolishing redundant infrastructure and facilities, and stabilising and clean-up activities throughout the Life of Mine.

Efforts were made since the 1980s to promote human-induced revegetation of the tailings facility. The learning from this endeavour asks many questions in terms of kind of species, methodology, duration of intervention, etc. Irrigation also proved expensive and impractical under the arid conditions and shows a high failure risk. This experience convincingly indicated that biophysical conditions need to be rehabilitated to allow natural vegetation endemic to the Namib to re-establish itself in disturbed areas.

Demolition, clean up and partial remedial efforts have been in progress since 1995. A number of facilities and waste sites were rehabilitated until 1998. Financed from operational budgets, the total area in question measures about 90 ha. No restoration interventions have been made; instead passive, but supported restoration is preferred. Natural re-growth is evident in most formerly disturbed sites at Rössing, regardless of the age or type of disturbance. Establishment of the perennials *Arthraerua leubnitziae* (pencil bush) and *Zygophyllum stapffii* (dollar bush) on these terrains indicates that, even without intervention, the mine will not leave its entire footprint devoid of life into perpetuity.[89]

Since the mid-2000s a number of areas on the mining lease have been drilled in search for new uranium bodies. A contractor, Namib HydroSearch, was requested to rehabilitate these areas as the exploration program allowed it. Exploration in the Z19 and Z20 areas commenced again in the 2020's with Z20 exploration currently ongoing.

[87] Brett, (2009)
[88] EEAN, (2008)
[89] Burke, (2010)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

The progressive rehabilitation programme was resuscitated in 2010 with the demolition of the acid plant and other redundant infrastructure. Currently, rehabilitation at Rössing entails several mechanical activities such as demolishing, remediation, geotechnical stability and protection against erosion.

Demanding climatic conditions, the scarcity of surface water, a high number of species adapted to aridity, and the lack of topsoil are some of the key biophysical determinants and are taken into account in the rehabilitation attempts at Rössing. Rehabilitation aims to initiate and accelerate natural recovery processes, a principle most appropriate to conditions in the Namib Desert where functioning of ecosystems at the landscape level requires special emphasis[90]. In order to facilitate natural recovery, the following base conditions have to be met:

- Suitable substrate needs to be available (stable, correct physical and chemical soil properties)
- Man-made landforms have to be suitable to support plant growth (no erosion and slope shapes and angles favouring seed and water catchment)
- The hydrological conditions need to be right to sustain natural processes
- Re-colonisation sources need to be nearby, and
- No pollution or other disturbances should interfere with the process of natural recovery.

Although rehabilitation is done as far as possible at Rössing, it is unlikely that all disturbed land will be rehabilitated. Backfilling the open pit, for example, is not a viable option. It is thus important to realize at an early stage that the residual impact area has to be calculated accurately and needs to be offset. Guidance from legislative and regulatory frameworks on biodiversity offsets and rehabilitation criteria in Namibia is limited. The sustainability of some offset opportunities is also questionable. The existence of exit plans and clarity with regard to relinquishment of land are some of the important prerequisites for Rössing.

Undoubtedly, the Namib Desert is one of the major attractions for visitors to Namibia. The part where Rössing is located is known for its scenic landscapes, picturesque vistas, solitude and uniquely adapted biotic life. Collectively refer to as *sense of place* these aspects of the Namib Desert are highly appreciated by many. Rössing highly respects *sense of place*. Rössing believes that maintaining this natural *sense of place* throughout the Life of Mine will result in a positive legacy after closure. This will be to the economic benefit of the region and to the enjoyment for the visiting tourist and the community member alike. Rehabilitation is a key initiative to achieve this vision.

5.2.4. MANAGEMENT OF NON-MINERAL WASTE

Namibian legislation is not particularly clear about the various types and definitions of waste, its management requirements and the agencies responsible. Currently at least eight ministerial bodies deal with waste management and pollution control in Namibia. Furthermore, there are no applicable national policies and standards in terms of waste management. The draft Pollution Control and Waste Management Bill is designed to address existing deficiencies and consolidate the legal framework while addressing related institutional fragmentation.

[90] Burke, (2005a)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

In the absence of a clear legislative framework, Rössing uses international standards such as ISO 14001:2015 as well as the Rössing Uranium Environmental Performance Standard E4 (Mineral waste, acidic and other impacted drainage control) for conformances and compliance in waste management. Classification and disposal guidelines have been taken from the South African *Minimum requirements for the handling, classification and disposal of waste (2nd Edition)*[91]. Accordingly, Rössing defines non-mineral (solid) waste as a generic term for waste not generated from mineral ore that comprises of redundant conveyor belts, domestic waste, wood pallets, building rubble; commercial and general dry industrial waste. It may also contain small quantities of hazardous substances dispersed within it, for example, batteries, and insecticides on domestic and commercial premises[92].

Waste products are thus divided into two classes. **General waste** is waste that does not pose a significant threat to public health or the environment if properly managed. Examples include domestic, commercial, certain industrial wastes and builder's rubble. Domestic waste is classified as general waste, even though it may contain hazardous components. This is because the quantities and qualities of hazardous substances in domestic waste are sufficiently small to be disregarded as a potential risk. General waste may be disposed of at any licensed landfill site.

Hazardous waste is waste that has the potential, even in low concentrations, to have a significant adverse effect on public health and the environment because of its inherent toxicological, chemical and physical characteristics. Hazardous waste requires stringent control and management, to prevent harm or damage and hence liabilities. It may only be disposed of at a licensed hazardous waste landfill site. Under the precautionary principle, waste is regarded as hazardous where there is any doubt about the potential danger of the waste stream to man or the environment.

Throughout the whole operation various waste products are generated. Effective and responsible waste handling and disposal are key elements of any environmental management system. All waste streams at Rössing are characterized, an inventory was composed and a risk assessment was undertaken to put operational procedures to regulate the management of the various waste items in place. An over-arching non-mineral waste management plan is in place to ensure sound non-mineral waste management through minimization of waste generation and safe handling, treatment and disposal of waste. The plan addresses all non-mineral wastes generated at Rössing during the operational as well as the decommissioning phases. A database for historical waste dumps is also maintained and guidance for the remediation of these sites during operations exists.

---

[91] (South African) Department of Water Affairs and Forestry, (1998)

[92] The draft Pollution Control and Waste Management Bill refers to waste as '*an undesirable or superfluous by-product, emission, or residue of any process or activity that has been discarded, accumulated or been stored for the purpose of discarding or processing. Waste products may be gaseous, liquid, solid or any combination thereof. Waste may originate from domestic, commercial or industrial activities, and include sewage sludge, radioactive waste, building rubble, as well as mining, metallurgical and power generation waste*.

The bill defines hazardous waste as '*any pesticide, herbicide or other biocide, radioactive substance, chemical or other substance and any micro-organism or energy form that has properties that, either by themselves, or in combination with any other thing, make it hazardous to human health or safety, or to the environment, and includes any substance, micro-organism or energy form defined as a hazardous substance in (future) regulations'*

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

Review of the waste management plan is conducted at least every four years. In short the objectives of the plan are:

- Avoid waste generation – the use of substitutes or alternative processes reduces the volume of total wastes and hence management requirements
- Reduce waste generation – waste reduction reduce costs of further treatment and decrease the risk of pollution associated with disposal facilities
- Segregate waste – allows for different waste streams to be recycled, reused or disposed of correctly
- Re-use and recycle waste – reduces the volume of waste disposed of and has the potential to improve economic gain

Specific targets for waste management at Rössing are set annually and progress are monitored and reported monthly, six-monthly and annually. Effectiveness is measured against the following performance indicators:

- Number of non-conformances recorded.
- Increase in number of recycled/re-used waste.
- Reduction in waste generated.
- Incidents of pollution.

All procedures for segregation, temporary storage and eventual transportation of waste are written up and authorised. Area owners are held responsible for the classification of the waste generated in their area and the management of safe and responsible handling and disposal of waste from their areas. Sorting of waste material is carried out at source, prior to removal. Collecting points of waste are demarcated and the disposal bins color-coded. Bins are placed in such a way that it ensures free access, for disposal as well as removal. Used grease and oil are contained and dispatch to storage area as per procedure JE50/WMP/002.

Waste bins on site are regularly removed, emptied and replaced in such a way that they do not become overfilled. The waste is also weighed and a register is kept for reporting against targets. General waste is disposed at a licensed landfill site offsite and managed to comply with all legislative requirements (environmental, safety and health). Access to the landfill and other disposal sites are controlled. The external recycling sites are frequently inspected and audited on a two yearly cycle. Records of waste generated, stored and disposed of are filed and maintained. Groundwater in the vicinity of the landfill site is monitored, according to operational procedure.

In the work areas frequent inspections are done to ensure compliance with procedures and that the management system is working effectively. These inspections cover waste segregation, storage, general housekeeping, and management of hydrocarbon and chemicals. All non-conformances identified during inspections are communicated to area owners and reported in order to investigate the causes of such non-conformances, to take corrective measures and to put measures in place to prevent similar future occurrences.

Disposal of recyclable items at the landfill site is restricted, as far as possible. Adequate resources are provided to ensure that salvageable waste material is collected and removed in such a way that the areas comply with all legislative requirements (environmental, safety and health). Radiation clearance is required before recyclable items and scrap metal are removed from site. Plastic containers (5, 10, 20, 25l) are holed and pressed before taken off site for disposal to prevent unauthorized use by third

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

parties. Empty 210L drums are removed to a temporary storage yard from where they are removed in bulk for recycling. Access to the temporary storage yard is controlled.

Redundant material and equipment that could potentially be contaminated on the mine site are not allowed to be taken offsite. This includes items such as pumps, tanks, pipes, concrete surfaces, soil, resin and infrastructure found in the processing plant of the mine. Contaminated objects are segregated according to the criteria contained in a procedure (JK65/PRD/101-Monitoring and identification of contaminated items). Transport is conducted according to provisions contained in the procedure (JK65/PRD/007-Transport of contaminated items) and disposal is done in accordance with another procedure (JK65/PRD/003-Disposal of contaminated items). Disposal of contaminated material is on the tailings facility where the quantity and disposal location of contaminated waste is recorded. Access to the contaminated waste disposal site is controlled.

Non-mineral waste is waste materials that are not generated from the mineral ore, for example redundant conveyor belts, chemicals, domestic waste, wood pallets, building rubble, scrap materials, used oils, and lubricants from maintenance activities. If waste is not stored and treated properly, it has a negative impact on the environment, health, and safety of the employees.

5.2.5. MANAGEMENT OF MINERAL WASTE

At Rössing mineral wastes are identified as waste rock and overburden, tailings and in the future heap leach waste (ripios). While Rössing managed the disposal of these waste streams throughout the Life of Mine, this was not always done through a formal waste management plan. A formal management plan for mineral waste is required by the Rössing Uranium Environmental Performance Standard E4 (Mineral waste, acidic and other impacted drainage control). The Standard sets the criteria against which Rössing is audited. It stipulates, inter alia, that waste disposal facilities should be located and designed to minimize environmental, health, safety and community impacts and risks. Facility location and design should be consistent with the long-term physical and chemical behaviour of the waste and must result in repositories that are physically and chemically safe and stable during operation and after closure.

Waste storage facilities are placed within permitted areas only. Considerations in the placement are:

- Preferentially placing waste within inactive open pits, underground workings or within existing disturbed areas
- Tying waste repositories into the surrounding topography to maintain regional drainage patterns and reduce visual impacts
- Avoiding placement on land with high biodiversity or ecosystem services values
- Avoiding placement in or near perennial surface water bodies or in large ephemeral drainage lines
- Avoiding placement of chemically reactive waste over important groundwater aquifers or recharge zones
- Avoiding placement in areas with significant archaeological or social value
- Avoiding placement in close proximity to local communities
- Preferentially placing chemically reactive wastes in drainage basins that already contain reactive waste (thereby avoiding placement in pristine drainages)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

- Avoiding placement in areas with poor foundation conditions due to topography, underlying geology or hydrology.
- Balancing economic considerations such as haul profiles, potential resource sterilization, and pumping costs with environmental, social and closure considerations.

The Rössing Mineral Waste Management Plan (JE20MMP009) is developed to comply with the standard as well as Namibian regulatory requirements. The intent of the plan is to ensure sound and effective mineral waste management by the minimization of waste generation and ensuring the safe handling, treatment and disposal of these wastes. The 3-yearly review of the Mineral Waste Management Plan for Rössing was done in 2022.

The purpose of the plan is to provide a documented record of issues related to mineral waste and to manage all mineral waste produced at Rössing in such a manner that disposal facilities and sites must be physically, biologically and chemically safe. For the purpose of this document mineral waste entails mineralised waste rock and processed waste rock (tailings), and excludes the dormant landfill site (where only non-mineral waste is disposed), commodities imported to site i.e. hydrocarbons, and sewage farms.

Waste rock dumps are typically coarse, angular fragments of very strong rock material that is resistant to mechanical disintegration and chemical decomposition, with the exceptions of amphibole schist and biotite schist. Both these are “minor” rocks in terms of volumes, and are furthermore mostly processed as ore. Typically thus, the Rössing dumps are of pervious, frictional material placed on competent, but steeply sloping foundations.

The mineral composition of waste rock consists mostly of quartz, albite, microcline (both feldspars) and mica. Marbles layers add calcite or dolomite to the list, while weathered samples can contain chloritoid, kaolin or gypsum. Waste rock has higher CaO and MgO contents than ore, which is mainly due to the marble present. Tailings material has a very similar composition with predominant quartz, albite, microcline, mica and small amounts of calcite or gypsum. Precipitates at the tailings facility are composed of chloritoid, potassium and ammonium jarosite, ammonium aluminium sulphate, ammonium manganese sulphate hydrate, quartz, feldspars and some mica. Ore and tailings are quite similar, except for the higher sulphur concentration in tailings, which can be ascribed to sulphate minerals such as jarosite and gypsum in tailings.

An inventory of mineral waste at Rössing is kept. It reflects the tonnage per year, the cumulative tonnage, surface area, volume and the location of waste. Site maps are maintained. The spatial footprint of mineral waste is also maintained and annually reported. Identification of the primary hazards posed by mineral waste is done. Primary hazards associated with mineral waste, reflecting the potential impacts, at Rössing are:

- Radioactivity from waste rock, low grade storage facilities and tailings facility (radon emanation and radionuclides in dust)
- Although there is a possibility that asbestos and asbestiform can be found in dust from the pit and crushing plant because of metamorphosed magnesium carbonate (such as marble) and the presence of serpentine, none has been found when monitoring so far
- Uranium and its decay products can be released into seepage water (from the tailings facility)
- Acidic drainage is possible where mineral wastes are in contact with water

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

- Residual nitrate, from the use of blasting agents, can be solubilised from waste rock and migrate to underlying groundwater

Reshaping of the huge man-made landforms represented by the waste rock dumps and the tailings facility needs to be minimised at closure and to achieve this aim, dumping progressively meets the final landform requirements. Additional work following closure (monitoring and maintenance) should thus be limited. With this in mind, Rössing follows a Waste Rock Disposal Planning and Design Strategy and in the case of the tailings facility an operating manual sets out the procedures to be followed in accordance with the engineering design. The following management objectives are emphasised:

- Geotechnical stability and access
- Radiation and radon emanation
- Surface drainage and rainwater leaching
- Rehabilitation and restoration requirements
- Visual appearance and aesthetics

Mineral waste facilities need to be geotechnically and erosionally safe and stable, not only during operation but also after closure. The waste rock dumps and tailings facility need to undergo a full geotechnical and geochemical review by an appropriately qualified independent engineering specialist at least once every two year. Information needs to be reviewed regularly and historical trends are examined so that the longer-term chemical behaviour can be assessed. Operation, safety and environmental aspects are periodically reviewed during an inspection by a suitably experienced and qualified engineer.

A good understanding of geotechnical factors governing mineral waste dump stability and the potential modes of failure at Rössing exist and directives for planning, design, construction and operation of these dumps are in place. Operational manuals regulate the management of the waste rock dumps as well as the tailings facility and comply with the RUL Management of Pit Slopes, Stockpiles, Spoils and Waste Dumps (RUL Safety Standard D3). The likelihood of injury to humans and wildlife is minimized through the design, construction and access control and through ensuring (geotechnical) stable conditions. In addition the facilities are made inaccessible for temporary and long-term use or habitation.

Inspections of the tailings facility are carried out quarterly by Water Waste and Land (WWL) Australia. Consultants from WWL and AQ2 undertake biannual reviews and produce a report to document the proceedings, findings and recommendations for improvement.

Radiation management at Rössing is regulated by the Radiation Management Plan (JK20/MMP/001). The radiation potential from mineral waste forms an integral part of the management plan, which aim to ensure that sources of ionising radiation are identified, quantified, controlled and minimised limited, and that exposures to these sources are limited. Dust management is regulated by several operational procedures, coordinated within the Rössing's Air Quality Management Plan (JE20/MMP/004).

The main source of potential groundwater pollution at Rössing is the tailings facility. Due to the acid-leaching process employed at Rössing the tailings solution is acidic and contains residual process chemicals, heavy metals and radio-nuclides. Another source

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

of groundwater contamination is leaching of nitrate, sulphate and uranium from the waste rock deposits overlying the gorges.

To ensure that water quality parameters remain as close as possible to the range of natural variability and to allow optimal water use after closure implies that surface water, groundwater and the biophysical environment is protected against exposure to hazardous waterborne chemicals. The surfaces of mineral waste dump facilities are therefore inward sloped to ensure that surface drainage is not allowed outwards. Downstream cut-off trenches prevent contaminated water to enter the Khan River.

A key mineralogical hazard to be considered is acidic drainage from mineral wastes (RUL Environmental Standard E4). Column rainwater leach tests on samples from the various waste rock disposal areas and low-grade ore stockpiles at Rössing indicated a possibility of acid rock drainage (ARD) from certain minerals, particularly those contained in the pyritic quartzite unit. But this rock type is mostly found within the ore material and it is processed through the plant. Thus, there is very little chance of ARD being formed at the rock waste dumps, but only at the tailings facility.

The low sulphide content of coarser mineral wastes and the neutralisation capacity of the marble lower the potential to generate acid rock drainage in the waste rock dumps further. Finally, the potential of the Rössing waste rock dumps to generate acid rock drainage is minimal due to the arid climate (average annual rainfall around 14 mm and net evaporation potential of 6,784 m^3/day).

Investigations and risk assessments were carried out to understand the stability and seepage of the tailings facility in terms of layout, geometry and raised embankments with and without remedial measures (i.e. buttressing). Input data is obtained from previous studies and reports, seepage modelling, piezometer readings and seismic loading criteria. Outputs from the seepage models are applied as input parameters into slope stability assessments.

The probability of major incidents and excessive rainfall event (for example slope stability failure and overtopping) occurring at the tailings facility will be minimised as long as the procedures of the operating manual are followed. Monitoring systems are in place to give early warning of the preventable hazards. If, however, an emergency situation does arise, the emergency response plan as described in the operating manual is to be followed. In an event which is not covered by the established plans, the situation is to be managed by the BRRP. Although major incidents involving the waste dump storage facilities are not listed in the BRRP, this programme will be used in the event of any major incident to the rock waste dumps.

The waste rock dumps and the tailings facility will remain as man-made landforms at mine closure. Visual impacts of the final landforms are minimized in order to maintain the characteristics and attractiveness of the surrounding landscape. Deposition of mineral waste is thus scheduled in such a way that it complements the contours of the surrounding landscape. A state that allows passive revegetation and integration into functioning ecosystems is the preferred option.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

5.3 THE DECOMMISSIONING PHASE

Any kind of development project has a lifetime. A mining project has a lifetime too, and the lifetime is normally limited to a few decades. As soon as mining becomes uneconomical, it is time to close a mine. Closure planning is an essential part of a mine's life cycle: it is a way of ensuring that all impacts are managed until the end of a mine's working life.

Closure planning is a continuous process at Rössing, and changes in operational circumstances, environmental conditions, legislative and regulatory frameworks, and stakeholder expectations were considered every time Closure Management plan is updated.

5.3.1 CLOSURE PLANNING: THE APPROACH

Closure planning at Rössing is driven by the Rössing Closure Standard and accompanying Guidance Notes, whilst also taking account of the guidance from the Chamber of Mines of Namibia and current draft on Mine Closure Framework being developed by Ministry OF Mines and Energy. Planning entails the development, maintenance and management of a process for eventual closure, which addresses all relevant aspects and impacts of closure in an integrated and multi-disciplinary way, and provides a fully scoped and accurate cost of closure to the company that is documented and auditable.

The Rössing Closure Standard and Guidance Notes are based on best industry practice and are compatible with the International Council for Mining and Metals' sustainable development principles. This Standard aligns the design, development, operation and closure of operations to ensure that adverse impacts on the human and natural environment are minimised and that a legacy remains which makes a positive contribution, i.e. that post-closure outcomes are optimised in terms of social, environmental and economic needs and expectations. Specifically, The Standard is intended to guide –

- improving the accuracy of closure cost estimates
- minimising the costs of closure
- the continued integration of closure planning into business plans
- the realisation of positive legacies for communities
- increased host community ownership for post-operational outcomes
- enhancement of Rössing's reputation, and
- Compliance with all applicable legal and other requirements.

The Guidance Note to the Rössing Closure Standard assists operations in meeting the requirements of the Standard with which operations are obliged to comply. There are also several other Rössing standards and guidance documents of relevance to closure planning. In summary, these documents contain guidelines on the following aspects:

- Planning for closure
    - The knowledge base
    - Closure strategy
    - Closure Management Plan and
    - Decommissioning Plan
- Implementation and operation
- Performance measurement
    - Cost estimating

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

- Review and monitoring

Thorough and comprehensive definition of the scope of measures to be undertaken at closure is necessary in order to reach a realistic estimation of the costs, and to provide assurance to shareholders that adequate financial provision for closure has been made. Reporting of closure provisions to the corporate body is an annual event.

The Minerals Policy for Namibia (2003) requires a Final Mine Closure Plan to be prepared before a Mining Licence is granted and the Chamber of Mines of Namibia has recently published its draft framework for mine closure[93]. The latter is based on the Australian Strategic Framework for Mine Closure with the aim of developing relevant and practical closure plans.

The initial closure plan dated, 2005 foresaw the potential closure of Rössing in 2009 or 2016, based on the prevailing business climate at the time. The closure plan which was updated in 2011, was based on the 2026 mine closure scenario.

The latest full closure plan update was prepared in 2022, this document was presented to MME, MEFT, MAWLR and NRPA and copies thereof were submitted to these regulators.

5.3.2 CLOSURE PLANNING AT RÖSSING[94]

Closure plans, including costing and provision of financial sureties, are based on approved Life of Mine plans only. This means that at the stage when a new expansion plan is approved, provisions are set aside on a continuous basis until the full cost is provided before the end of Life of Mine, or project.

Closure strategies are developed during the financial and technical feasibility studies for projects. Increasing levels of closure detail are developed as the studies progress from an initial concept via the stages of order of magnitude, prefeasibility, feasibility and final design. If a project finally results in an activity that becomes part of Rössing's operations (and thus part of the Life of Mine plan), the scope of the Closure Plan for Rössing is adapted accordingly to include the additional activities.

Rössing's closure plans are guided by an aspirational vision for closure that is translated into objectives and targets. In order to achieve those, a closure strategy is developed by analysing impact mitigation alternatives using sustainable development criteria and choosing a preferred alternative for each aspect or facility. Implementation plans for these preferred alternatives are then developed and the necessary closure costs calculated. Closure cost calculations are updated annually. The present closure obligation for Rössing is calculated at N$1,630m.

A Rössing Rehabilitation Trust Fund was established and makes provision for closure expenditure that will be incurred by the mine, in order to comply with statutory obligations and the requirements of the Ministry of Mines and Energy as well as the Ministry of Environment and Tourism. Clause 15.2 of the Trust Fund Agreement stipulates: *The mining company shall before the end of its financial year concerned, pay to the Fund a contribution towards the estimated cost of implementing the measures so approved.* The agreement also stipulates the formula to be used to calculate the annual contribution.

[93] Chamber of Mines of Namibia, (2009)
[94] Information for this section was obtained from the Rössing Closure Plan, (2011)

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

As at the end of 2023, the Rössing Rehabilitation Trust Fund had a cash balance of N$1,632m.

The Closure Plan presents a defined closure strategy, an extensive knowledge base, and the costing and scheduling of activities that were developed for the 2026 closure scenario. Rössing Uranium Limited intends to implement mine closure according to the discussions and conclusions detailed in this Closure Plan, and will provide adequate resources to achieve this goal. Should mine closure become inevitable unexpectedly, due to *force majeure*, the Closure Plan might have to be modified according to prevailing circumstances, but it will nonetheless guide the closure process according to the concepts it contains.

Under the current scenario backfilling of the open pit at Rössing is not considered as a viable option at the time when the mine closes. With this presumption in mind, current operations at the open pit are guided by the following management objectives:

- to minimise the likelihood of injury to humans and wildlife by means of appropriate design and constructing, access control and providing safe and stable conditions
- to manage radiological protection so that doses do not exceed allowable limits and prescribed constraints
- to minimise surveillance and maintenance needs at the time of mine closure through appropriate design of the pit void and associated control structures
- to maximise the beneficial use of the pit at the time of mine closure.

In summary closure measures are detailed and include

- No backfilling of the open pit with mineral waste; use of the open pit as evaporation area for reclaimed surface seepage as well as a containment area for contaminated infrastructure and demolition materials; and covering of waste in the pit with a 10 m-layer of waste rock to minimise the likelihood of scavenging for materials.
- Demolition of plant facilities where infrastructure is not suited to further beneficial use; removal of contaminated materials to onsite hazardous waste facility; and remediation of areas no further to be used.
- Covering tailings facility walls and beaches with rock to control erosion; access restriction to tailings facility with fencing and signage; control systems for groundwater management to continue for 30 years after closure; continued operation of seepage control system until seepage has stopped; removal of dust plumes from around tailings dam and disposal in tailings dam; visual blending of tailings into environment with rock coverings; and regular monitoring and maintenance of pumping system.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

6 APPENDIX 1: LEGISLATIVE FRAMEWORK

Statutory requirements relevant to environmental management at Rössing, according to Rössing's Environmental and Health and Safety Legal Register, could be divided between International Conventions, Regional Agreements, Domestic Legislations and Domestic Policies. The information contained in the Legal Register cannot be construed as legal advice but provides a summary of relevant international, regional and domestic laws and policies applicable to Rössing's operations in Namibia.

6.1 STATUTORY REQUIREMENTS

6.1.1 INTERNATIONAL CONVENTIONS AND REGIONAL AGREEMENTS

After independence in 1990 South African legislation remained prominent in Namibia but in some sectors it has been replaced by new laws. Presently some sectors are still regulated by outdated acts, or new legislation has only emerged to draft form. In some instances Namibian legislation has been enacted to give effect to obligations contained in international agreements.

In terms of the Namibian Constitution (Article 144), *"... the general rules of public international law and international agreements binding upon Namibia under this Constitution shall form part of the law of Namibia."* In short this means that all international agreements to which Namibia is a party automatically form part of Namibian law.

A summary of the international and regional laws and policies relevant to Rössing's operations in Namibia are listed below:

- United Nations Convention on the Law of the Sea, 1982
- Convention on Biological Diversity, 1992
- Vienna Convention for the Protection of the Ozone Layer, 1985
- Montreal Protocol on Substances that Delete the Ozone Layer, 1987
- United Nations Framework Convention on Climate Change, 1992
- Kyoto Protocol on the Framework Convention on Climate Change, 1998
- International Maritime Dangerous Goods (IMDG) Code

- SADC Environmental Policy and Regulatory Framework for Mining (2001)
- SADC Protocol on Mining (1997)

6.1.2 DOMESTIC LEGISLATION AND POLICIES

The Namibian Constitution contains two clauses, articles 91(c) and 95(l) that are of particular relevance to sound environmental management practice. In summary, these refer to:

- guarding against over-utilisation of biological natural resources;
- limiting over-exploitation of non-renewable resources;
- ensuring ecosystem functionality;
- protecting Namibia's sense of place and character;
- maintaining biological diversity; and
- pursuing sustainable natural resource use.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

The State is committed to actively promote and maintaining the environmental welfare of Namibians by formulating and institutionalising policies that can realise sustainable development objectives. General principles for sustainable development and sound environmental management are part of acts such as the Environmental Management Act (No 7 of 2007).

The Environmental Management Act 2007 (Act No. 7 of 2007) was promulgated in December 2007 through Government Notice number 232 (GG 3966). The Act has three main purposes:

1. To make sure that people consider the impact of activities on the environment carefully and in good time.
2. To make sure that all interested or affected people have a chance to participate in environmental assessments.
3. To make sure that the findings of environmental assessments are considered before any decisions are made about activities that may affect the environment.

The Act came into operation in February 2012 through Government Notice No 28 (GG 4878). At the same time, regulations were promulgated that determine:

1. Listed activities that may not be undertaken without an Environmental Clearance Certificate (issued by the Environmental Commissioner).
2. The process to apply for the Environmental Clearance Certificate.
3. Environmental Impact Assessment regulations.

Listed activities that may not be undertaken without an Environmental Clearance Certificate are:

1. Energy generation, transmission and storage activities.
2. Waste management, treatment, handling and disposal activities.
3. Mining and quarrying activities.
4. Forestry activities.
5. Land use and development activities.
6. Tourism.
7. Agriculture and aquaculture activities.
8. Water resource developments.
9. Hazardous substance treatment, handling and storage.
10. Infrastructure.

Furthermore two definitions are of particular relevance:
Activity: “means any physical work that a proponent proposes to construct, operate, modify, decommission or abandon or an activity a proponent proposes to undertake”.

Construction: “means the building, erection or modification of a facility, structure or infrastructure that is necessary for the undertaking of an activity, including the modification, alteration, upgrading or decommissioning of such facility, structure or infrastructure”.

It is important to note that these regulations apply not only to new activities and construction, but also to the modification, alteration, upgrading and decommissioning of any existing facilities, structures or infrastructure.

As implied by the Act, an Environmental Management Plan must be submitted and approved by the relevant authorities. The Environmental Management Plan thus forms the foundation of environmental impact management, also at Rössing.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

In terms of environmental management, the Namibian Constitution (Government of Namibia, 1990) and the Environmental Management Act (Act No 7 of 2007), the Environmental Assessment Policy (MET, 1994) and the Minerals Act (Act No 33 of 1992) provide particular guidance. In addition, a number of other pieces of legislation and policies are of relevance:

- Allied Health Professions Act 7 of 2004
- Atomic Energy and Radiation Protection Act 5 of 2005
- Atmospheric Pollution Prevention Ordinance 11 of 1976.
- Constitution of the Republic of Namibia 1 of 1990
- Electricity Act 4 of 2007
- Environmental Management Act 7 of 2007
- Explosives Act 26 of 1956
- Foreign Investment Act 27 of 1990
- Forest Act 12 of 2001
- Hazardous Substances Ordinance 14 of 1974
- Hospitals and Health Facilities Act 36 of 1994
- Labour Act 11 of 2007
- Marine Resources Act 27 of 2000 (and accompanying regulations Government Notice (GN) 241, Government Gazette (GG) 2657, 7/12/2001)
- Medicines and Related Substances Control Act 13 of 2003
- Minerals (Prospecting and Mining) Act 33 of 1992
- Mines, Works and Minerals Ordinance 20 of 1968: Regulations (GN143, GG2927 of 1 October 1968)
- Namibian Ports Authority Act 2 of 1994 and Port Regulations promulgated in terms of this section in GN 117 published in GG2549 of 5 June 2001
- National Heritage Act 27 of 2004
- Petroleum Products and Energy Act 13 of 1990 and regulations relating to the purchase, sale, supply, acquisition, usage, possession, disposal, storage, transportation, recovery and refinement of used mineral oil are published in GN 112 of 1991 (GG 281 of 21 October 1991) (“1991 regulations”) and the petroleum product regulations are published in GN 155 of 2000 (GG 2357 of 23 June 2000) (“2000 regulations”)
- Public Health Act 36 of 1919
- Road Traffic and Transport Act 22 of 1999
- Soil Conservation Act 76 of 1969 as amended in South Africa to March 1978
- Social Security Act 34 of 1994
- Water Act 54 of 1956
- Water Resources Management Act 11 of 2013

- Environmental Assessment Policy for Sustainable Development and Environmental Conservation, 1994
- National Environmental Health Policy, 2002
- Minerals Policy of Namibia, 2003
- General Environmental Assessment Guidelines for Mining (Onshore and Offshore) Sector of Namibia
- Policy for the Conservation of Biotic Diversity and Habitat Protection, 1994
- National Environmental Health Policy, 2002

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

7 APPENDIX 2: RÖSSING PROCEDURES

7.1 OPERATIONAL PROCEDURES RELEVANT TO THE HEALTH, SAFETY AND ENVIRONMENT MANAGEMENT SYSTEM

Code of Practice	
HSE Management System Code of Practice	JA05/COP/003
Procedures	
Environmental audit schedule	JA80/SCH/001
Monitoring and Measurement	JA65/MSP/001
Communication and Reporting	JA45/MSP/002
Document Control Procedure	JA40/MSP/003
Record keeping	JA75/MSP/004
Updating and review of Legal and other requirements	JA10/MSP/005
Hazard identification, risk evaluation and risk management	JA15/MSP/006
External Communications/Complaints	JA45/MSP/007
Reporting and investigation of HSE incidents and/or non-conformances	JA70/MSP/010 & MSP/011 merged
Training, competency and awareness	JA30/MSP/013
HSE Auditor Register	JA80/REG/001
HSE Audit Schedule	JA80/SCH/001
HSE Purchasing Criteria	JA35/MSP/013
Management of Change	JA 55/MSP/001
Appendix 1 - Proposal Form guidelines	JA 55/MSP/001.APP01
Appendix 2 - Level 1 Change	JA 55/MSP/001.APP02
Appendix 3 - Request Proposal Form	JA 55/MSP/001.APP03
HSE Committee Meetings for Rossing	JA45/MSP/008
HSE & Product Quality & Quantity Audit and inspection procedure for Rossing	JA80/MSP/001
Vendor pre-Qualification	JA35/PRC/001
Purchasing of chemicals	JA50/PRC/001
Sustainable sand management	JA50/PRC/003
Major Maintenance of Acid tanks	JA50/PRC/002
PPE Procedure	JA50/PRC/004
Customer Audit Procedure	JA80/PRC/002

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

7.1.1 HEALTH, SAFETY AND ENVIRONMENT MANAGEMENT PLANS

Sustainable sand management	JA20/MMP/003
Product Stewardship Plan	JA20/MMP/004
Biodiversity	JA20/MMP/005
Tailings Dam Dust Management Plan	JA20/MMP/010
Radiation Management Plan	JK20/MMP/001
Non-Mineral Waste Management Plan	JE20/MMP/001
Hazardous Material and Contamination Control Management Plan	JE20/MMP/002
Greenhouse Gas Emissions Management Plan	JE20/MMP/003
Air Quality Management Plan	JE20/MMP/004
Biodiversity Action Plan	JE20/MMP/006
Noise and vibration management plan	JE20/MMP/008
Mineral waste management plan	JE20/MMP/009
Water Management Plan	JA10/MMP/001

7.1.2 HEALTH, SAFETY AND ENVIRONMENT POLICIES

HSE Policy	JA05/POL/001
RUL Smoking Policy	JK05/POL/001
PPE Policy	JA05/POL/002
Fatigue Management Policy	JA05/POL/003
Clean Shaven Policy	JK05/POL/003
RUL Alcohol & Drug Policy	JK05/POL/004
Occupational Exposure Limits applied at Rössing	JK50/STD/001
HSE Policy Strategies	JA10/STR/001
HIV & Aids Policy Agreement	
Golden Rules	JA05/CHK/COP003 App006
Mobile Phone Usage Policy	JH05/POL/001

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

7.2 OPERATIONAL PROCEDURES RELEVANT TO HEALTH

Codes of Practice	
Peer Educator Programme	JK45/COP/001
Occ. Hygiene Monitoring	JK65/COP/002
Control of Asbestos at work	JK65/COP/003
Respiratory Protection Programme	JK65/COP/004
Thermal Stress	JK65/COP/005
Protection Against Ionising Radiation	JK65/COP/006
Protection Against Ultra Violet Radiation	JK65/COP/007
Control of Substances Hazardous to Health	JK65/COP/008
Hearing Conservation	JK65/COP/009
Human Vibration Protection	JK65/COP/011
Procedures	
Maintenance work carried out on the CIX contactors	JK50/PCL/001
Aerotesting Procedure	JK65/PIN/001
Operating the Thermo Eberline Handecount	JK65/PIN/002
Instrument Procedure for the Automess 6150 AD4 Dose Rate Meter	JK65/PIN/003
Operating Instructions for the Electra and DP2R/4A Probe	JK65/PIN/004
Management of Health Instruments and equipment.doc	JK65/PIN/005
Personal Monitoring of LLRD using the Myriam Instrument	JK65/PIN/006
Personal monitoring of RDP using the DoseManPro instrument	JK65/PIN/007
Thermal Stress	JK65/PRC/001
Maintenance of Water Coolers and Emergency Units	JK50/PRC/002
Area Noise Survey	JK65/PRC/003
Personal Noise Survey	JK65/PRC/004
Alcohol & Drug Testing Procedure for Cottage	JK65/PRC/005
Alcohol & Drug Testing Procedure for Windhoek	JK65/PRC/006
Confined Space Clearances	JK65/PRC/007
Measurement of Whole Body Vibration	JK65/PRC/008
Measurement of Hand-arm Vibration	JK65/PRC/009
Particulate Monitoring Particulates, Mists, Fumes and Vapours	JK65/PRC/010
Diesel Particulate Monitoring	JK65/PRC/011
Alcohol & Drug Procedure	JK65/PRC/012
Wood dust Monitoring	JK65/PRC/013
Confine Space clearances	JK65/PRC/014
HIV & Aids Transfer Procedure	JK65/PRC/015

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

7.4.1 OPERATIONAL PROCEDURES RELEVANT TO RADIATION

Radiation Protection when working with Sealed Radiation Sources	JK50/PRD/001
Urinalysis Sampling Procedure	JK65/PRD/002
Disposal of Contaminated Items	JK65/PRD/003
Removal of Scrap	JK65/PRD/004
Removal of Equipment and Material from Site	JK65/PRD/005
Decontamination of Contaminated Items	JK65/PRD/006
Transport of Contaminated Items	JK65/PRD/007
Monitoring of Employees Exiting FPR During unavailability of Thermo Electron PCM-2 Portal Monitor	JK65/PRD/008
Uranium Oxide Spillage	JK60/PRD/009
Monitoring & Identification of Contaminated Items	JK65/PRD/010
Product Shipment Inspection & Monitoring	JK65/PRD/011
Baseline Monitoring of Empty Containers	JK65/PRD/012
Analysis of Smear Sample for Alpha Radiation with Handecount	JK65/PRD/013
Procedures for Maintenance Work Carried out on the CIX Contactors	JK50/PRD/014
Area Radiation Survey for Total Alpha and Beta Contamination	JK65/PRD/015
Area Survey for External Gamma Radiation	JK65/PRD/016
Area Radiation Contamination Survey using Smear Samples	JK65/PRD/017
Contact radiation monitoring (Beta/Gamma) in Final Product Recovery	JK65/PRD/018
The monitoring of Personal Radiation Dose	JK65/PRD/019
Personal External Dose Monitoring with a Dosicard	JK65/PRD/020
Monthly pregnancy test	JK65/PRD/021
Container Packing & Strapping Procedure	JK65/PRD/022
Personal monitoring of RDP using the DoseManPro instrument	JK65/PRD/023
Scales Calibration	JK65/PRD/024
Determination of transport requirements for transporting radioactive materials”?	JK65/PRD/025
Microwave testing	JK65/PRD/026
Guidelines on Equipment leaving site	JK65/PRD/027
Alpha Analysis of Smear Samples with the Hand-E-Count (new instrument	JK65/PRD/028
Low Frequency EMF workplace Analysis	JK65/PRD/029
	FPR10
Inspection of Drums	FPR11
Drum Information Stencilling	FPR12
Drum Packing and Handling of Containers	FPR13

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

7.3 OPERATIONAL PROCEDURES RELEVANT TO SAFETY

Codes of Practice	
Vehicles and Driving	JH50/COP/007
Off-site Vehicles and Driving Standard	Appendix A
Cranes and Lifting	JH50/COP/011
First Responder Training	JH50/COP/012
Storage of flammable and Explosive Material	JH50/COP/013
Aisles, Storage and Demarcating	JH50/COP/014
Stacking and Storage	JH50/COP/015
Colour Coding	JH50/COP/016
Barricading and Demarcation	JH50/COP/017
Machine Guarding	JH50/COP/018
Compressed Gas Cylinders/Pressure Vessels	JH5O/COP/019
Hand Tools	JH50/COP/020
Work, Yard and Back Areas	JH50/COP/021
Appointment of Responsible Persons	JH50/COP/023
Permit to Work Systems	JH50/COP/026
Working at Heights	JH50/COP/030
Personal Protective Equipment	JH50/COP/031
The role of an OHSE Representative	JH50/COP/032
Fire Training	JH50/COP/033
Electrical Safety	JH50/COP/035
Procedure for cutting a lock	JH50/COP/036
Procedures	
Tyre Management	JH50/PRC/001
Confined Space Procedure	JH50/PRC/002

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

7.4 OPERATIONAL PROCEDURES RELEVANT TO ENVIRONMENT

Procedures	
Non-Mineral Waste Management	JE50/WMP/001
Disposal/re-use of Hydrocarbons	JE50/WMP/002
Disposal of capacitors	JE50/WMP/003
Disposal practice for the Rössing Landfill Site	JE50/WMP/006
Procedure for action taken in the event of a diesel/oil spillage	JE50/WMP/010
Disposal of oil and diesel filters	JE50/WMP012
Bio-remediation of hydrocarbon contaminated soil and sludge	JE50/WMP/014
Disposal of Oil Trap Residue to the Oil Separation Plant	JE50/WMP/015
Purchasing of chemicals	JA50/PRC/001
Setting up of the Environmental Aspect Register	EMS/OPS/006
Air blast Ground Vibration Monitoring Programme	JE50/PRC/002
Inventory and Inspection of Chemicals in the lab	JE50/PRC/004
Determining of GHG procedure	JE65/PRC/001
Environmental Noise Monitoring Procedure	JE65/PRC/003
Land disturbance reporting	JE65/PRC/004
Biodiversity Monitoring and Information Management	JE65/PRC/005
Procedure for Storing, Transporting, Usage and Disposal of Hazardous Materials of Puma Energy (Namibia)	JE50/PRC/005
Instructions for Mercury Kit	JE50/PIN/001
Instruction for the ph fix Indicator strips	JE50/PIN/002
Dust Deposition Sampling	JE50/PIN/003
Downloading Data from the OSIRIS Dust Monitor at the Crushing Circuit	JE50/PIN/004
Operating Instructions for the spike pH5/6 meter (Analysing soil contamination)	JE50/PIN/005
Multi-Vertical Sampler	JE50/PIN/006
PM10	JE50/PIN/007
Operating Instructions for Total Petroleum Hydrocarbon (TPH) Test Kit	JE50/PIN/008

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

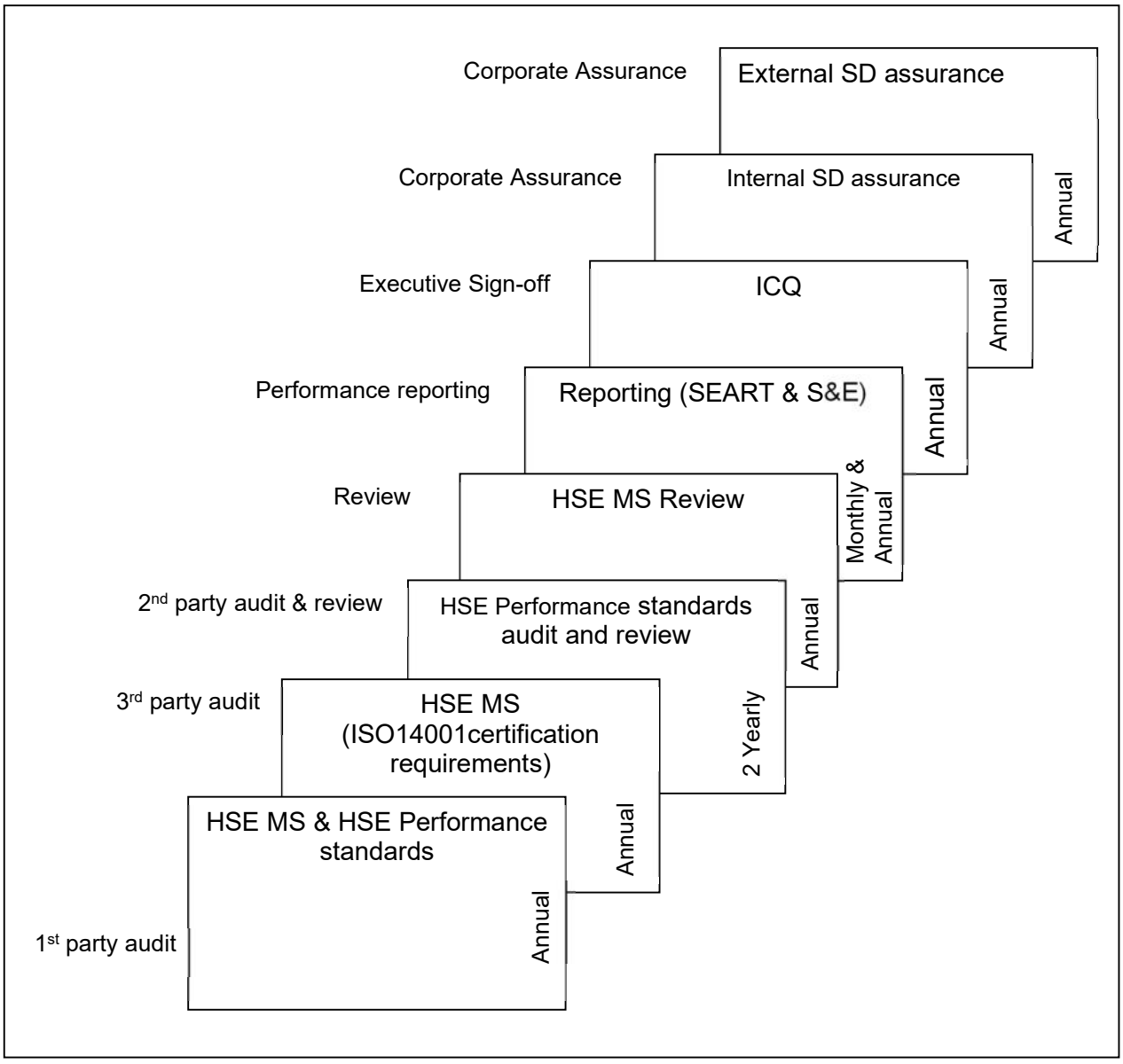
7.4.1 OPERATIONAL PROCEDURES RELEVANT TO WATER

Rössing water strategy.	JE05/STR/001
Standard Compliance (Rössing).	JE10/STD/001
Rössing Water Management Plan.	JA10/MMP/001
Khan river Vegetation Monitoring.	JE65/OWM/002
Bioremediation of Hydrocarbon Contaminated Soil and Sludge	JE50/WMP/014
Operation of oil separation plant.	JE50/OWM/001
Operation and monitoring of the Seepage Control systems.	JE50/OWM/002
Monitoring of the sewage plant.	JE65/OWM/003
Operation of the sewage plant.	JE50/SOP/003
Procedure for the operation of septic tanks	JE50/SOP/004
Rössing water balance procedure.	JE65/OWM/001
Water Quality Monitoring.	JE65/OWM/004
Water Quality management.	JE50/MSP/001
Fresh water supply management.	JE50/OWM/005
Water recycling and reuse.	JE50/OWM/008
Weekly Determination of RDS and Seepage Evaporation Rates.	JE65/OWM/005
Seepage Recycling on the Tailings dam.	JE50/OWM/009
Treatment of TDX boreholes with Sodium hydroxide.	JE50/OWM/007
Freshwater Demand planning.	JE20/OWM/001

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

8 APPENDIX 3: SUMMARY OF AUDITS AND CERTIFICATION

The HSE assurance approach followed at Rössing.



The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

9 REFERENCES

Abrahams A. and Anderson, F. (2004): Investigation into the Possible Increase in External Radiation Doses for 2004 at Final Product Recovery, Internal Memorandum, Rössing Uranium Ltd

Ashton P.J., C.A. Moore and P.H. McMillan (1991): An environmental impact statement for the Rössing Uranium Mine, Namibia. Published report for Rössing: CSIR, Division of Water Technology.

Ashton, P.J., L. Godfrey, R. Meyer and G. Dunn (2000): Environmental impact assessment of the proposal to expand the importation, storage and transfer of bulk sulphuric acid to Rössing Mine, Namibia: Environmental Impact Report. Published report for Rössing: CSIR, Division of Water, Environment and Forestry Technology (Report No. ENV-P-C-2000-030).

Atomic Energy Corporation of South Africa, (1988): An investigation of Rn-222 at Rössing Uranium Limited. A report for the period October 1987 to September 1988, Rössing Uranium Limited

Aquaterra Consulting (2005): Rössing groundwater model: Updated calibration. Unpublished report for Rössing: Aquaterra Consulting.

Aurecon (2011a): Social and Environmental Impact Assessment Phase 2b: Proposed expansion of Rössing Uranium Mine. Published report for Rössing: Aurecon.

Aurecon, (2011b): Social and Environmental Management Plan: Phase 2 Exploration drilling in the mine licence area within the Namib-Naukluft Park. Published report for Rössing: Aurecon.

Belnap, J. (2001): Factors influencing nitrogen fixation and nitrogen release in biological soil crusts. In: Belnap, J. and Lange, O.L. (eds): Biological soil crusts: structure, function and management. Springer Ecological Studies 150: 241-261.

Brett, R. (2009): Review of the biodiversity assessment at Rössing Uranium, Namibia. Unpublished report for Rössing: Fauna and Flora International and Rio Tinto partnership.

Burke, A. (2005a): Rössing's Biodiversity Strategy: Biotope mapping, reconstruction of the pre-mining situation and assessment of biodiversity value. Unpublished report for Rössing: EnviroScience.

Burke, A. (2005b): Biotope mapping, reconstruction of the pre-mining situation and assessment of biodiversity value. Unpublished report for Rössing: EnviroScience.

Burke, A. (2007): Biotope mapping for the Rössing Uranium mine expansion project in the eastern accessory works area. Unpublished report for Rössing: EnviroScience.

Burke, A., Kyläkorpi, L., Rydgren, B. and Schneeweiss, R. (2008): Testing a Scandinavian biodiversity assessment tool in an African desert environment, Environmental Management 42: 698-706.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.

A PRINTED COPY IS AN UNCONTROLLED COPY

Burke, A. (2009): Biotope assessment for Rössing's license area, south of the Khan River. Unpublished report for Rössing: EnviroScience.

Burke, A. (2010): Input to the development of a restoration programme at Rössing Uranium. Unpublished report for Rössing: EnviroScience.

Burke, A. (2011): More of the same – or new patterns? Biotope assessment at Rössing Uranium during an exceptional season. Unpublished report for Rössing: EnviroScience.

Campbell, O. (1998): Wildlife follow-up survey – November 1998. Rössing Uranium Limited. Unpublished report.

Chamber of Mines of Namibia, (2009): Annual review. Windhoek, Chamber of Mines of Namibia.

CSIR, (1998): An assessment of the potential environmental impacts of the proposed aquifer recharge scheme on the Khan River, Namibia. CSIR, Division of Water, Environment and Forestry Technology (Report No. ENV/P/C – 97104.

Curtis, B.A. and Mannheimer, C.A. (2005): Tree atlas of Namibia. Windhoek: National Botanical Research Institute.

Dames and Moore (1981): Seepage and pollution control - Phase I. Unpublished report for Rössing: Dames and Moore.

Dames and Moore (1982): Seepage and pollution control - Phase II. Unpublished report for Rössing: Dames and Moore.

Dames and Moore (1983): TARGET – A mathematical model for Rössing Uranium Limited. Unpublished report for Rössing: Dames and Moore.

De Beer, G.P. and Leuschner, A.H. (1988): Assessment of the occupational dose from the various radiation sources in the open pit area at RUL. Unpublished report for Rössing: Atomic Energy Corporation of South Africa.

D Beer, G.P. (1990): Estimation of the Average Radiation Dose to the Population of Arandis from Radioactivity Originating from Natural as well as Mining Related Sources. Unpublished report for Rössing: Atomic Energy Corporation of South Africa.

De Beer, G.P. (1997a): An assessment of the radiological impact associated with the use of Rössing tailings for maintenance of haulage roads in and around the open pit. Unpublished report for Rössing: Atomic Energy Corporation of South Africa.

De Beer, G.P. (1997b): An assessment of the radiological impact associated with the use of seepage water from the Rössing tailings dam for dust suppression in the open pit. Unpublished report for Rössing: Atomic Energy Corporation of South Africa.

De Beer, G.P., Ramlakan, A.J. and Schneeweiss, R. (2002): An assessment of the post-closure radiological impact of Rössing Uranium Mine. Report GEA-1582. Unpublished report for Rössing: Nuclear Energy Corporation of South Africa, Pretoria.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

De Beer, G. P. and Ramlaken, A. J. (2003): Post-closure public dose assessment for the Phase III expansion of the Rössing Uranium Mine. Report GEA-1617. Unpublished report for Rössing: Nuclear Energy Corporation of South Africa.

De Beer, G.P and Liebenberg, G.R., (2008): Dose assessment for a life-of-mine extension (LOME) of the Rössing Uranium Mine. Unpublished report for Rössing: Nuclear Energy Corporation of South Africa.

De Villiers, D. and De Beer, G.P. (2011): Report on the radiological public hazard assessment for the expansion of Rössing Uranium Mine in Namibia. Unpublished report for Rössing: Nuclear Energy Corporation of South Africa.

EEAN / Environmental Evaluation Associates of Namibia, (2008): Rössing Biodiversity Assessment. Unpublished report for Rössing: EEAN.

Evans, R.D. and Lange, O.L. (2001): Biological soil crusts and ecosystem nitrogen and carbon dynamics. In: Belnap, J. and Lange, O.L. (eds): Biological soil crusts: structure, function and management. Springer Ecological Studies 150: 263-279.

Everett, M. (2001): An assessment of the dose attributable to radon at a number of receptor locations surrounding Rössing Uranium Mine. Unpublished report for Rössing: EnviroSolutions.

EnviroSolutions, (2002): An assessment of the background radon concentrations for pre-mining conditions in the present mining grant area of Rössing Uranium Limited. Unpublished report for Rössing: EnviroSolutions.

Grundling, A. and Leuschner, A.H. (1988): An investigation of 222Rn concentrations at RUL. A report for the period October 1987 to September 1988. Unpublished report for Rössing: Atomic Energy Corporation of South Africa.

Grundling, A. and Leuschner, A.H. (1990): Modelling Environmental Radon Concentrations Associated with Mining Activities at Rössing Uranium Ltd. Unpublished report for Rössing: Atomic Energy Corporation of South Africa.

Isaack, J.B. (2001): Preliminary post closure radiological safety evaluation for Rössing Uranium Mine. Rio Tinto Technical Services: Unpublished report (Ref: GBJ016)

Loots, S (2006): Red list field assessments of *Lithops ruschiorum* and *Adenia pechuelii* in the Rössing Uranium Mine concession area. Unpublished report: National Botanical Research Institute.

Loots, S. 2011: National conservation assessment and management of two Namibian succulents with specific reference to the Rössing Uranium Mine. Published report for Rössing: National Botanical Research Institute.

National Planning Commission, (2012) Namibia 2011 Population and Housing Census Preliminary results. Windhoek, National Planning Commission.

Ninham Shand, (2008): Social and environmental impact assessment: proposed expansion project for Rössing Uranium Mine in Namibia: Phase 1 ~ acid plant, ore sorter and SK4 pit

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

Parc Scientific and EnviroSolutions, (2001): An assessment of the airborne and deposited dust levels attributable to dust sources at a number of receptor locations surrounding Rössing. Unpublished report for Rössing: PARC Scientific Pty Ltd.

Kinahan, J. (2007): Archaeological assessment of SK Area in ML 28. Unpublished report for Rössing: Quaternary Research Services
Rössing Foundation, (2009): The Rössing Foundation 1978 – 2008. Windhoek, The Rössing Foundation.

Rössing Uranium Limited, (2005): Rössing Closure Management Plan. Unpublished report: Rössing Uranium Limited.

Rössing Uranium Limited, (2008): Land Use Management Plan. Unpublished document: Rössing Uranium Limited.

Rössing Uranium Limited, (2011): Report to stakeholders. Published report: Rössing Uranium Limited.

Rössing Uranium Limited, (2011): Closure Management Plan. Unpublished report: Rössing Uranium Limited.

Rössing Uranium Limited, (2012): Dust Management Plan. Unpublished document: Rössing Uranium Limited.

Rössing Uranium Limited, (2012): Radiation Management Plan Unpublished document: Rössing Uranium Limited

SAEIA, (2010): Strategic Environmental Assessment for the central Namib uranium rush. Windhoek, Ministry of Mines and Energy

SIAPAC in Association with Golder Associates Africa (2003): Sustainability Assessment for the Life Extension of Rössing Uranium Mine

Simonis Storm Securities, (2010): The Namibian uranium industry: Economic impact and counter valuation. Published report: Simonis Storm Securities.

(South Africa) Department of Water Affairs and Forestry, (1998): Minimum requirements for the handling, classification and disposal of waste (2nd Edition) Pretoria.

Smit, P. (2011): Biodiversity and rehabilitation at Rössing. Unpublished document. Rössing Uranium Limited.

Stacey, J 2006: Rössing Uranium Limited. Rössing Mine Lease bird survey 2005-6. Unpublished report for Rössing: BirdLife International.

Steffen, Robertson and Kirsten Inc, (2010): Water specialist study for the Phase II SEIA for the Rössing mine expansion. Unpublished report for Rössing.

Strydom, R. Goede, P., Goosen, C., van Staden, M and Steyn, A. (1989): The measurement of radon exhalation rates from identified sources at RUL Unpublished report for Rössing: Atomic Energy Corporation of South Africa.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

Strydom, R., (2006): Atmospheric dispersion modelling of radon and long-lived radioactive dust for current, life-of-mine extension and post closure mine operating scenarios. Unpublished report for Rössing: PARC Scientific Pty Ltd.

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

10 ABBREVIATIONS USED IN THIS DOCUMENT

ALARA	As Low As Reasonably Achievable
ART	Anti-retroviral treatment
ASDP	Arandis Sustainable Development Project
BAP	Biodiversity Action Plan
Bq	Becquerels
CaO	Calcium Oxide
CCD	Counter Current Decantation
CH_4	Methane
CIX	Continuous ion exchange
cm	Centimetre
CO	Carbon monoxide
CO_2-e	Carbon dioxide equivalent
DWA	Department of Water Affairs
EEAN	Environmental Evaluation Association of Namibia
EIA	Environmental Impact Assessment
EMS	Environmental Management System
EPL	Exploration Prospecting Licence
FPR	Final Product Recovery
g	gram
GHG	Greenhouse Gas
GJ	GigaJoule
HEF	High Energy Fuel
HIV/AIDS	Human Immunodeficiency Virus infection / Acquired Immunodeficiency Syndrome
HSE	Health, Safety and Environment
HSE MS	Health, Safety and Environment Management System
IAEA	International Atomic Energy Agency
ICRP	International Commission for Radiological Protection
IPCC	International Panel on Climate Change
ISO	International Organization for Standardization
IT	Information technology
IUCN	International Union for the Conservation of Nature
kg	kilogram
kV	kiloVolt
L	Litre
M	mega, one million
m	meter
m^3	cubic meter
mamsl	metres above mean sea level
mg:	milligram
MgO	Magnesium Oxide
ML	Mining Licence
mSv	milliSieverts, 10^{-3} Sv
µm	micrometre
MVA	MegaVolt Ampere
MWH	MegaWatt Hours
Na_2CO_3	Sodium carbonate
NBRI	National Botanical Research Institute
NECSA	Nuclear Energy Corporation of South Africa
NO_x	Nitrogen Oxide

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

NPI	Net Positive Impact
NSX	Namibian Stock Exchange
NRPA	National Radiation Protection Authority
OK liquor	The chemical solution containing uranium trioxide
PCB	Polychlorinated biphenyl
PM10	Particulate Matter < 10 µm
PPE	Personal Protective Equipment
ppm	Parts Per Million
RTZ	Rio Tinto Zinc Corporation
RUL	Rössing Uranium Limited
s	second
SAIEA	Southern African Institute for Environmental Assessment
SABS	South African Bureau of Standards
SEA	Strategic Environmental Assessment
SEIA	Social and Environmental Impact Assessment
SEMP	Social and Environmental Management Plan
SX	Solvent Extraction
SO_2	Sulphur Oxide
t	Tonne
TDS	Total Dissolved Solids
TLD	Thermo Luminescent Dosimeter
TPM	Total Particulate Matter
UN	United Nations
UNSCR	United Nations Security Council Resolution
U_3O_8	Uranium oxide
Yellow cake	Ammonium diuranate

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

11 CHANGES AND REVISION STATUS

Issue and Revision History				
First Issue	**Issue date**	**Prepared by**	**Approved by**	
1.0	30/11/2012	Pierré Smit	Mpho Mothoa	
Version number	**Revision date**	**Revised by**	**Approved by**	**Reason for change**
1.1	29/02/2016	R. Schneeweiss	B. Uris	Periodic review
Version number	**Revision date**	**Revised by**	**Approved by**	**Reason for change**
1.2	01/03/2017	I Shaduka	J. Mwenze	Periodic review
1.3	25/04/2018	I Shaduka	J. Mwenze	Periodic review
1.4	25/06/2021	S Gaeseb	J. Mwenze	3-yearly review ECC application
1.5	05/09/2024	S Gaeseb	J. Mwenze	3-yearly review ECC application

The official copy of this file is available on the Rössing HSE intranet. Before using a printed, uncontrolled copy, verify that it is the most current version by checking the document effective date on the Rössing HSE intranet.
A PRINTED COPY IS AN UNCONTROLLED COPY

Description / Typification of the environmental impact				Risk rating after mitigation			Compliance requirements and guidelines (legislation and other regulatory frameworks)			How is the impact and aspect managed?			
Aspect (Hazard)	**Description of the scenario, i.e. how it can happen**	**Impact (Threat)**	**Description of the potential outcome, i.e. what can happen**	**Consequence**	**Likelihood**	**Risk rating**	**International**	**National**	**Rossing**	**Is the impact measured, monitored, reported and disclosed - internal, external? Are the management controls documented, reviewed, audited? Are preventative measures (avoidance, mitigation, rehabilitation) in place?**	**MONITORING FREQUENCY**	**PERMIT REQUIREMENT**	**Responsible Persons**
Air emissions	Burning of fossil fuel and the transport, storage, use and disposal of reagents and discarded items emits and releases gaseous substances (e.g. GHG) and vapours (e.g. chlorine)	Air pollution	The quality of ambient air worsens as a result of sudden and continuous releases of gaseous emissions, in the form of particulates, vapours and fumes.	Very Low	Unlikely	Class III	• United Nations Framework Convention on Climate Change, 1992 • Kyoto Protocol to the UN Framework Convention on Climate Change, 1997 • Vienna Convention for the Protection of the Ozone Layer, 1985 • Montreal Protocol on substances that deplete the Ozone Layer, 1987 • Import and Export Control Act 30 of 1994: Regulation No. 80 of 2004, Prohibition of the import into Namibia of ozone depleting substances • Labour Act, 11 of 2007 and its Regulations (gazetted in 1997) relating to the Health and Safety of Employees at Work • Environmental Management Act 7 of 2007 and Regulations (promulgated in 2012)	• Explosives Act 26 of 1956 and Regulations • Mines, Works and Minerals Ordinance 20 of 1968: Regulations • Atmospheric Pollution Prevention Ordinance 11 of 1976 • Import and Export Control Act 30 of 1994 • E1 Standard - Air quality, Noise control and Greenhouse Gases (GHG) and accompanying Guidance • E3 Standard - Biodiversity, Rehabilitation and Land use management and accompanying Guidance • RUL Closure Management Plan & Draft Mine Closure Framework.	All sources of GHG emissions are listed (JE65/PRC/001). Accordingly projections of energy consumption and GHG emissions are made and reporting against these projections are done monthly and annually.	Projections calculated monthly	No Permit Required	Environmental Advisor
	Mechanical and chemical processes and materials release fumes			Very Low	Likely	Class III				Annual stack emissions monitoring is done at the FPR to assess the efficiency of the stack filters. Chlorine detectors with an alarm system, for safety purposes, are in place at the sewage plant. Outcomes on several specialist studies (e.g. Volatile Organic Compounds) were done at various areas and indicated that the risk is low.	Annually (Stack emission)	No Permit Required	Environmental Advisor
	Sudden releases of non-inhalable particulate matter and nuisance dust from blasts, explosions, demolition activities, etc.	Air pollution and soil contamination	Non-inhalable particulate matter and nuisance dust pollute the air and after deposition (fall-out) can have adverse ecological impacts (e.g. on biological soil crusts, micro-fungi and cyanobacteria.	Very Low	Likely	Class II				Continuous improvement in air quality management is guided by the documented plan JE20/MMP/004. Air quality standards JE65/STD/001) and the air emission inventory (JE65/PRC/001). Dust suppression on unsurfaced roads in operational areas is done. A road sweeper is used on tarred surfaces. Engineering controls such as dust extractors, scrubbers and baghouses are in place at source of emissions. Best practices are shared. Wind direction, timing, stemming, etc. are considered in the planning of blasts.	Monthly (PM10, meterological data, dust fallout)	No Permit Required	Environmental Advisor
	Chronic release of non-inhalable particulate matter and nuisance dust from vehicular movement, earth moving activities and other operational activities (e.g. stack emissions, construction, grit blasting, crushing, stockpiling, etc)									Continuous improvement in environmental dust management is guided by the documented plan JE20/MMP/010. Dust fall-out is monitored and recorded internally - monthly on site and annually to Rossing - to reduce dust through innovative controls: Dust deposition sampling (JE50/PDN/003), Assessment of airborne particulates with multi-vertical samplers (JE50/PRN/006); Met One PM10-E Sampler (JE50/PRN/007 Exceedances are reported monthly. Regular inspections and audits are conducted. Clean-up of fall-out dust is part of rehabilitation and scheduled closure planning activities.			
	Wind erodes, transport and re-deposit tailings dust outside the tailings facility		Airborne tailings dust, in particular during wind events, pollute the air and can result in extensive contamination of the top soil after re-deposition	Very High	Likely	Class IV							
Noise and vibration	Acute vibration is generated from blasts, explosions, demolition activities, etc	Ecological disturbance - nuisance on humans & animals, and infrastructural damage.	Exposure to noise and vibration - chronic or acute - may keep animals away from pasture, water and migratory routes. Infrastructure damage	Very Low	Almost certain	Class II	• The United States Bureau of Mines (USBM) RI 8507 Criteria for safe blasting, 1980	• Explosives Act 26 of 1956 and Regulations • Mines, Works and Minerals Ordinance 20 of 1968: Regulations • Nature Conservation Ordinance 14 of 1975 • Minerals (Prospecting and Mining) Act 33 of 1992 • Minerals Policy of Namibia, 2003 • Environmental Management Act 7 of 2007 and Regulations (promulgated in 2012) • National policy on human-wildlife conflict management (2009)		Monthly (Noise & Vibration, Environmental noise)	No Permit Required	Environmental Advisor
	Chronic vibration is generated from operational activities (earthmoving, construction, crushing, stockpiling, etc)									The management and continuous improvement of environmental noise and vibration is guided by a Noise and Vibration Management Plan (JE20/MMP/008) Environmental vibration is monitored and measured according to a procedure JE50/PRC/002. Environmental noise is monitored and measured according to a procedure (JE65/PRC/003). Both impacts are monthly reported in order to minimize noise to threshold levels and to identify exceedances. Engineering solutions and continuous business improvements attempt to mitigate the environmental impacts of noise and vibration. Regular inspections and audits are conducted. Best practices are shared.			
	Acute noise is generated from blasts and sounds of other operational activities such as instantaneous bangs and hooches, sterms, etc												
	Chronic noise is generated from sounds of operational activities (e.g. earth moving machines and vehicular movements, and processes such as crushing, stockpiling, milling, construction, maintenance, etc.)												
Land clearance	The existing operational areas of the tailings facility, open pit, stockpiles, waste rock dumps, processing plant, solar PV plant, office areas and infrastructure, as well as cleared land (graded and bladed areas), compacted areas, sand and other borrow pits, earth piles and exploration areas comprise a total footprint of about 2640 ha at Rössing currently.	Habitat loss and habitat fragmentation	Operational activities within the existing footprint and continuous extensions (as a result of exploration drilling, patrolling, inspection, maintenance, etc.) and land clearance, grading and blading, compaction, borrow pits, sand piling and human-induced erosion modify the topography, disturb topsoil stability, create habitat fragmentation and degradation, reduce organisms and alter the ecological structure and functioning of the landscape.	High	Unlikely	Class III	• United Nations Convention on Biological Diversity, 1992	• Nature Conservation Ordinance 14 of 1975 • Constitution of the Republic of Namibia 1 of 1990 • Minerals (Prospecting and Mining) Act 33 of 1992 • Environmental Investment Fund of Namibia Act 13 of 2001 • Minerals Policy of Namibia, 2003 • Environmental Management Act 7 of 2007 and Regulations (promulgated in 2012) • National policy on human-wildlife conflict management (2009)	• E3 Standard - Biodiversity, Rehabilitation and Land use management and accompanying Guidance • RUL Closure Management Plan & Draft Mine Closure Framework.	The Mineral Waste Management Plan (JE20/MMP/009) guides the disposal of mineral waste. This is in close association with other over-arching management plans. Overall, land use management is guided by a drafted Land Use Management Plan (LUMP) (JE20/MMP/005). A land use database is kept to report on the geographical extent of the current footprint, per land use category. The georeferenced database, of the various disturbances caused by mining activities, is kept by the Survey Department. Changes in land use disturbance are reported annually to Rossing, according to the Land Disturbance Reporting procedure (JE65/PRC/004). Land use disturbances are managed by applying the mitigation hierarchy, in alignment with the Biodiversity Action Plan (BAP) (JE20/MMP/006) to minimize the footprint through avoidance, mitigation and rehabilitation. Access is patrolled and restricted internally by the Support Services department. Trespassing and illegal activities are reported and handled by the respective authorities. Annexure O: Draft Social and Environmental Management Plan Environmental clearance certificate	AD-HOC	No Permit Required	Protection services Environmental Advisor
	Extensions required by operational activities result in continuous encroachment into areas outside the current footprint.			High	Possible	Class IV							
	Linear infrastructure in and outside the footprint area cause landscape barriers		Linear infrastructure restrict migration routes and disturb the structure and functions (connections) of the landscape ecology.	High	Unlikely	Class II							
	Unpermitted vehicular movement on the land under the auspices of Rössing and into proximate protected areas.		Uncontrolled access to public and employees on informal and unproclaimed roads can favour illegal activities such as poaching and specimen collection and can also have knock-on affects such as biodiversity loss, topsoil compaction and result in landscape scars.	Low	Possible	Class III							
(Flood) lighting	Flood lights are used during the night to increase visibility for workers.	Biodiversity losses	The use of flood lights can change the habitat ranges of nocturnal species.	Low	Possible	Class III					N/A	Environmental clearance certificate	Environmental Advisor
Pesticides	Some pests are controlled through the use of pesticides.		Control of pests (with pesticides) can kill species indiscriminately.	Very Low	Rare	Class I	• United Nations Convention on Biological Diversity, 1992 • Stockholm Convention on Persistent Organic Pollution (POP) 2001	• Nature Conservation Ordinance 14 of 1975 • Environmental Management Act 7 of 2007 and Regulations (promulgated in 2012)	• E3 Standard - Biodiversity, Rehabilitation and Land use management and accompanying Guidance	Planned and controlled fumigation programs, with mitigatory measures, are in place. Invasions and genetic pollution potential is regarded as a low risk at Rössing. Biodiversity monitoring and information management is guided by a procedure (JE65/PRC/005).	Ad hoc as new chemicals get on site	No permit required	Foreman Maintenance Engineering & Projects Environmental Advisor Health Advisor
Biotic invasions	Conditions for invasive species (feral animals and alien plants) are favourable on site.	Genetic pollution	Multiplying of alien plants and feral animals can happen to the cost of natural biodiversity; hybridization can weaken biodiversity integrity	Very Low	Possible	Class I	• United Nations Convention on Biological Diversity, 1992			The drafted BAP (JE20/MMP/006) documents all impacts to biodiversity and is closely coupled to the LUMP (JE20/MMP/005). Through the BAP and LUMP the mitigation hierarchy is applied to to minimize the footprint through avoidance, mitigation and rehabilitation, to determine the residual impact and to calculate the need for having a positive impact - for example by means of additional conservation actions and offsets.	On-going	No permit required	Environmental Advisor Horticulture contractor
Hazardous materials	Transport, storage, usage and disposal of hazardous materials	Soil contamination	When hazardous materials are not contained during transport, storage, usage and disposal legislative, spillages and disposal of hazardous waste can occur and contaminate soil	Very Low	Likely	Class II	• The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, 1992 • Stockholm Convention on Persistent Organic Pollution (POP) 2001	• Soil Conservation Act 76 of 1969 as amended in 1978 • Hazardous Substances Ordinance 14 of 1974 • Petroleum Products and Energy Act 13 of 1990 and Regulations (of 1991 and 2000) • Environmental Management Act 7 of 2007 and Regulations (promulgated in 2012)	• E2 - Hazardous materials and non-mineral waste control and minimisation	A Hazardous Material and Contamination Control Management Plan (JE20/MMP/002) exists to guide continuous improvement in the environmental management of hazardous substances. Purchasing of chemicals is guided by a procedure (JA50/PRC/001) and the keeping of inventories and inspections of chemicals in laboratories is guided by a procedure (JE50/PRC/004) as well as checksheets, while Material Safety Data Sheets exist for all hazardous substances. Specific procedures guide the storage, transport, use and disposal of major consumables, such as sulphuric acid (JA50/PRC/005); hydrocarbon materials (JE50/PRC/006); sodium carbonate (JE50/PRC/006); sodium hydroxide (JE50/PRC/007); magnafloc (JE50/PRC/008); resin (JE50/PRC/009); iron oxide (JE50/PRC/010); manganese dioxide (JE50/PRC/011); solvents (JE50/PRC/012) Hydrocarbon spillages are cleaned up. The handling of hazardous materials and hydrocarbons is confined to designated areas. Decanting happens in dedicated areas with bunding, spillage trays, trenches and collecting sumps and is controlled by standard operational health and safety procedures. Maintenance schedules exist and regular inspections and audits take place to check the various controls (continuous monitoring system, emergency equipment e.g. sumps).	Regular inspections and audits	* Environmental Clearance Certificate * Permit for Used Mineral Oil * Import Permit: 009 for Sulphuric Acid * Permit for Explosive Magazine * Explosive Permits (15 tons Ammonium Nitrate Group 7) * Explosive Permit 30 tons matrix Group 5) * Ammonium Nitrate permit * Environmental Clearance Certificate for Service Station	* Environmental Advisor: Hazardous materials and non-mineral waste control * Processing -Senior Chemist * Procurement: Logistics & Supply Chain
Industrial effluent and Return Dam Solution (RDS)	Handling of industrial effluent and Return Dam Solution (RDS)	Soil contamination Groundwater contamination	Leakage, overflow and spillage of industrial effluent (from the plant, for example) and RDS (from Lake Andrew, for example) contaminate soil	Low	Almost certain	Class III	UNECE - The Water Convention and Protocol on Water and Health	• Water Act 54 of 1956 and Regulations • Mines, Works and Minerals Ordinance 20 of 1968: Regulations • Soil Conservation Act 76 of 1969 as amended in 1978 • Hazardous Substances Ordinance 14 of 1974 • Minerals (Prospecting and Mining) Act 33 of 1992 • Minerals Policy of Namibia, 2003 • Environmental Management Act 7 of 2007 and Regulations (promulgated in 2012) • Water Resources Management Act 11 of 2013	• E5 Standard - Water usage and quality management	Emergency pumps, trenches and sumps exist in the processing plant area where spillages can occur. In addition some surfaces are sloped and sealed (in the case of areas were hazardous substances are handled). Regular inspections and audits are conducted and maintenance schedules are followed. Waste water and effluent are reused at Rössing. List of procedures: "Rössing water strategy (JE05/STR/001) Rössing Water Management Plan (JA10/MMP/001). Operation and monitoring of the Seepage Control systems (JA50/OWM/SCP/002) Rössing water balance procedure (JA50/OWM/WBP/001) Water Quality Monitoring (JE65/OWM/004). Water Quality management (JE65/MSP/001) Water recycling and reuse (JE50/OWM/003). Weekly Determination of RDS and Seepage Evaporation Rates (JE65/OWM/005) Seepage Recycling on the Tailings dam (JE65/OWM/006) Treatment of TDX boreholes with Sodium hydroxide (JA50/OWM/WSM/004).	Weekly	Industrial and Domestic Effluent Disposal Exemption Permit	Processing: Tailings Dam & Water Management Project Hydrogeologist
Seepage	Management of seepage from the tailings facility		Overflow and / or dysfunction of seepage trapping facilities cause soil contamination	Very High	Likely	Class IV				* Continuous on automated systems * weekly on manual systems * Annual Water Quality Monitoring Program	Industrial and Domestic Effluent Disposal Exemption Permit	Processing: Tailings Dam & Water Management Project Hydrogeologist
Tailings	Management of tailings sludge	Soil contamination Biodiversity losses Groundwater contamination	Incorrect deposition of tailings sludge (outside the tailings facility) erosion and failure of the tailings dam wall can contaminate soil.	Moderate	Rare	Class II	Global Industry Standard on Tailings Management (GISTM)	ES Standard - Management of Tailing and Water Storage Facilities E5 - Water usage and quality management		Management of the tailings facility is guided by an operational manual for the paddy system and tailings deposition plan. Tailings management is in compliance to the current state license. Cleanup and removal of spillages of ore and tailings are regulated by means of standard operational procedures.	Daily and weekly	Industrial and Domestic Effluent Disposal Exemption Permit	Processing: Tailings Dam & Water Management
Non-mineral waste	Generation, collecting and disposal of non-recyclable non-mineral waste (including garden refuse,building rubble and sewage sludge)	Habitat loss and habitat fragmentation	Inappropriate reduction and inefficient ways to collect, transport and dispose non-recyclable waste can contaminate soil.	Very Low	Likely	Class II	• The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, 1992	• Soil Conservation Act 76 of 1969 as amended in 1978 • Hazardous Substances Ordinance 14 of 1974 • Petroleum Products and Energy Act 13 of 1990 and Regulations (of 1991 and 2000) • Environmental Management Act 7 of 2007 and Regulations (promulgated in 2012)	E2 - Hazardous materials and non-mineral waste control and minimisation	Management of non-mineral waste is guided by the Non-mineral Waste Management Plan (JE20/MMP/001). The plan contains targets to reduce non-mineral waste and operational activities of non-mineral waste management are guided by a procedure (JE50/WMP/001). Waste seperation for disposal and recycling happens at source. Designated luggerbins are provided for the disposal of non-mineral waste, according to procedure (JE50/WMP/001). Waste management facilities are inspected weekly and audited annually through 1ste, 2nd or 3rd party audits. Waste records are recordrd monthly and reported monthly and annually. Monitoring of the sewage plant (JE65/OWM/003). Operation of the sewage plant (JE50/SOP/003).	* Waste management facility is inspected regularly and audited annually (1st, 2nd or 3rd party audits). * Waste inventory reconciled weekly, monthly and annually	* Environmental clearance certificate	* Environmental Advisor: Hazardous material and non-mineral waste control and minimisation *Engineering & Projects: Contractor Management
	Generation, collecting and disposal of recyclable non-mineral waste		Disposal at the landfill site modifies the natural topography, reduce organisms and alter the ecological structure and functioning of the landscape.	Very Low	Rare	Class I	• United Nations Convention on Biological Diversity, 1992 • Minimum requirements for Waste Disposal by Landfill (South Africa, DWAF 1994)	• Environmental Management Act 7 of 2007 and Regulations (promulgated in 2012)		A procedure guides the operation and disposal practice at the landfill (JE50/WMP/006), which also designates the collecting and sorting, temporary storage and disposal areas at the landfill site.			
Unchannelled surface water	Free-flowing water erodes, transport and re-deposit loose material downstream	Fluvial erosion and soil contamination	Run-off from the mineral depositories (tailings facility and waste rock dumps) can cause downstream soil contamination.	Moderate	Rare	Class III	UNECE - The Water Convention and Protocol on Water and Health	• Water Act 54 of 1956 and Regulations • Soil Conservation Act 76 of 1969 as amended in 1978 • Hazardous Substances Ordinance 14 of 1974 • Environmental Management Act 7 of 2007 and Regulations (promulgated in 2012) • Water Resources Management Act 11 of 2013	• H4 - Hazardous substances management • E5 - Water usage and quality management • E3 - Biodiversity, rehabilitation and Land use management • RUL Closure Management Plan & Draft Mine Closure Framework.	Main releases from mineral waste storage facilities have the potential to contaminate aquatic pathways. A comprehensive control and monitoring system is operational to prevent contamination that derives from effluent from the plant area and tailings seepage. This includes a dewatering system with cut-off trenches and abstraction boreholes monitoring and seepage control, guided by the Water Quality Management procedure (JE50/MSP/001) and aligned to the procedures Operation and Monitoring of the Seepage Control Systems (JE50/OWM/002), Water Quality Monitoring (JE65/OWM/004), Water Recycling and Reuse (JE50/OWM/003), Weekly Determination of RDS and Seepage Evaporation Rates (JE65/OWM/005), Seepage Recycling on the Tailings Dam (JE65/OWM/006), Operation of the Seepage Plant (JE65/OWM/003), Monitoring of the Seepage Plant (JE65/OWM/003) and Operation of Septic Tanks (JA50/OWM/004). Infrastructure includes a borehole monitoring, seepage entrapment and a dewatering system with cut-off trenches and abstraction boreholes. Inside some areas working surfaces are sealed and sloped, accompanied by sumps with emergency pumps. Regular inspections and audits are conducted. Maintenance schedules exist. Soil erosion potential is negligible in the and environment where the mine is located. The risk of fluvial erosion of the waste rock dumps is thus low. The coarse nature of the tailings material and the inherent drainage characteristics result in an acceptable minimal risk of slope failure. For closure it is planned that the tailings facility will be capped with a waste rock cover to prevent possibilities of wind and water erosion. Mineral waste is characterized according to the Rossing Standard (E10). The potential to generate Acid Rock Drainage (ARD) for mineral wastes is low due to the absence of sulphide minerals and the low annual rainfall. Main ARD releases would contaminate aquatic pathways, but comprehensive control and monitoring systems are in place.	N/A	No Permit Required	Processing: Tailings Dam & Water Management Project Hydrogeologist
	Free-flowing and stationery surface water infiltrates	Groundwater contamination	Infiltration of run-off from the mineral depositories (tailings facility and waste rock dumps) and stationery surface water can cause groundwater contamination.	Low	Possible	Class III							
	Free-flowing water on the waste rock dumps may generate ARD (Acid Rock Drainage) primary products and mobilize and dispense ARD primary and secondary products			Very Low	Rare	Class I							
Spillage of contaminated water	The water management system to cope with leakages and overflows of contaminated water, run-off from contaminated areas and the erosion and failure of the tailings facility after heavy rainfall events as well as constant seepage from the tailings facility can cause unpredictable and unaccounted events of contamination		Dysfunction of run-off, effluent and seepage trapping facilities (for example during heavy rainfall events) result in soil contamination and radioactive contamination of aquatic pathways downstream (off-site).	High	Rare	Class III					AD-HOC	Industrial and Domestic Effluent Disposal Exemption Permit	Processing: Tailings Dam & Water Management Project Hydrogeologist
Leachates	Rainfall and disposal of water can create leachates from the landfill		Leachates from the landfill can contaminate groundwater	Moderate	Unlikely	Class II	• Minimum requirements for Waste Disposal by Landfill (South Africa, DWAF 1994)			At the landfill, downstream monitoring of groundwater is monitored according to the Water Quality Monitoring procedure (JE65/OWM/004). Emissions of greenhouse gases from the landfill is recorded monthly and reported monthly and annually.	Annual water quality monitoring program	Industrial and Domestic Effluent Disposal Exemption Permit	Processing: Tailings Dam & Water Management Project Hydrogeologist
Hazardous materials	Transport, storage, usage and disposal of hazardous materials		When hazardous materials are not contained during transport, storage, usage and disposal, spills can lead to groundwater contamination.	Low	Rare	Class I	• The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, 1992			Designated luggerbins are provided for the disposal of hazardous and contaminated waste according to the Non-mineral Waste Management Plan (JE20/MMP/001) and the accompanying procedure (JE50/WMP/001). Waste is compressed and then able to modified facilities (at Welwitia Bay).	Adhoc inspections and audits	* Environmental clearance certificate	* Environmental Advisor: Hazardous material and non-mineral waste control * Processing Operations: Tailings & Water Management
Hazardous materials	During transport, storage usage and disposal in abnormal (weather,collisions) conditions,	Soil contamination groundwater contamination air pollution biodiversity	Uncontrolled spillages and leakages of Hazardous materials can lead to soil, groundwater and air pollution, biodiversity in the immediate habitat	Moderate	Unlikely	Class III	The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, 1992	• Water Act 54 of 1956 and Regulations • Hazardous Substances Ordinance 14 of 1974 • Environmental Management Act 7 of 2007 and Regulations (promulgated in 2012) • Water Resources Management Act 11 of 2013	• H4 - Hazardous substances management • E5 - Water usage and quality management • E3 - Biodiversity, rehabilitation and Land use management	Transporting, Storing, Using and Disposing of Sulphuric Acid at Rössing JE50/PRC/014 Transporting, storing,using & disposing of anhydrous Ammonia at Rossing JE50/PRC/013 Transporting, storing, using & disposing of Manganese Dioxide at Rossing JE50/PRC/011 Transporting, Storing, using& disposing of solvents at Rossing JE50/PRC/012 Transporting, storing, using& disposing of Resin at Rossing JE50/PRC/009 Transprting, storing, using & disposing of Magnafloc 333 flocculant at Rossing JE50/PRC/008 Transport, storing, using& disposed of Sodium Hydroxide at Rossing JE50/PRC/007 Transport, storing, using& disposed of Sodium Carbonate at Rossing JE50/PRC/006	* Weekly acid line checks and adhoc inspections * Ammonia testing every Tuesday at 19H00	* Authorisation letter from Rossing MD for the underground storage of hydrocarbons * Clearance certificate for Service Station	* Environmental Advisor: Hazardous materials and non-mineral waste control
Hazardous materials	Fire/ explosions during transportation, usage, storage and disposal of Hazardous materials (Ammonium nitrate, Solvent, Resin)	Air pollution soil pollution biodiversity and habitat distruction groundwater contamination	During an explosion or fire of Hazardous material during transport, usage, and disposal, fujmes generated could affect air quality and fire fighting chemicals could contaminate the surrounding areas and ground water.	Moderate	Rare	Class II		Water Act 54 of 1956 and Regulations • Hazardous Substances Ordinance 14 of 1974 • Environmental Management Act 7 of 2007 and Regulations (promulgated in 2012) • Water Resources Management Act 11 of 2013		Transporting, storing, using& disposing of Resin at Rossing JE50/PRC/009 If an explosion or fire occurs offsite or on site the Emergency Response Team (ERT) will attend to the incident. The ERP is supported by the Business Resilience Management Plan (BRMP): JA20/MMP/007 .containment and clean up of the spilled material followed by soil rehabilitation Rossing has a procedure in place for fire emergency(JA60/PRC/005) on site.. for offsite fire emmergencies, the BRRP procedure Emergency Response Plan (JA20/MMP/008) will be applied..	* Fire Drill is practiced every year * Fire detection system installed	* Sasol Namibia Explosives Continuous Import Permits (<150 tonnes Ammonium Nitrate) *Sasol Namibia Explosives Continuous Import Permits (<30 tonnes Matrix)	* Environmental Advisor: Hazardous material and non-mineral waste control * Protection Services * Business Resilience Management Plan (BRMP)
Hydrocarbons	When hydrocarbons are not contained during transport, storage, usage and disposal spills can lead to contamination		Leakages and spillages (including localized explosions) of hydrocarbons can adversely affect groundwater quality.	Very Low	Unlikely	Class I				Hydrocarbons are controlled by standard operational procedures - Disposalle-use of Hydrocarbons (JE50/WMP/002); procedure for Action Taken in the Event of a Diesel /oil Spillage (JE50/WMP/010) Disposal of Oil/diesel filters (JE50/WMP/012) and Disposal of Oil Trap Residue to the Oil Separation Plant (JE50/WMP/015). Removal of hydrocarbons from water is guided by the Operation of the Oil Separation Plant procedure (JE50/OWM/001).	Adhoc inspections and audits	* Permit For Used Mineral Oil * Environmental clearance certificate	* Environmental Advisor: Hazardous material and non-mineral waste control *Engineering & Projects: Contractor Management * Processing Asset Management: Extraction Maintenance
Hydrocarbons	Major spill of hydrocarbons during transport, storage usage and disposal	Groundwater contamination habitat destruction surface water contamination	The hydrocarbon can infiltrate into theground and contaminate ground water resources, or reach open surface water and affect aquatic microorganisms and biodiversity in the immidiate habitat	Low	Rare	Class I	The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, 1992	• Water Act 54 of 1956 and Regulations • Hazardous Substances Ordinance 14 of 1974 • Petroleum Products and Energy Act 13 of 1990 and Regulations (of 1991 and 2000) • Environmental Management Act 7 of 2007 and Regulations (promulgated in 2012) • Water Resources Management Act 11 of 2013	• H4 - Hazardous substances management • E5 - Water usage and quality management • E3 - Biodiversity, rehabilitation and Land use management	Transporting, Storing, Using and Disposing of Hydrocarbon Materials at Rössing JE50/PRC/015 If a major spillage of hydrocarbons occur (for example: the rail tanker derailed while transporting diesel from Walvisbay to site and >1000 L is spilled), the Emergency Response Team (ERT) will attend to the incident. The ERP is supported by the Business Resilience Management Plan (BRMP): JA20/MMP/007 "Procedure for Action Taken in the Event of a Diesel/Oil Spillage" JE50/WMP/010". .containment and clean up of the spilled material followed by soil rehabilitation. bund walls to contain the entire content of the storage container	Adhoc inspections and audits	* Permit For Used Mineral Oil * Environmental clearance certificate	* Environmental Advisor: Hazardous material and non-mineral waste control *Engineering & Projects: Contractor Management * Processing Asset Management: Extraction Maintenance
Hydrocarbons	Hydrocarbon explosions and fires could be caused by lightning, electrical faults, people not adhering to safe work procedures, vehicle collision and accidents,	air pollution soil pollution biodiversity and habitat distruction ground water contamination	During an explosion or fire of hydrocarbons during transport, usage, and disposal, fujmes generated could affect air quality and fire fighting chemicals could contaminate the surrounding areas and ground water.	Moderate	Unlikely	Class II				Transporting, Storing, Using and Disposing of Hydrocarbon Materials at Rössing JE50/PRC/015 If an explosion or fire occurs offsite or on site the Emergency Response Team (ERT) will attend to the incident. The ERP is supported by the Business Resilience Management Plan (BRMP): JA20/MMP/007 .containment and clean up of the spilled material followed by soil rehabilitation. Rossing has a procedure in place for fire emergency(JA60/PRC/005) on site. for offsite fire emmergencies, the BRRP procedure Emergency Response Plan (JA20/MMP/008) will be applied..	Adhoc inspections and audits	* Permit For Used Mineral Oil * Environmental clearance certificate	* Environmental Advisor: Hazardous material and non-mineral waste control *Engineering & Projects: Contractor Management * Processing Asset Management: Extraction Maintenance
Excessive water use	Water is a scarce resource in Namibia and even more so in the Namib Desert, where Rössing is located.	Waste	Unwise use of water occurs in the form of unsound usage (e.g. washdowns), leaks and bursts and excessive evaporation of open standing water .	Very Low	Likely	Class II	UNECE - The Water Convention and Protocol on Water and Health	• Water Act 54 of 1956 and Regulations • Environmental Management Act 7 of 2007 and Regulations (promulgated in 2012) • Water Resources Management Act 11 of 2013	• E5 - Water usage and quality management • E3 - Biodiversity, rehabilitation and Land use management	Water use at Rössing is guided by controls such as the Freshwater Supply Management procedure (JA50/MSP/001), Freshwater Demand Planning procedure (JE20/OWM/001) and the Rössing Water Strategy (JE05/STR/001). Water consumption is monitored against water targets and the Water Balance procedure (JE65/OWM/001) and is reported monthly and annually. Freshwater constitutes about one-third of the total water consumption at Rössing since about two-thirds are recycled water obtained from the tailings facility.	Monthly	Khan River Abstraction Permit Industrial and Domestic Effluent Disposal Exemption Permit	Processing: Tailings Dam & Water Management Project Hydrogeologist
Drainage disturbance	Some operational activities (e.g. waste rock dumps, tailings facility, plant area and open pit) caused the permanent blocking and / or re-routing of drainage lines.	Habitat loss and habitat fragmentation	Altering of drainage lines caused species and habitat losses and disrupted the ecological structure and functioning of the landscape.	Very High	Almost certain	Class IV					AD-HOC	Environmental clearance certificate	Processing: Tailings Dam & Water Management Project Hydrogeologist
Abstraction	Water is extracted from the Khan River for the purpose to suppress dust, mainly in the open pit area.	Dewatering	Abstraction of water from the Khan River may result in the lowering of the water table and can have knock-on effects downstream - for users as well as for riparian vegetation.	High	Rare	Class III				Abstraction limits are permitted per agreement with the State, valid until 2026. The water abstracted is saline and only used for dust suppression. The abstraction of 600m3/day is below the safe allowable limit. Rössing Water Management Plan (JA10/MMP/001) Khan river Vegetation Monitoring (JE65/OWM/002) Rössing Water Management Plan (JA10/MMP/001). Operation and monitoring of the Seepage Control systems (JA50/OWM/SCP/002).	Monthly	Khan River Abstraction Permit Industrial and Domestic Effluent Disposal Exemption Permit	
Radiation	Release of uranium dust and radioactive residue enter atmospheric patheays.	Radioactive contamination	Radioactive contamination of atmospheric and downstream aquatic pathways may lead to exposures of employees and neighbouring communities	Low	Rare	Class I	• The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, 1992 • ICRP, (1993): Protection Against Radon-222 at Home and at Work. • ICRP, (1994): Dose Co-efficients for Intakes of Radionuclides by Workers. • ICRP, (1995): Age-Dependent Doses to Member of the Public from the Intake of Radionuclides: Part 4 Inhalation Dose Coefficients. • IAEA, (1996): International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources • IAEA, (1998): Radiation Protection Recommendations as Applied to the Disposal of Long-lived Solid Radioactive Waste. • IAEA, (2004): Occupational Radiation Protection in the Mining and Processing of Rare Materials • IAEA Safe Management of Wastes from the Mining and Milling of Uranium and Thorium Ores (Safety Series No. 85 of 2004)	• Water Act 54 of 1956 and Regulations • Atmospheric Pollution Prevention Ordinance 11 of 1976. • Atomic Energy and Radiation Protection Act 5 of 2005 and Regulations • Environmental Management Act 7 of 2007 and Regulations (promulgated in 2012) • Water Resources Management Act 11 of 2013	• E5 - Water usage and quality management • E1 Standard - Air quality, Noise control and Greenhouse Gases (GHG) and accompanying Guidance E3 - Biodiversity, rehabilitation and Land use management • RUL Closure Management Plan & Draft Mine Closure Framework. • E2 - Hazardous materials and non-mineral waste control and minimisation • H6 - Radiation • H7 - Carcinogenic substances	The mine Radiation Management Plan (JK20/MMP/001), approved by the NRPA and its implementation regularly audited by the same institution, details Radiation Safety Management at Rössing, including the public dose monitoring program. Existing critical groups are assessed to be exposed to less than 0.25 mSv/a as a result of operating conditions, or after mine closure. Comprehensive water management procedures are in place to prevent groundwater contamination. Measures include a borehole monitoring, seepage entrapment and a dewatering system with cut-off trenches and abstraction boreholes. No contaminated (radioactive) waste is allowed to leave site and this is disposed at a demarcated waste site situated on the tailings facility. Rössing applied for a license of this site from the NRPA, in alignment with the Radiation Management Plan. Records are kept monthly. Disposal of Contaminated Items (JK65/PRC/003). Non-Mineral Waste Management (JE50/WMP/001)	Annualy (isokinetic), Continuous on automated systems	No Permit Requirement	Environmental Advisor
	Leakages, spillages and overflows of contaminated water as well as constant seepage from the tailings facility can amplify the possibility of groundwater (radioactive) contamination.			High	Possible	Class IV					AD-HOC	Industrial and Domestic Effluent Disposal Exemption Permit	Processing: Tailings Dam & Water Management
	Spillage of ore and tailings from conveyor belts can cause radioactive contamination of soil, water and air.			Low	Unlikely	Class I					Monthly (Dust fallout and PM10) monitoring	No Permit Requirement	Environmental Advisor
	Contaminated (radioactive) waste is generated and disposed daily			High	Rare	Class III							
	Equipment may be exposed to radioactive contamination			Low	Almost certain	Class II					AD-HOC	No Permit Required	Radiation Safety Advisor
Operational activities	Land use disturbance (footprint) of Rössing as a result of the dimensional growth of mineral waste is constantly increasing.	Visual intrusion	Vertical growth of the tailings facility and the waste rock dumps are instrusive to

Consequence / Likelihood	1-Minor	2-Medium	3-Serious	4-Major	5-Catastrophic
A-Almost certain	Moderate	High	Critical	Critical	Critical
B-Likely	Moderate	High	High	Critical	Critical
C-Possible	Low	Moderate	High	Critical	Critical
D-Unlikely	Low	Low	Moderate	High	Critical
E-Rare	Low	Low	Moderate	High	High

Rating	Class	Risk management response
Critical	*Class IV*	*Risks that significantly exceed the risk acceptance threshold and need urgent and immediate attention.*
High	*Class III*	*Risks that exceed the risk acceptance threshold and require proactive management. Includes risks for which proactive actions have been taken, but further risk reduction is impracticable. However active monitoring is required and the latter requires the signoff by Business Unit senior management.*
Moderate	*Class II*	*Risks that lie on the risk acceptance threshold and require active monitoring. The implementation of additional measures could be used to reduce the risk further.*
Low	*Class I*	*Risks that are below the risk acceptance threshold and do not require active management. Certain risks could require additional monitoring.*

Consequence	MINOR	MEDIUM	SERIOUS	MAJOR	CATASTROPHIC
Non-Economic (Social and Environmental)					
HEALTH	Reversible health effects of little concern, requiring first aid treatment at most. Can include minor irritations of eyes, throat, nose and or skin, or minor unaccustomed muscular discomfort.	Reversible health effects of concern that would typically result in medical treatment. Can include temperature effects; travel effects; stress; and sunburn.	Severe, reversible health effects of concern that would typically result in a lost time illness. Can include acute / short-term effects associated with extreme temperature effects; or musculo-skeletal effects; vibration effects; nervous system effects; some infectious diseases; and non falciparum malaria.	Single fatality or irreversible health effects or disabling illness. Can include effects of suspected carcinogens, mutagens, teratogens and reproductive toxicants, progressive chronic conditions and/or acute / short-term high-risk effects	Multiple fatalities or serious disabling illness to multiple people. Can include effects of known human carcinogens, mutagens, teratogens and reproductive toxicants, and life-threatening respiratory sensitization and falciparum malaria
SAFETY	Low level short term subjective inconvenience or symptoms. Typically a first aid and no medical treatment.	Reversible injuries requiring treatment, but does not lead to restricted duties. Typically a medical treatment.	Reversible injury or moderate irreversible damage or impairment to one or more persons. Typically a lost time injury.	Single fatality and/or severe irreversible damage or severe impairment to one or more persons.	Multiple fatalities or permanent damage to multiple people.
ENVIRONMENT (on site)	Near-source confined and promptly reversible impact (Typically a shift)	Near-source confined and short-term reversible impact (Typically a week)	Near-source confined and medium-term recovery impact (Typically a month)	Impact that is unconfined and requiring long-term recovery, leaving residual damage (Typically years)	Impact that is widespread-unconfined and requiring long-term recovery, leaving major residual damage (Typically years)
ENVIRONMENT (off site)	Not applicable	Near-source confined and promptly reversible impact (Typically a shift)	Near-source confined and short-term reversible impact (Typically a week)	Near-source confined and medium-term recovery impact (Typically a month)	Impact that is unconfined and requiring long-term recovery, leaving residual damage (Typically years)
COMMUNITY (community trust)	Tangible expressions of trust / mistrust amongst a handful of community members with no influence on public opinion and decision-makers.	Tangible expressions of trust / mistrust amongst a few community members with some influence on public opinion and decision-makers.	Tangible expressions of trust / mistrust amongst some community members with moderate influence on public opinion and decision-makers.	Tangible expressions of trust / mistrust amongst most community members with significant influence on decision-makers.	Widespread loss / gain of trust across the community setting the agenda for decision-makers and key stakeholders.
COMMUNITY (stakeholder relationship)	Key stakeholder(s) express support / dissatisfaction informally.	Key stakeholder(s) express support / dissatisfaction formally.	Key stakeholder(s) threaten to oppose or disengage / strengthen offers to support or engage.	Key stakeholder(s) actively oppose or actively refuse to engage / actively support and engage.	Key stakeholder(s) oppose and actively get others to oppose / engaged and actively get others to support.
COMMUNITY (cultural heritage)	Reparable damage to site or item of low cultural significance occurs/avoided.	Irreparable damage to site or item of low cultural significance occurs/avoided.	Repairable damage to site or item of cultural significance occurs/avoided.	Irreparable damage to site or item of cultural significance occurs/avoided.	Irreparable damage to site or item of international cultural significance occurs/avoided.
REPUTATION	Community complaint resolved via existing site procedures. Impact on reputation of several work areas within an operation. One off public exposure in local media, word of mouth or local mythologies.	Impact on reputation of Business Unit. Significant public exposure in local media.	Impact on reputation of Product Group. Comment from national NGO which impacts credibility with neighbours/regional government. Public exposure in national media.	Impact on reputation of Rio Tinto Group. Comment from international NGO. Public exposure in international media.	Severe impact on reputation of Rio Tinto Group. Severe prolonged comment from international NGO. Greater than three years public exposure in international media.
CONFORMANCE / COMPLIANCE	Non-conformance with internal requirement with very low potential for impact. Non-compliance with external / community commitment goes unnoticed by external party/parties, requiring minimal effort to correct.	Non-compliance with external or non conformance with internal requirement with low potential for impact. Non-compliance with community commitment, requiring limited effort to correct.	Non-compliance with external or non conformance with internal requirement with moderate potential for impact. Moderate penalties for breach of legislation, contract, permit or licence. Non-compliance with community commitment reported formally, requiring significant effort to correct.	Breach of licences, legislation, regulation or repeated non-compliance with high potential for prosecution. Breach of contract with significant penalty clauses imposed. Systemic non-conformance with Rio Tinto work cycles or standards with high potential for impact.	Suspended or severely reduced operations imposed by regulators. Breach of community commitment results in direct loss of established consents with widespread secondary effects.
Economic Consequence types (Operational)					
Capital Costs	< 1.6%	1.6% - 5%	5% - 10%	10% - 30%	> 30%
Schedule	< 2.5%	2.5% - 7.5%	7.5% - 15%	15% - 45%	> 45%
Operation & Maintenance Costs	< 0.6%	0.6% - 2.5%	2.5% - 7.5%	7.5% - 15%	> 15%
Production Volumes	< 0.6%	0.6% - 2.5%	2.5% - 7.5%	7.5% - 15%	> 15%
Business Unit Revenue	< 0.25%	0.25% - 1%	1% - 3.5%	3.5% - 7%	> 7%

Likelihood	Likelihood description	Frequency	Substance Exposure
ALMOST CERTAIN	Recurring event during the life-time of an operation / project	Occurs more than twice per year	Frequent (daily) exposure at > 10 x OEL
LIKELY	Event that may occur frequently during the life-time of an operation / project	Typically occurs once or twice per year	Frequent (daily) exposure at > OEL
POSSIBLE	Event that may occur during the life-time of an operation / project	Typically occurs in 1-10 years	Frequent (daily) exposure at > 50% of OEL Infrequent exposure at > OEL
UNLIKELY	Event that is unlikely to occur during the life-time of an operation / project	Typically occurs in 10-100 years	Frequent (daily) exposure at > 10% of OEL Infrequent exposure at > 50% of OEL
RARE	Event that is very unlikely to occur during the life-time of an operation / project	Greater than 100 year event	Frequent (daily) exposure at < 10% of OEL Infrequent exposure at > 10% of OEL

CNNC
Rössing Uranium
Working for Namibia

ANNUAL ENVIRONMENTAL MANAGEMENT REPORT
2024

TABLE OF Contents

1 Introduction 5
1.1 Location 5
1.2 Shareholding 5
1.3 Scale of operation 6
1.4 Current life-of-mine 6
2 BRIEF DESCRIPTION OF THE ENVIRONMENT 6
2.1 Geology 6
2.2 Climate 6
2.3 Topography and soils 7
2.4 Biogeography 8
2.5 Surface and groundwater 8
2.6 Air quality 9
2.7 Sites of archaeological and cultural interest 10
2.8 Land use 10
3 ENVIRONMENTAL MANAGEMENT AT RÖSSING 11
3.1 The management system 11
3.2 Environmental monitoring localities 12
4 Environmental performance in 2024 12
4.1 Environmental awareness and training 12
4.1.1 World Environment Day 12
4.1.2 Birdwatching event 13
4.1.3 Snake Handling training 14
4.1.4 In-house waste management training 14
4.2 Clean-ups & Donations 14
4.2.1 Wapaleka 14
4.2.2 Project Shine 15
4.2.3 Donations to the community 16
4.3 Energy efficiency and greenhouse gas emissions 16
4.4 Air quality management 18
4.4.1 Environmental dust 18
4.4.2 Ambient dust fallout 19
4.4.3 Noise and vibration 20
4.5 Water management 22
4.5.1 Total water usage 22

4.5.2 Khan River water usage 23
4.5.3 Groundwater quality protection ..... **Error! Bookmark not defined.**
4.6 Waste management ..... **Error! Bookmark not defined.**
4.6.1 Management of non-mineral waste ..... **Error! Bookmark not defined.**
4.6.2 Management of mineral waste 27
4.6.3 Chemical substance management 27
4.7 Biodiversity management 28
4.8 Progressive rehabilitation 29

List of Figures

Figure 1: Location of Rössing mine **5**
Figure 2: Variation in annual rainfall at Rössing, (1984-2024) **7**
Figure 3: Temperatures measured at Rössing mine, 2024 **7**
Figure 4: Tokens of Sustainably Harvested Bamboo Utensil sets **13**
Figure 5: Team of enthusiastic learners, birdwatching at the Walvis Bay Lagoon. **13**
Figure 6: Snake handling training **14**
Figure 7: Teams participating in "Wapaleka Campaign". 15
Figure 8: Environment Day Mini Clean-up Campaign 15
Figure 9: Swakopmund community members during the clean-up sessions. 16
Figure 10: RAD truck offloading wooden pallets at COSDEC & Urban Agricultural project in Swakopmund. 16
Figure 11:: Energy consumption, 2011-2024 (gigajoules per tonnes of U3O8 produced) 17
Figure 12: Carbon dioxide emissions, 2015-2024 (tonnes of CO2 equivalent per tonne of U3O8 produced) **17**
Figure 13: PM10 dust monitoring network samplers and dust fall-out buckets **18**
Figure 14: PM10 dust monitoring network samplers and dust fall-out buckets **19**
Figure 15: Monthly average PM10 dust concentration, 2024 **19**
Figure 16: Monthly averages of daily boundary dust-deposition **20**
Figure 17: Air blast and Ground Vibration, 2024 **21**
Figure 18: Environmental noise over a period of 10 minutes, 2024 **21**
Figure 19: Freshwater use per month, 2024 (cubic meter) **22**
Figure 20: Water quality overview for 2024 **24**
Figure 21: Locations discussed for water quality. **Error! Bookmark not defined.**
Figure 22: Waste generated, recycled, and disposed during 2024. 27
Figure 23: Completed Progressive Rehabilitation Projects 29

List of Tables

Table 1: Geographical position of localities relative to wind direction **10**
Table 2: Mineral waste disposed in 2018-2024 (volume in tons) **27**

Acronyms and Abbreviations

µm	micrometre, 10^{-6} m
dB	decibel
cm	centimetre
CO	carbon monoxide
CO_2-e	carbon dioxide equivalent
CSIR	Council for Scientific and Industrial Research
DWA	Department of Water Affairs
EMS	Environmental Management System
FPR	Final Product Recovery plant
GHG	greenhouse gas
GIS	Geographic Information Systems
GJ	gigajoule
GJ/kt	gigajoules per kilotonne
HSE	health, safety and environment
HSE MS	Health, safety and environment management system
IUCN	International Union for Conservation of Nature
km	kilometre
L	litre
m	metre
M	mega, one million
m^3	cubic metre
mamsl	metres above mean sea level
MAWLR	Ministry of Agriculture, Water and Land Reform
mg	milligram
mg/kg	milligram per kilogram
mg/L	milligrams per litre
mg/m^3	milligram per cubic metre
mg/m^2	milligram per square metre
ML 28	Rössing Uranium Limited's Mining Licence 28
m/s	metre per second
m^3/s	cubic metres per second
MSDS	material safety data sheets
m^3/t	cubic metre per tonne
NO_x	nitrogen oxide
PM_{10}	particulate matter smaller than 10 microns in diameter
ppm	parts per million
SANS	South African National Standards
SO_2	sulphur oxide
SOP	standard operation procedure
TPH	total petroleum hydrocarbon
TPM	total particulate monitors
TSF	Tailings Storage Facility
UN	United Nations
UNSCR	United Nations Security Council Resolution
U_3O_8	uranium oxide
yellowcake	ammonium diuranate

1 INTRODUCTION

1.1 Location

Rössing Uranium Limited operates a large-scale, low-grade uranium mine in the Namib Desert, located in the sparsely populated Erongo Region of Namibia (Figure 1).

The mine is situated 12 km from the town of Arandis, which lies 70 km inland from the coastal town of Swakopmund.

The mine site covers a mining licence and accessory works area of about 180 km², of which 25 km² is used for mining, waste disposal, and processing. Rössing mine is located approximately 25 km upstream of the confluence of the Khan and Swakop rivers.

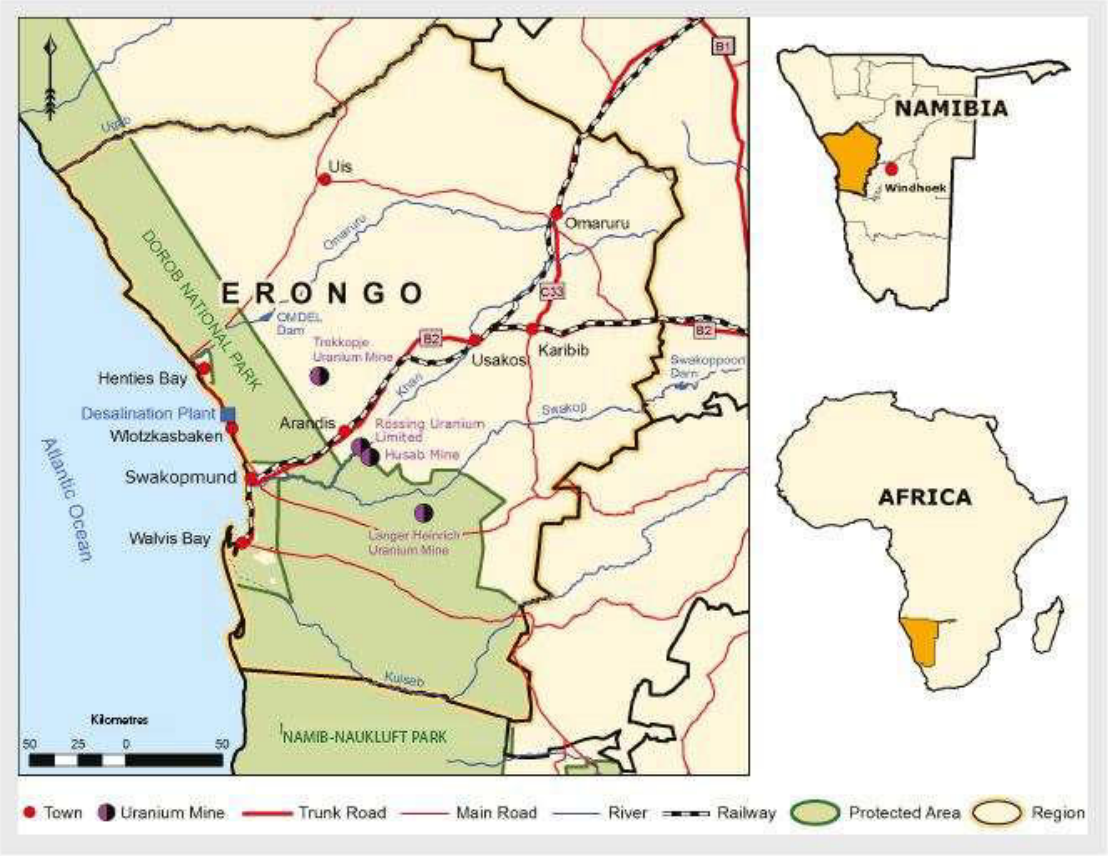


Figure 1: Location of Rössing mine

1.2 Shareholding

Rössing Uranium Limited's majority shareholder is China National Uranium Corporation Limited (CNUC), which holds 68.6% of the company's shares.

The Namibian Government maintains a 3% shareholding but possesses majority voting rights (51%) on matters of national interest.

The Industrial Development Corporation of South Africa owns a 10% stake in the company, while the Iranian Foreign Investment Company holds 15% of shares, an investment dating back to the company's establishment in the early 1970s.

The remaining 3% of shares are distributed among individual shareholders.

1.3 Scale of operation

Rössing is the world's longest-running open-pit uranium mine, operating continuously 24 hours a day, 365 days a year. It is one of two uranium mines currently active in Namibia and contributes significantly to global uranium oxide production.

In 2024, the production of uranium oxide for the year is 2,600 metric tonnes compared to 2,920 metric tonnes in 2023. A total of 30,334,678 metric tonnes (2023: 16,683,199 metric tonnes) of ore were mined from the open pit, while 8,486,056 metric tonnes (2023: 9,301,890 metric tonnes) of ore were milled.

1.4 Current life-of-mine

The current life-of-mine plan is ending in 2036 however, there are studies underway to inform feasibility of extending beyond 2036.

2 BRIEF DESCRIPTION OF THE ENVIRONMENT

2.1 Geology

The Rössing uranium deposit is situated within the central portion of the late-Precambrian Damara orogenic belt, a geological formation about 50 km wide that stretches northeast for more than 100 km in west-central Namibia. The Damara belt is characterized by folded, steeply inclined meta-sedimentary rocks-including gneiss, schist, quartzite, and marble-arranged in a northeast-southwest trending zone.

The geology of the Rössing mining area is dominated by a dome structure and features pegmatitic granite, known as alaskite, which intruded into the surrounding meta-sediments. Uniquely, Rössing hosts the world's largest known uranium deposit found in granite. The uranium ore varies greatly in both nature and grade, occurring as large masses or as narrow bands interspersed within barren meta-sediments.

Most of the primary and secondary uranium mineralisation is found within the alaskite, although not all alaskite is mineralised; much of it contains little or no uranium or is of sub-economic grade. Uraninite is the principal ore mineral, accounting for 55% of the uranium content, with secondary uranium minerals making up 40%, and the refractory mineral betafite comprising the remaining 5%. The average ore grade at Rössing is very low, at just 0.035%. The uranium ore is composed of 70–90% alaskite and is further classified into four types based on the host rock composition.

2.2 Climate

Rössing is situated in an arid area and receive very low annual precipitation. In 2024, the total annual rainfall received on the mine was 4 mm. The annual rainfall, and the long-term rainfall average, is displayed in Figure 2.

Rössing rainfall measurements indicate an average annual rainfall of about 27 mm over the years.

In terms of temperature, the variation between daily minimum and maximum temperatures are wide. The lowest temperatures are recorded during June and the highest temperatures are recorded in March, as shown in Figure 3. The coldest months usually begins in April and continues to July before temperatures start picking up again during summer.

In 2024, at Rössing the predominant winds experienced were blowing from west-southwest.

The combination of the low rainfall, high temperatures, the wide temperature ranges and prevalent winds result in high evaporation rates that vary between 6 and 15 mm per day. The potential evaporation is thus around 3,000 mm per annum.

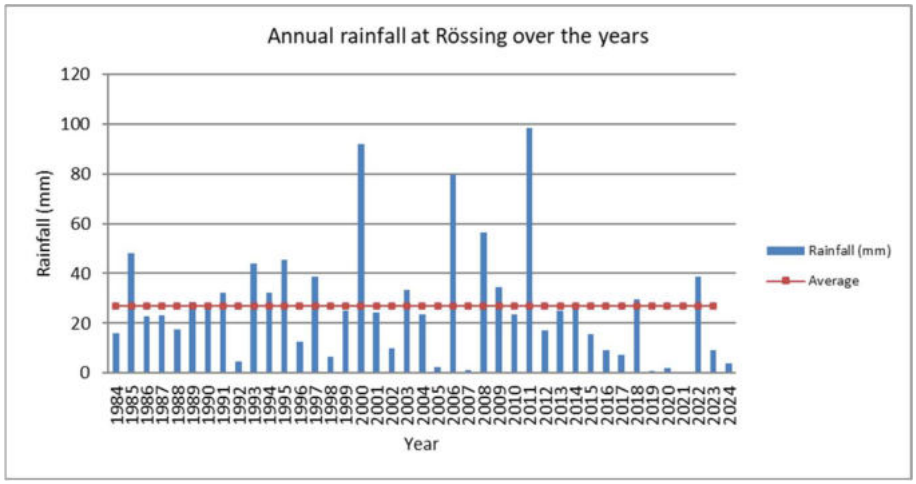


Figure 2: Variation in annual rainfall at Rössing, (1984-2024)

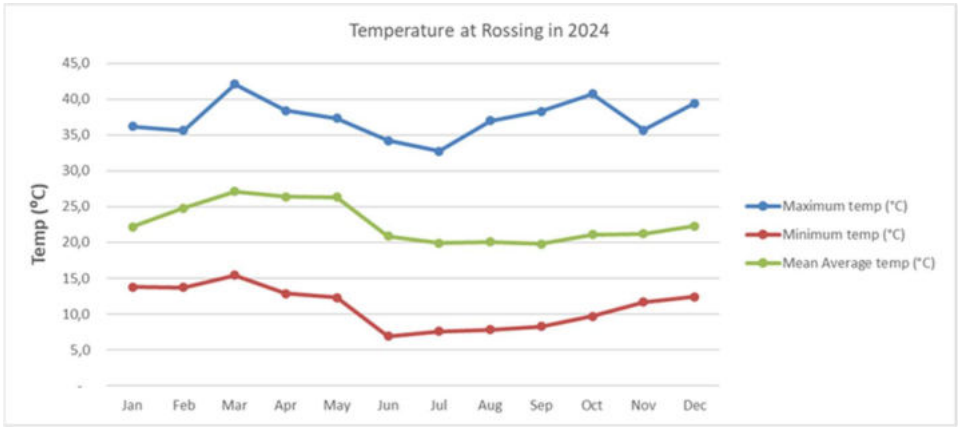


Figure 3: Temperatures measured at Rössing mine, 2024

2.3 Topography and soils

The Rössing tenement is situated at an average altitude of 575 meters above sea level. The western, northern, and northeastern parts of the area mainly consist of broad peneplains characterized by flat terrain. This landscape is intersected by shallow drainage lines and stormwater gullies that channel water into the Khan River. Moving closer to the Khan River, the flat plains transition into more undulating terrain, which becomes increasingly rugged approaching the Swakop River.

Soils around Rössing are generally shallow, typically less than 25 cm deep, and contain a high proportion of coarse fragments and occasional concretions. These soils exhibit high pH values and commonly feature hard surface and near-surface crusts. Such crusts reduce rainfall infiltration, leading to increased surface runoff.

In sheltered locations, sand deposits of varying depths occur, consisting of a mixture of dark to light brown grit, quartz, and feldspar fragments. Coarse materials are also found on the slopes of some hills, with deposit thicknesses varying up to approximately 1.5 meters.

The deepest soils are found along drainage lines and mainly consist of infertile, almost sterile alluvial deposits of varying thickness. Across much of the hill slopes and gravel plains within the mine tenement, the topsoil is shallow, poorly developed, infertile, and often absent.

2.4 Biogeography

On the gravel plains at Rössing, vegetation is dominated by sparsely-scattered dwarf shrubs and ephemeral grasslands. This is also the case for the undulating hills and mountains with sparse grass cover. A total of 21 biotopes are discernible to identify landform boundaries in association with ecosystem functions and characteristic plant species. To date, a total of 241 plants species have been identified in the mine vicinity.

Sparse riparian vegetation marks the drainage lines, in particular the Khan River. In general, vegetation relates strongly to the frequency, intensity and duration of flooding events. A few species dominate: Anaboom (Faidherbia albida, previously Acacia albida), Camel thorn tree (Vachellia erioloba, still more commonly known as Acacia erioloba), Tamarisk (genus Tamarix) and thickets of the Mustard tree (Salvadora persic). The relative denser riparian vegetation provides food and shelter to many animal species and sustains important migration and dispersal routes as a result.

A total of 272 species of ground-living insects are recorded at Rössing; this excludes flying groups such as moths and lacewings. The rocky hillsides, in particular those located along the Khan River, are regarded as the most important habitats of invertebrates.

The Namib Desert is known for its reptile diversity, particularly of lizards and geckos. At Rössing, 33 reptile species are expected to occur. Two species, Merolis sp. Nov and Pedioplanis husabensis, are of special concern. Three species of frogs are known to occur at Rössing. From a local perspective, the Khan River has the highest bird species diversity, indicating the importance of water availability and consequent-supported plant life, as well as the diversity of cliff habitats.

Mammal diversity at Rössing is not very high, as is typical in the central Namib. Climatic variation is closely coupled with marked changes in the abundance of animal species. Many of the animal species that occur around use a wide range of habitats or may cross a wide range in the course of migrating from one habitat to another. Common animal species include klipspringer, oryx, springbok, ostrich, kudu, Hartmann's zebra, dassie (rock hyrax), black-backed jackal, baboon and rodents (particularly gerbils).

2.5 Surface and groundwater

Open-surface water in the Namib Desert is a rarity and may occur only ephemerally during the rainy season. Flowing surface water on the mining licence area only occurs after heavy rainfall. Run-off in the drainage lines is an episodic, brief event and peaks and periods of run-off vary widely.

Due to their alluvium beds, the tributaries of the Khan River contain subsurface water flow for most of the year. Permeability of the alluvium is high, and the alluvium has also a high storage capacity with the water table being within 2 to 3 m of the surface.

Seasonal springs and small pools may occasionally form in the Khan River and in the gorges that drain into the Khan River. Only one natural perennial spring occurs in the Rössing area and is located in a side-arm of Panner Gorge.

Groundwater flows and rainfall seepage at Rössing is mainly along fractures and focus towards the gorges that drain into the Khan River.

Super-imposed on the natural groundwater system are sources and sinks created by mining. The open pit, more than 300 m deep, cross-cuts the hydrogeological connection between the existing Processing

Plant and the Khan River receiving environment. It acts as a cut-off trench and enables the interception and subsequent evaporation of potentially contaminated water moving downstream from the plant area.

The open pit also creates a cone of groundwater table depression that cuts off groundwater flow through bedrock and alluvial channels. Around the open pit, hydrogeological parameters of storage and permeability are very low.

The current elevation of the bottom of the open pit is substantially lower than the level of the Khan River (3 km to the south), and the regional water table (about 20 m below ground). The Khan River is also separated from the open pit by a low-permeability rock mass and the possibility of water from the Khan River entering the pit void is significantly reduced this way.

The natural groundwater quality in the vicinity of Rössing is very saline with total dissolved solids concentrations of 20,000 – 40,000 milligrams per litre (mg/L). The only groundwater potentially suitable for agricultural use near Rössing is found in the Khan River. This water is brackish and only suitable for livestock watering.

As a result of the high salinity of the water in the Khan River, the only beneficial uses of the water are for industrial purpose, such as dust suppression. Despite its salinity, the very hardy natural vegetation along the river depends on this water and abstraction is closely linked to monitoring of the water table.

2.6 Air quality

Rössing experiences high wind speeds, especially during winter, with historical gusts reaching up to 34.9 m/s. In 2024, the average daily wind speed was measured at 1.7 m/s, with the highest one-hour wind speeds recorded at 8.5 m/s during March and June. These elevated wind velocities contribute to the potential for airborne dust and other impurities.

The transport of dust and pollutants toward inhabited areas depends on the relative positions of receptor points and prevailing wind directions, as summarized in Table 1. While deposited dust generally does not pose a direct health risk, its visibility can lead to public complaints. Suspended dust particles smaller than 10 micrometres (PM10) can be inhaled and may affect human health depending on concentration and exposure duration.

Dust also poses environmental risks, as heavy metals can settle onto soil and plant foliage, causing ecological harm. To address concerns about nuisance dust potentially affecting lands adjacent to Rössing's mining licence area (ML 28), dust deposition is monitored at multiple stations around the mine.

Most dust generated in the open pit is fugitive, but blasting activities serve as point sources for particulate emissions. Large blasts occur approximately every two weeks, with smaller blasts two to three times weekly. As the pit deepens, the size and impact of blast dust plumes decrease. Dust from smaller blasts tends to settle within the pit on benches and roads, where it can be remobilised by wind and vehicle traffic.

Among eight common air impurities identified, five (SO_2, CO, NO_x, PM10, and dust deposition) are emitted at Rössing. However, only PM10 and dust deposition are considered significant and are regularly monitored. Annual monitoring of SO_2, CO, and NO_x is conducted, especially in relation to emissions from the yellow cake roasting process at the Final Product Recovery (FPR) plant. Greenhouse gas emissions, expressed as CO_2-equivalent, are estimated monthly based on fuel consumption, electricity use, and explosives for blasting.

Noise and vibration from mining and processing activities, including material handling and on-site transport, are also monitored to mitigate impacts on local communities and wildlife. Monitoring includes spot checks, targeted surveys, and regular risk assessments. Air blasts and ground vibrations

are additionally tracked for geotechnical purposes, such as assessing the stability of man-made landforms.

Table 1: Geographical position of localities relative to wind direction

Locality	Distance from mine	Direction	Relative to wind direction
Arandis Town	5 km	Northwest	Does not lie in the direction of E, NE, or SW winds
Arandis Airport	6 km	West	Lies in the direction of E wind
Swakopmund small holdings	50 km	Southwest	Lies in the direction of NE wind at a distance
Swakopmund Town	60 km	Southwest	Lies in the direction of NE wind at a distance
Walvis Bay	75 km	South-southwest	Lies in the direction of NE wind at a distance
Henties Bay	88 km	Northwest	Does not lie in the direction of E, NE, or SW winds

2.7 Sites of archaeological and cultural interest

A total of 49 archaeological and historical sites have been recorded within the Rössing area. While there is some evidence of occupation dating back to the upper Pleistocene, most sites are from the last 5,000 years. Notably, a cluster of sites is associated with grass-seed digging activities in well-drained soils derived from weathered granite, estimated to date post-AD 1000. These seed-digging sites are mainly found around low-lying granite outcrops with shallow depressions that may hold water after rains. Such locations are linked to traditional seed-gathering practices still observed by Damara-speaking communities today.

Historical sites in the area include remnants of the narrow-gauge railway that operated between Khan Mine and Arandis siding until approximately 1918.

Overall, the Rössing tenement is not considered an area of outstanding archaeological significance and lacks the dense site clusters typical of other regions of the Namib Desert escarpment and ephemeral river systems. The highest heritage value sites are located outside the main mining focus areas, where disturbance is minimal. Within the mining area and zones of high disturbance, heritage value is generally low, and the sites show low vulnerability to disturbance. Most archaeological and historical sites here are of low individual significance.

2.8 Land use

Apart from the town of Arandis, there is no significant active land use in the immediate vicinity of the Rössing mining licence area. Water resources in the region are extremely limited, making agriculture largely unfeasible-even along the ephemeral Khan and Swakop rivers. The nearest commercial farmland is situated approximately 15 km to the east, while communal land borders lie about 15 km to the north.

Closer to the coast, along the lower Swakop River, several smallholdings engage in commercial farming, producing asparagus, olives, mushrooms, and vegetables, primarily to supply Swakopmund and Walvis Bay. These areas also support tourism and leisure activities.

The Rössing mining licence area is located within the #Gaingu Conservancy. Population density in the conservancy, especially south of the main road, is very low. Approximately 720 hectares of the mining licence overlap with the Namib-Naukluft Park on the southern bank of the Khan River. The Dorob National Park lies about 10 km to the west of the mining area. Both parks are classified as Category 2 protected areas by the International Union for Conservation of Nature (IUCN).

3 ENVIRONMENTAL MANAGEMENT AT RÖSSING

3.1 The management system

All operational activities at Rössing are managed to ensure that impacts on both the biophysical and socio-economic environment are kept within acceptable limits. The mine operates under all relevant national legislative and regulatory frameworks, and its activities are guided by an integrated Health, Safety, and Environment Management System (HSE MS). This system aligns with international standards ISO 14001, ISO 45001, and ISO 9001, with Rössing holding ISO 14001 certification since 2001.

The HSE MS is designed to identify key health, safety, and environmental risks and aspects, guide operational procedures, and drive continuous improvement. All potential impacts are recorded in a business or site risk register, along with corresponding mitigation and operational controls.

Serving as a key tool for achieving Rössing's objectives and legal obligations, the HSE MS promotes efficient resource use and can yield financial benefits, resulting in a win-win for both environmental and business performance. The system is subject to regular external ISO audits, and in 2021, Rössing was successfully recertified for ISO 14001:2015, valid until 2024.

Since 2005, Rössing has also implemented Health, Safety, and Environmental Performance Standards to foster annual employee commitment to improving impact management. Under its current ownership, Rössing maintains these high standards and continues to apply robust systems for managing HSE risks across all facilities.

The overarching goals of environmental management at Rössing include:

- Assessing environmental impacts throughout all phases of mining, from design to decommissioning
- Developing and managing monitoring systems to maximize avoidance, minimization, and rehabilitation of adverse impacts
- Ensuring compliance with environmental regulations and management plans
- Reducing the use of non-renewable resources
- Maximizing positive environmental outcomes
- Avoiding, minimizing, and rehabilitating negative impacts
- Preventing contamination through containment, recycling, and removal measures
- Protecting and enhancing cultural, heritage, and archaeological resources
- Keeping communities informed and involved in decision-making
- Promoting awareness, training, and responsibility in environmental management

The formalized, integrated HSE MS enables Rössing to coordinate operations, personnel, equipment, and processes in line with best practices for environmental management. The system incorporates planning, implementation, checking, corrective action, and management review, supporting the identification of key environmental aspects and the development of standard operating procedures for continual improvement.

Annual HSE management reviews, conducted by senior leadership, are a vital part of this process. These reviews ensure the effectiveness of the HSE MS, help focus management attention, and authorize actions or resources needed to further improve HSE performance and compliance.

3.2 Environmental monitoring localities

The comprehensive environmental monitoring network at Rössing includes ambient dust fallout buckets, lithops monitoring, water quality monitoring boreholes, environmental noise and vibration and weather stations for meteorological parameters (see Appendix 5).

4 ENVIRONMENTAL PERFORMANCE IN 2024

Rössing's Environmental Management Plan contains a concise description of the management of environmental aspects and impacts at the mine, covering the various mine phases, from the designing to the decommissioning phase.

No significant environmental incidents occurred during 2024 and no deviation from the Environmental Management Plan was reportable to the respective authorities. In 2024 exploration activities in the Z20 area has commenced, park entry permits are in place from the Ministry of Environment, Forestry and Tourism (MEFT).

As a resource-intensive industry, Rössing's operations have the potential to impact on natural resources and the environment. For this reason, Rössing focuses continuously on improving environmental management programmes to maximise benefits and to minimise negative impacts. Key environmental management programmes include:

- Energy efficiency and greenhouse gas emissions
- Air quality control (including emissions of dust, other impurities, noise and vibration)
- Water management
- Waste management (both mineral and non-mineral waste)
- Chemical substance management, and
- Land-use management (including biodiversity, rehabilitation and closure).

As part of continuous improvement, there were notable improvements in the environmental monitoring space, as well as awareness on environmental aspects, such as waste management, air quality monitoring and water quality management. To mention a few:

- The Rössing access road, speed limit was reduced from 100km/h to 80Km/h to minimise vehicle/wildlife collisions.
- Snake and scorpion handling training aimed at safe capture and relocation of these animals.
- The use of Environmental stable isotopes as an additional tool to support existing methods of groundwater quality monitoring.
- Various progressive rehabilitation and clean-up projects were identified for action, these are aimed at minimising mine closure liabilities.
- A tailor-made training programme for each working area in addition to the annual HSE training & inductions.

The performance in 2024 with regard to the environmental management programmes is discussed in the next sub-sections.

Environmental awareness and training are integral components of our environmental management system.

4.1 Environmental awareness and training

4.1.1 World Environment Day

In 2024, World Environment Day was themed "Land Restoration, Desertification, and Drought Resilience." This theme highlights the critical need to address land degradation, combat desertification,

and enhance our resilience to droughts. As part of our commitment to the environmental stewardship, tokens of "Sustainably Harvested Bamboo Utensil Sets" were distributed to the workforce. In promotion of the 3R's, these tokens symbolize our dedication to sustainability and reducing single use plastics.

Figure 4: Tokens of Sustainably Harvested Bamboo Utensil sets

4.1.2 Birdwatching event

The Rössing annual birdwatching event was hosted at the scenic Walvis Bay Lagoon. The event aims to give participants an opportunity to view the unique birdlife, and to promote a long-term interest in birds, linked to conserving local and wilderness biodiversity.

The 2024 event attracted 114 learners from schools in Walvis Bay, Swakopmund, and Arandis. With the aid of a professional birdwatching guide, participants could identify different bird species and get insight into associated facts (differentiating physical features and reasons for their evolutionary adaptations, diets, migration routes, etc).

Learners were provided with binoculars and a printout with pictures of bird and their names, with which they could spot and identify different birds along the lagoon. A fun quiz was arranged for learners to participate and win prizes.

Figure 5: Team of enthusiastic learners, birdwatching at the Walvis Bay Lagoon.

4.1.3 Snake Handling training

Snakes and scorpions, which frequently wander into operational areas, are captured and relocated within the mining licence boundary. To ensure safe handling of the critters, the business annually offers a voluntary snake and scorpion handling course. In 2024, 10 employees received snake handling training from an external service provider. The course equips the volunteers with theoretical knowledge and practical skills required to safely capture and relocate the reptiles. Only trained and certified employees are permitted to handle snakes on the mine.

Figure 6: Snake handling training

4.1.4 In-house waste management training

The Rössing Environmental Performance Standard requires all employees who are involved with hazardous materials handling and waste handling to be trained so that they understand the environmental hazards and risks for routine activities and emergency actions.

To ensure compliance on waste management, regular inspections are carried out in workshops, storage, and disposal areas. The outcome of inspections from operations indicates that waste management is a challenge in most areas and there is a lack of basic understanding in waste sorting and segregation. This was addressed through customised training modules on waste management, in addition to the HSE trainings conducted among all employees. An estimate of over 300 employees including contractors attended the e-learning module and face to face Hazardous Material and Waste management training.

4.2 Clean-ups & Donations

4.2.1 Wapaleka

The “Lekka Wapaleka clean-up campaign” continued throughout the year as it’s of vital importance to always maintain housekeeping to avoid any possible HSE incidents (**Figure 7).**

Figure 7: Teams participating in "Wapaleka Campaign".

A mini clean-up initiative in celebration of the World Environment Day was held on the 05 June 2024, involving 60 employees who cleared litter along the access road from the mine entrance to the Arandis T-junction (**Figure 8**).

Figure 8: Environment Day Mini Clean-up Campaign

4.2.2 Project Shine

As part of our social responsibility, Rössing continue to support the Project Shine clean-up campaign under the management of Swakopmund municipality. Rössing was a founding member of the Project Shine initiative and with input from various stakeholders the mine sustained this project successfully since its inception.

Project Shine has been successfully managed since it was first launched in 2007 on World Environmental Day. The project aimed at minimizing negative impacts of pollutants on the environment and to encourage environmental cleanliness in Swakopmund and has been successfully achieved for over 10 years.

The project was launched on 08 March 2024 at the Swakopmund Municipal Council Chambers and runs over a period of 6 months. A total of 1340 bags were collected by the groups and disposed of at the landfill site.

In 2024, Rössing donated N$50 000 to the continuation of the project. The funds were earmarked for supporting projects shine to execute its mandate of cleaning-up the roads and an awareness/education campaign. Rössing has also committed to support the project with an evaluator and a 4x4 vehicle on monthly evaluation sessions. By supporting such initiatives, Rössing aim's to be the leader in environmental stewardship in Namibia.

Figure 9: Swakopmund community members during the clean-up sessions.

4.2.3 Donations to the community

RUL continue to promote the 3R's by supporting community projects through donation of timber (100 tonnes) to the vocational training centres (COSDEF, NIMT), Erongo Constituency offices, Sonstraaltjie kindergarten, Arandis Town Council, and the Urban Agricultural Project under the management of Swakopmund Municipality **(Figure 10)**.

Figure 10: RAD truck offloading wooden pallets at COSDEC & Urban Agricultural project in Swakopmund.

4.3 Energy efficiency and greenhouse gas emissions

As part of the environmental commitment and priority given to protecting the environment, Rössing measures and manages its greenhouse gas ("GHG") emissions and energy intensities. This assists in improving energy efficiencies and reduce GHG emissions. The sources of GHG emissions at Rössing include electricity and fuel consumption, the transporting of reagents and uranium oxide, blasting (use of explosives), waste management areas (the sewage plant, rubbish disposal, and landfill site), and the extraction and processing of ore. The intensity of emissions reported per unit of uranium oxide produced.

In 2024, the total energy consumption of the mine was 1,534,366 GJ for 2,600 tonnes of uranium oxide drummed. This converts to an annual energy consumption of 590 GJ per tonne (GJ/t) of uranium oxide produced, which is 14% below the projected internal target of 688 GJ/t uranium oxide produced (see **Figure 11).**

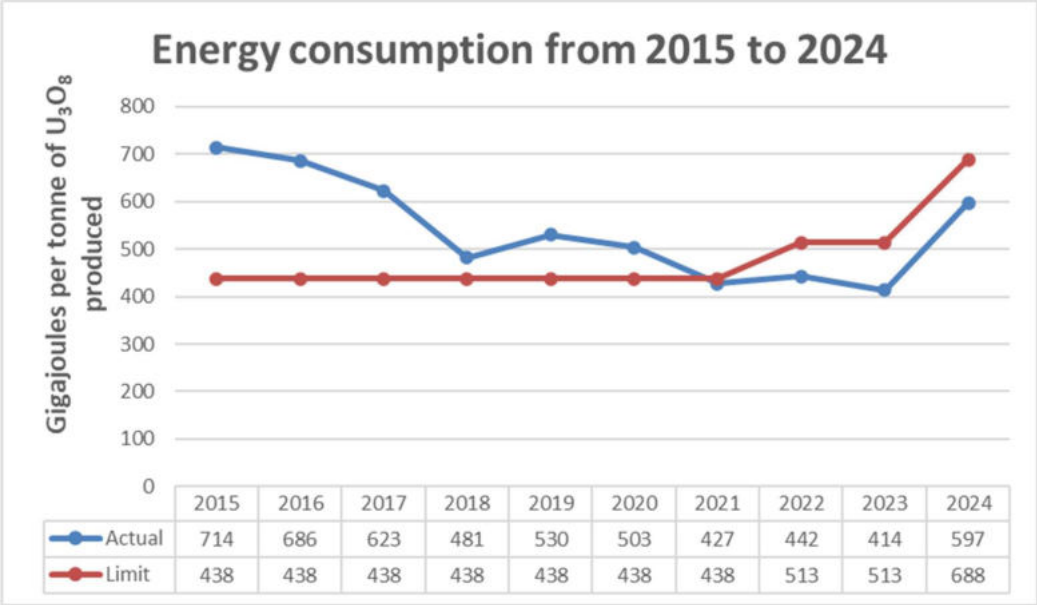


Figure 11:: Energy consumption, 2011-2024 (gigajoules per tonnes of U3O8 produced)

In the reporting year, emissions of carbon dioxide (CO2) per unit of production amounted to 65 tonnes of CO2 equivalent per tonne (CO2-e/t) of uranium oxide, which is 22% below the internal threshold of 83 tonnes CO2-e/t of uranium oxide for the year (**see Figure12).**

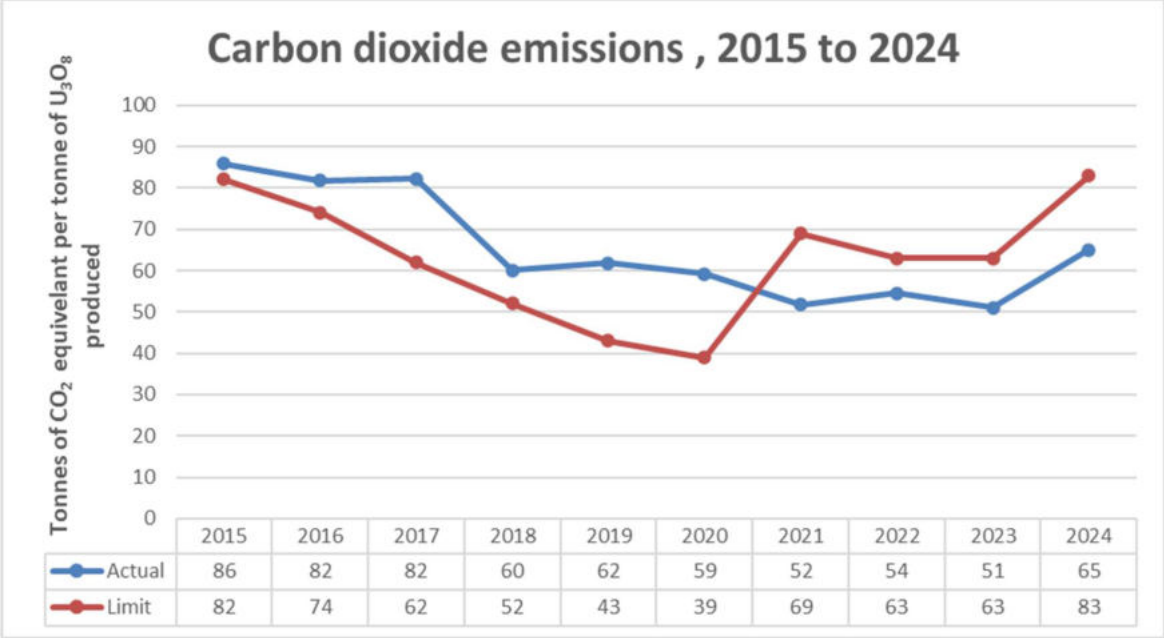


Figure 12: Carbon dioxide emissions, 2015-2024 (tonnes of CO2 equivalent per tonne of U3O8 produced)

Both the energy consumption per ton of uranium oxide and carbon dioxide emissions per unit of production exceeded internal targets due to the two-month shutdown in March and April. During this period, while production was halted, energy use and emissions continued, leading to high energy intensity per ton of uranium oxide and CO2 equivalent per tonne of uranium oxide.

4.4 Air quality management

Rössing Uranium over the years has setup an Air-quality Management programme that guides how to manage the environmental dust around the mine. The AQM Program in place helps in quantify dust and mitigation when necessary. Rössing Uranium commits to help protect the environment from the harmful effects of air pollution caused by mining activities. Therefore, Air emissions are listed in an inventory, and all air-quality standards applied at the mine are documented.

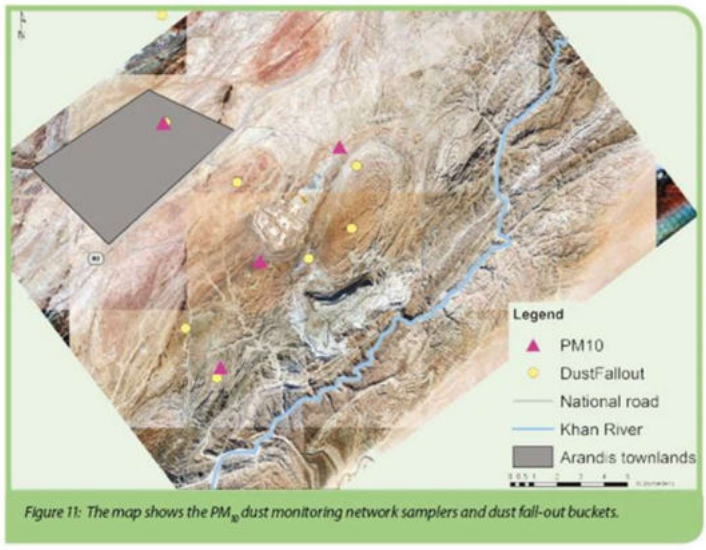


Figure 13: PM10 dust monitoring network samplers and dust fall-out buckets

4.4.1 Environmental dust

Rossing Uranium is situated in a desert environment, where it is windy during winter months. During the windy times dust can be transported up to several kilometres. Hence, dust is expected during the mining operations such as ours and of great public concern especially to the residents of Arandis and Swakopmund.

The AQM Program in place helps in quantify dust fallout and allow mitigation when necessary. The measures are taken to ensure that exposure levels do not exceed the adopted occupational limits and that the controls efficiently detect differentiations resulting from process changes etc.

There are two types of dust measured: firstly, a very fine inhalable dust invisible to the naked eye that is comprised of particulate matter less than 10 micron (known as PM10), and secondly, fallout dust, which is visible on the ground and comprised of lager particles, including PM10.

The measure of PM10 is the weight of particles less than or equal to ten micrometres in diameter in one cubic metre of air. When inhaled, these tiny particles are not filtered out by the body and therefore reach the lungs.

We monitor PM10 dust levels onsite at three dust monitor stations and at one station in the nearby town of Arandis **(see Figure 14).**

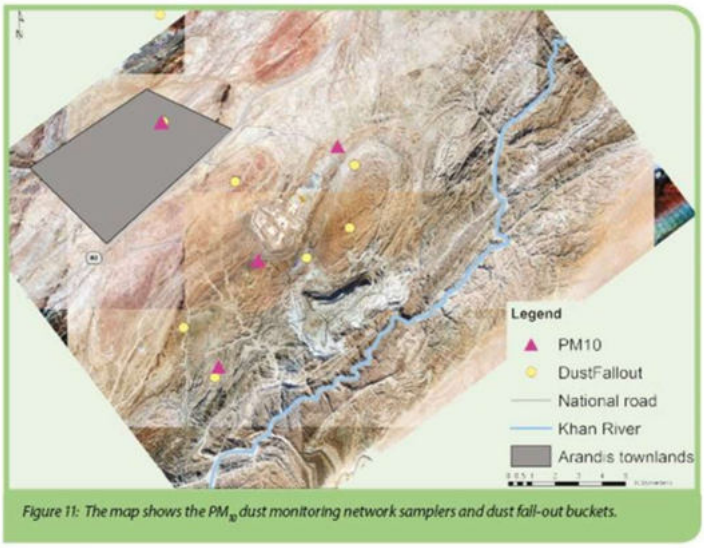


Figure 14: PM10 dust monitoring network samplers and dust fall-out buckets

The levels measured in 2024 showed that the PM10 dust concentrations at the available stations were all below the adopted World Health Organization standard of 75µg/m3 (see Figure 12). Monitoring equipment availability was a challenge in 2024, as our aging units became faulty – a replacement strategy has been approved. Availability of the Arandis, Boundary and Tailings stations were prioritised, in that sequence. The station at the Communications Management Centre (CMC) was sacrificed, as it is located upwind of the predominant wind direction – replacement unit is expected in early 2025.

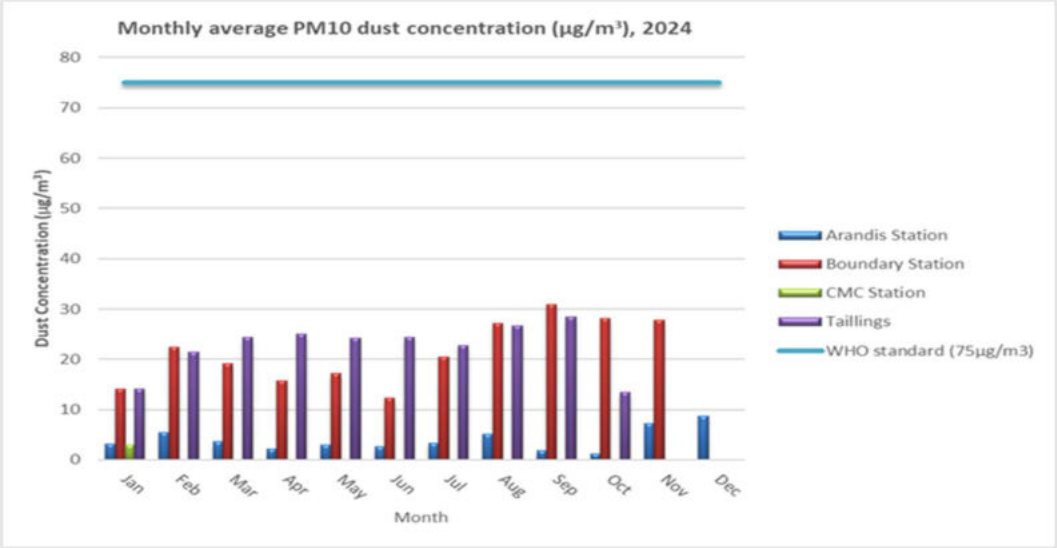


Figure 15: Monthly average PM10 dust concentration, 2024

4.4.2 Ambient dust fallout

Dust fallout is measured as aspect of the air quality management at Rössing as a result of our mining activity which may adversely affect the surrounding environment and residential inhabitants.

Rössing has adopted to the South African National Dust-control Regulation (SA NDCR) and World Health Organisation in the absence of Namibian legislation, the limits are 600 mg/m2 per day for

residential and 1,200 mg/m2 per day for non-residential areas with an annual average target of 300 mg/m2 per day.

Fallout dust is measured at six stations at different locations along the mine The dust fallout limit is 600mg/m2 per day , as required by the adopted South African National Dust-Control Regulation ("SA NDCR") standard.

During 2024, values measured at the six stations ranged between 3 and 93 mg/m2 per day (see Figure 16). All measured deposition rates were well below the selected or adopted South African dust-control regulation. All measured deposition rates were well below the adopted SA NDCR.

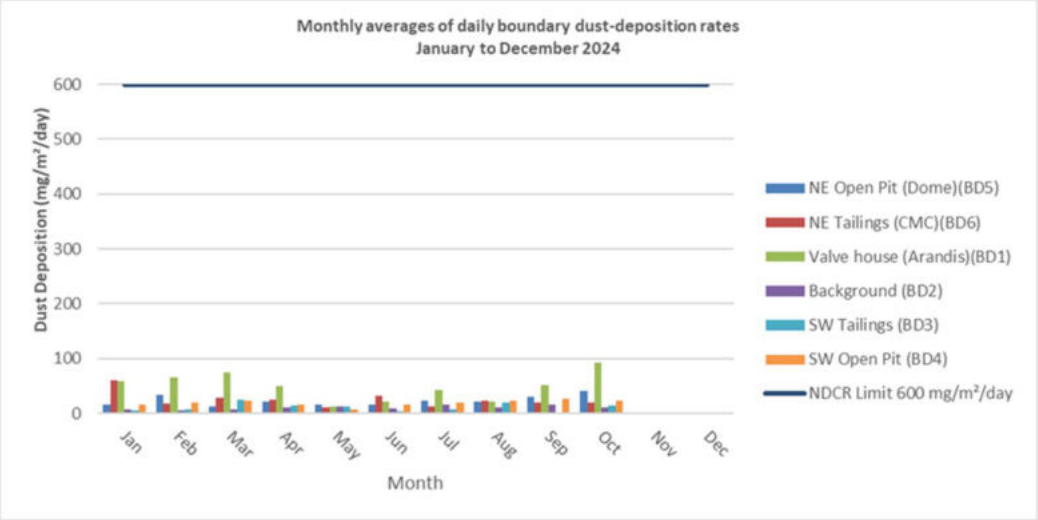


Figure 16: Monthly averages of daily boundary dust-deposition

4.4.3 Noise and vibration

As part of the Environmental Management Programme, Rössing Uranium limited (RUL) monitors Noise and Vibration among other activities. Namibia has no legislation on Environmental Noise and Vibration; therefore, RUL have adopted to the best practice or s**tandard**s of United States Bureau of

Mines (USBM) RI 8507 criteria for safe blasting, and for operational noise to the relevant South African National Standards Code of Practice, SANS 10103:2008 (SANS, 1992).

Ground vibration and air blasts is monitored during every blasting event. Blasting have a possibility of impacting on the general living conditions or lifestyle of a mine's neighbours. Thus, to monitor ground vibration and air blast, measuring points were established at the mine and in Arandis.

During 2024, both air-blast and ground vibration levels have been consistently below the limits of 134 dB and 12.5 mm/s respectively see **figure 17.**

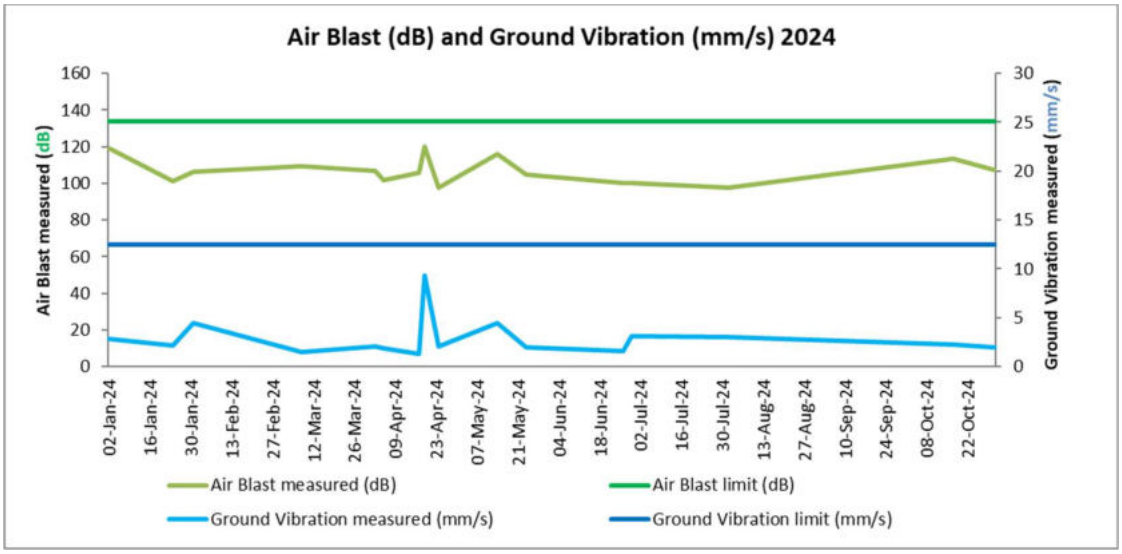


Figure 17: Air blast and Ground Vibration, 2024

Environmental noise is monitored and reported monthly. Environmental noise is measured over snapshots of ten minutes at six stations around the mine boundary. There were a few exceedances in 2024 during which noise levels, as recorded at the sampling points on the mine boundary, were above 45 dB(A) and, thus, has exceeded the standard (Figure). The events during which noise levels exceeded the standard are not attributed to the operational activities at the mine but are the result of natural sounds (windy) during the monitoring session.

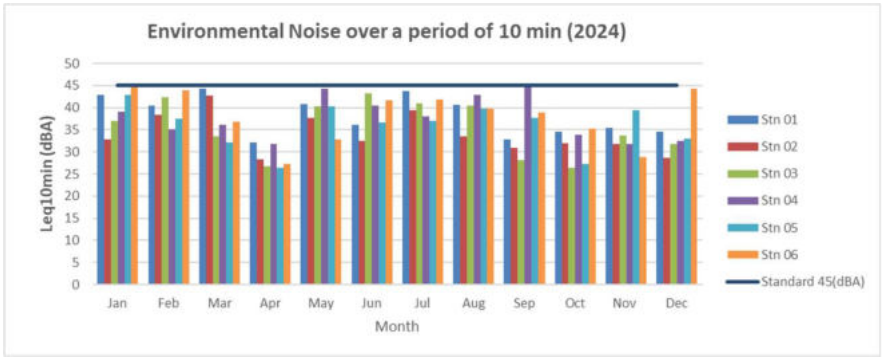


Figure 18: Environmental noise over a period of 10 minutes, 2024

4.5 Water management

Water management at Rössing is guided by a formal water strategy and Water Management Plan, which are developed according to our Performance Standard on "Water quality protection and water management".

Water management covers all activities connected to water abstraction, transport, storage, usage (potable and process), impounded water and groundwater. The intent of the Standard is to ensure efficient, safe and sustainable use and protection of water resources and ecosystems.

In accordance with the Namibian legislation, specifically the Water Resources Management Act No. 11 of 2013, the Ministry of Agriculture, Water and Land Reform (MAWLR) serves as the custodian of all water resources in the country. Under this mandate, MAWLR issued two permits to Rössing Uranium Limited (RUL). However, these permits are set to become obsolete on 28 February 2025 and will be replaced by new licenses. RUL has since submitted its application for the new licenses in compliance with the legislative requirements.

- Industrial and Domestic Effluent Disposal Exemption Permit # 674, and
- Khan River Water Abstraction Permit # 10 200.

4.5.1 Total water usage

The monthly freshwater usage (Figure 19) totals to 2.68 Mm^3 for 2024, this amount is 3.3 per cent below the planned 2.77 Mm^3 for the year. The planned fresh water annual volumes are based on planned tonnes to be milled for that year. Fresh water consumed per tonne of ore milled was 0.316 m^3/t and the ratio of fresh water to total water consumed was 0.36.

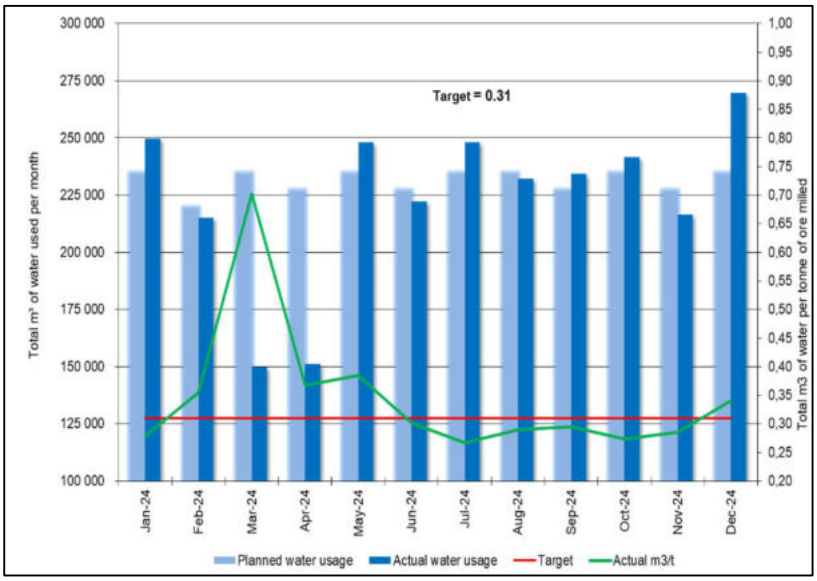


Figure 19: Freshwater use per month, 2024 (cubic meter)

Monthly freshwater usage was below the planned water usage for most of the months. Worth noting, is the actual water usage for March and April, which was severely affected by our annual maintenance shutdown Also, we had interruptions in water supply in November due to sulphur outbreak after which production was interrupted by several unprecedented pipe bursts, resulting in lower water usage against the planned target.

Monthly freshwater usage exceeded planned levels in January, May, July, September, October, and December, Figure 18. This deviation from plan was primarily caused by reduced seepage inventories due:

- Low Return Dam Solution (RDS) Recovery: Challenges in recovering solution from active paddocks.
- Transition to New Paddocks: Movement operations introduced inefficiencies.
- Water Entrainment in Slime: Increased water retention in residual materials.
- Pump Unavailability: Reduced water recycling efficiency.

Reduced seepage recovery required sustained freshwater input to meet the processing plants water demand during those months.

4.5.2 Khan River water usage

Saline groundwater from the Khan River aquifer, in conjunction with biodegradable dust suppressant polymers, is used to suppress haul-road dust in the open pit. However, no saline ground water was abstracted from the Khan River in 2024.

Although we didn't abstract the permitted volume, we continue to monitor the vegetation and water levels in the Khan River to prevent over-abstraction, based on the ecosystem response. In compliance with the abstraction permit conditions, annual reports derived from the water-level and vegetation-monitoring programmes are sent to the Ministry of Agriculture, Water and Land Reform.

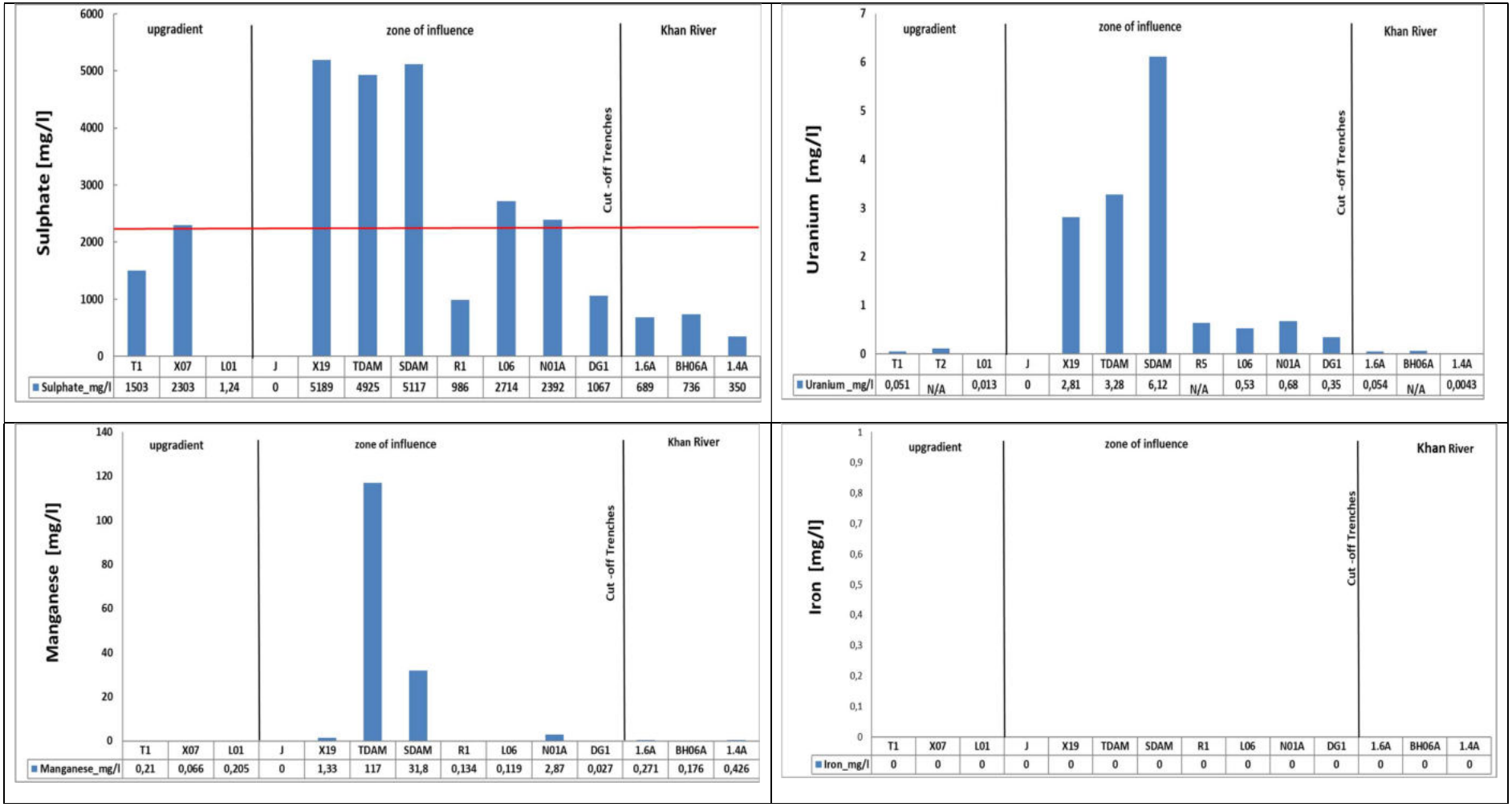


Figure 20: Water quality overview for 2024

Rössing developed a Non-Mineral Waste Plan (JE20/MMP/001) and a Non-mineral Waste Procedure (JE50/WMP/001) that addresses all non-mineral wastes generated through operational phases to ensure sound management through minimisation of waste generation and safe handling, treatment, and disposal of waste.

In 2024, waste was managed through an integrated waste management contractor appointed since 2016, ensuring proper treatment and disposal in line with permits licensing requirements and best practice. The waste contractor manages both hazardous and non-hazardous waste streams onsite and ensuring proper treatment and disposal.

As part of good corporate governance, RUL monitors all waste streams taken offsite for recycling purposes and disposal. All offsite facilities managing RUL waste, must be verified through an inspection assessment to confirm legal compliance of the facility and that waste is being managed properly. During 2024, the verification assessment was carried out at the Swakopmund Landfill Site, Rent-A-Drum and GAC facility with no major findings observed.

We continue to support the circular economy through the recycling and reuse of suitable waste streams. In 2024, 2,002 tonnes of recyclable waste were processed offsite, split as follows:

- 213 tonnes hazardous waste (mainly used oil and batteries)
- 1,789 tonnes non-hazardous waste (e.g. scrap metal, pallets, plastic, and packaging)

Key highlights:

- Used oil recycled: 206.4 tonnes
- Scrap metal recycled: 1,438.9 tonnes
- Wooden pallets donated: 201 tonnes to local schools, training centres, and community projects as part of the company's 3Rs (reduce, reuse, recycle) programme in support of local communities
- Tyres reused: 88.6 tonnes repurposed by a fishing company for harbour use

Onsite waste disposal/storage

- Certain contaminated waste streams (e.g. radioactive materials, air filters, processed mineral waste) are not permitted to leave the site. These are disposed of within approved, regulated zones onsite.
- In 2024:
- 59.9 tonnes of radioactive mechanical waste were safely disposed at the approved site
- 6,133 tonnes of hazardous contaminated waste (mining, plant, rubble) were placed at the TSF
- 168.9 tonnes of used tyres were stored onsite due to the absence of national recycling options
- We also safely stored radioactive contaminated grease and diesel drums from processing operations, pending the development of approved disposal routes.
- 1000 tonnes of hydrocarbon contaminated soil was successfully treated at the bioremediation facility and recycled back into operation for dressing.

During the year, 457.55 tonnes of hydrocarbon contaminated soil/sludge was transported to the facility for storage. Rent-A-Drum partnered up with SpillTech to treat the contaminated soil backlog (2684.23 tonnes) stored at the facility. For the first trial, two batches were treated, and the sampled results (C10 – C40) were 9 100mg/kg which is within the acceptable limits of Rossing (10 000mg/kg) and the South African soil screening values for total petroleum hydrocarbons. A total of 1000 tonnes of hydrocarbon contaminated soil was successfully treated and recycled back into operation for dressing.

Due to a lack of recycling facilities nationally, 171.05 tonnes of both light vehicle and HT tyres generated were collected and stored at the designated areas onsite. Due to a shortage of a storage capacity for the potentially radioactive contaminated hydrocarbons, a new yard was identified in the processing plant and commissioned. Contaminated grease and diesel drums generated from Final Product Recovery (FPR) are currently being stored at the new yard while the business investigates a long-term solution.

Garden and medical waste

Further enhancements in waste housekeeping were made in 2024. All historic and current garden refuse (1,352.3 tonnes) was cleared from dormant sites and disposed of at the Swakopmund municipal landfill.

Medical waste generated onsite (0.08 tonnes) was managed and incinerated through a registered facility.

Off-site disposal

The mine generates different types of hazardous waste streams, these includes used paper oil filters, hydraulic hoses, used grease, contaminated PPE, fluorescent tubes and others. RUL continuously ensure that our hazardous wastes are managed correctly and disposed of accordingly with a legally registered facility.

All non-recyclable and hazardous waste that qualifies for offsite disposal was transported to approved landfills.

- Hazardous waste: 27.9 tonnes (Walvis Bay Hazardous Landfill)
- Non-hazardous waste: 1,610.1 tonnes (Swakopmund Landfill)

To ensure that there are no footprints left in the environment, all off-site movements were accompanied by valid disposal certificates.

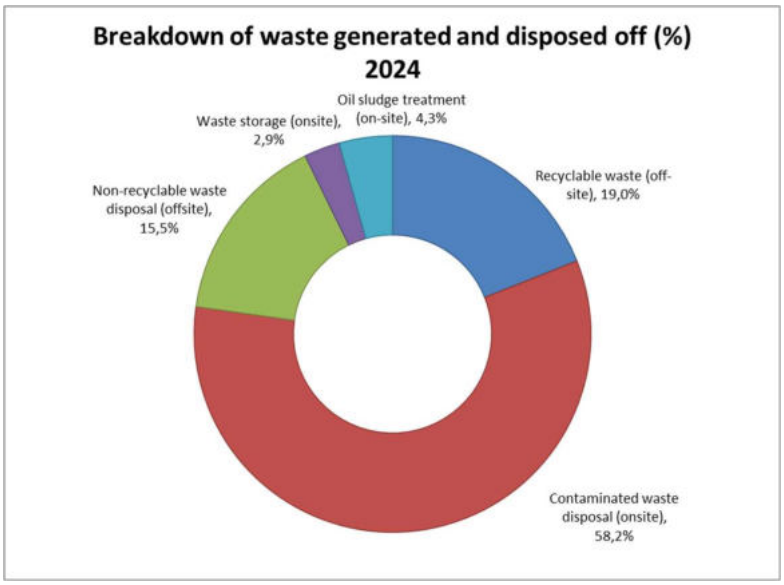


Figure 21: Waste generated, recycled, and disposed during 2024.

4.5.3 Management of mineral waste

In 2024, total mineral waste generated amounted to 28.3 million tonnes, comprising:

- 8.49 million tonnes of tailings
- 19.77 million tonnes of waste rock

The increase in waste rock, compared to 6.78 million tonnes in 2023, was due to the opening of two mining areas: Pit Bottom and Phase 4, with the latter contributing the bulk through overburden stripping.

By maximising in-pit dumping and placing waste on existing rock piles, we continued to limit land disturbance and improve operational efficiency.

Cumulative mineral waste generated over the past 48 years (as of Dec 2024):

- Total mineral waste inventory: 1,550.49 million tonnes consisting of:
  - Waste rock: 1,039.94 million tonnes
  - Tailings: 510.55 million tonnes

Total footprint: ~1,633.85 ha south-east of Arandis Town and north of the Khan River.

An updated inventory of mineral waste at Rössing is kept by mining engineers, Table 2 depicts volumes since 2018.

Table 2: Mineral waste disposed in 2018-2024 (volume in tons)

Year	2018	2019	2020	2021	2022	2023	2024
Waste rock dumps	11,459,319	13,289,588	10,000,000	10, 541, 648	7, 363, 794	6,783, 467	8,498, 486
Tailings storage facility	8,851,288	8,006,059	8,700,000	9,622, 798	8, 972, 926	9, 301, 893	19,770, 160

4.5.4 Chemical substance management

Rössing uses existing Namibian legislation, international standards such as ISO 14001:2015, as well as the Rössing Performance Standard E2 (Hazard materials and non-mineral waste control and minimisation) for conformances and compliance in terms of chemical substance management.

Rössing strives to ensure that all hazardous materials are handled safely and controlled responsibly, and all risks to the environment are mitigated. Thus, procedures are in place to prevent spillages and environmental contamination from the transport, use, storage, and disposal of hazardous materials. A Hazardous material and contamination control management plan (JE20/MMP/002) is in place at Rössing. The plan guides:

- safety and responsibility of usage and control of hazardous material handled by Rössing.
- control measures to minimise the risks and the environmental impacts due to spill or other escapes, and
- properly characterise and manage cases of contamination on site.

The plan also entails controls to prevent or minimise spillages during the handling and storage of chemical substances, conducting of routine inspections, monitoring procedures for leaks, integrity testing for deterioration of storage tanks and pipelines, spill and leakage detection equipment and emergency response plans. Regular internal and external audits, inspections and monitoring is conducted.

The Rössing standard requires an inventory of all hazardous substances and locations onsite to be maintained and valid material safety data sheet (MSDS) to accompany the hazardous material during storage, handling and transportation.

All employees who handle hazardous material are required to attend a compulsory training on hazardous material substances on an annual basis. Stakeholders (suppliers, service providers and end-users) are engaged to provide support in purchasing of chemicals and to ensure continuous improvement. Furthermore, the plan identifies the needs for engineering controls to prevent spillages into the environment, for example by means of constructing secondary containment bunds.

For the site preparedness, an acid derailment and ammonia drills were held on the mine access road and onsite to ensure that mitigation measures are in place. Both drills were a success with no major concerns/observation identified.

The biannual Environmental Monitoring Report for the operation of the existing consumer fuel installation was compiled by the Geo Pollution Consultants and submitted to MEFT in April and in September 2024 in compliance to the ECC. There were no major environmental non-conformance of hazardous material spillages/leakages reported in 2024.

4.6 Biodiversity management

The protection of environmental quality, including biodiversity, is important at Rössing. We take pride in the conservation of biodiversity within the ambit of the Rössing mining licence, in the surrounding communities, as well as in Namibia at large. Biodiversity management is a practice of protecting and preserving the wealth and variety of species, habitats, ecosystems, and genetic diversity on the planet, which is important for our health, wealth, food, and the services we depend on.

In 2024, Rössing continued to enshrine biodiversity protection in the Health, Safety, Environment and Communities (HSSEC) policy by assessing and considering ecological values and land-use aspects in investment, operational and closure activities. We continued to be proud members of the Namibia Environmental and Wildlife Society (NEWS).

Our goal remains to create a positive impact on biodiversity and contribute to conservation in Namibia at large. Rössing was involved in various biodiversity awareness campaigns, surveys, and assessments aimed at creating awareness and strengthening understanding about the importance of biodiversity amongst the workforce, communities and the Namibian population.

4.7 Progressive rehabilitation

Rehabilitation and land-use planning are critical to reducing environmental liability and ensuring the long-term sustainability of Rössing's mining footprint. Our approach prioritises progressive rehabilitation during operations rather than deferring action until closure, in line with international best practices.

Progressive rehabilitation involves the clean-up and restoration of disturbed areas throughout the life of mine. This proactive approach reduces future closure costs, limits environmental impact, and allows mining to continue uninterrupted.

In 2024, rehabilitation activities focused on:

- Clean-up of decommissioned or underutilised sites
- Waste removal from legacy storage areas for proper disposal
- Transporting waste to designated disposal zones to prevent long-term accumulation

Of 11 planned clean-up projects, three were completed, while nine were deferred to 2025 pending regulatory approvals - which have since been secured. One notable example includes the successful excavation and removal of redundant kerosene tanks from the solvent extraction (SX) plant.

Excavated and disposed redundant kerosene tanks which was buried at SX Plant

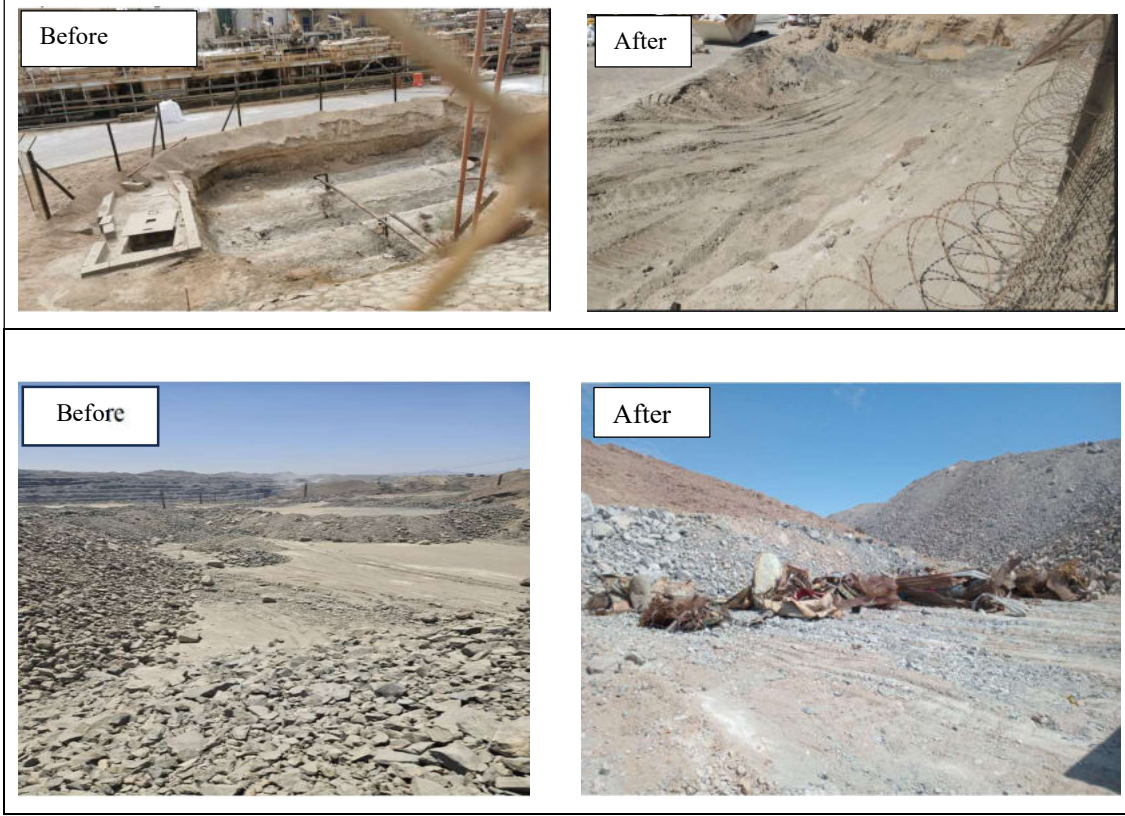


Figure 22: Completed Progressive Rehabilitation Projects

ECC – 00247 Serial: qZjmKR247

REPUBLIC OF NAMIBIA

MINISTRY OF ENVIRONMENT, FORESTRY AND TOURISM

OFFICE OF THE ENVIRONMENTAL COMMISSIONER

ENVIRONMENTAL CLEARANCE CERTIFICATE

ISSUED

In accordance with Section 37(2) of the Environmental

Management Act (Act No. 7 of 2007)

TO

Rossing Uranium Limited
P. O. Box 22391, Windhoek

.....

TO UNDERTAKE THE FOLLOWING LISTED ACTIVITY

Proposed Construction of Rossing Uranium Mine Desalination Plant near Swakopmund, Erongo Region.

MINISTRY OF ENVIRONMENT, FORESTRY AND TOURISM
Private Bag 13306
WINDHOEK, NAMIBIA
21 OCT 2022
ENVIRONMENTAL COMMISSIONER
REPUBLIC OF NAMIBIA

ENVIRONMENTAL COMMISSIONER

Issued on the date: 2022-10-17

Expires on this date: 2025-10-17

(See conditions printed over leaf)

Reduce
Reuse
Recycle

NAMIBIA IS NOT A TRASH BIN
RIGHT THING

This certificate is printed without erasures or alterations

ECC –

CONDITIONS OF APPROVAL

1. This environmental clearance is valid for a period of 3 (three) years, from the date of issue unless withdrawn by this office
2. This certificate does not in any way hold the Ministry of Environment, Forestry and Tourism accountable for misleading information, nor any adverse effects that may arise from these activities. Instead, full accountability rests with the proponent and its consultants
3. This Ministry reserves the right to attach further legislative and regulatory conditions during
4. the operational phase of the project
5. All applicable and required permits are obtained and mitigation measures stipulated in the EMP are applied particularly with respect to management of ecological impacts.
6. Strict compliance with national heritage guidelines and regulations is expected throughout the life-span of the proposed activity, therefore any new archaeological finds must be reported to the National Heritage Council for appropriate handling of such.

REPUBLIC OF NAMIBIA

MINISTRY OF ENVIRONMENT, FORESTRY AND TOURISM

Tel: (00 264) 61 284 2111
Fax: (00 264) 61 232 057

Cnr Robert Mugabe &
Dr Kenneth Kaunda Street
Private Bag 13306
Windhoek
Namibia

OFFICE OF THE ENVIRONMENTAL COMMISSIONER

NOTIFICATION OF DECISION

REF NUMBER: ECC- 00247 **DATE OF ISSUE: 18 OCTOBER 2022**

DETAILS OF PROPONENT:

Rossing Uranium Limited
P. O. Box 22391
Windhoek
Namibia

Dear Sir/ Madam

SUBJECT: NOTIFICATION ON APPLICATION FOR ENVIRONMENTAL CLEARANCE TO UNDERTAKE THE PROPOSED LISTED ACTIVITY: Proposed Construction of Rossing Uranium Mine Desalination Plant near Swakopmund, Erongo Region.

Notice is herewith given in accordance with section 37(2) of the Environmental Management Act, Act 7 of 2007 and Environmental Impact Assessment Regulations of 2012 (GG 4878): that a decision in respect to your application No. **APP 603** for Environmental Clearance Certificate to undertake a listed activity has been reached.

DECISION

An Environmental Clearance Certificate (ECC) to undertake the listed activities specified in the environmental assessment report and draft management plan dated September 2022, is granted (**ECC- 00247**). The_applicant / proponent is therefore advised to comply with conditions of approval set out in **Section C** of this notification.

A. **DETAILS OF THE PROPOSED ACTIVITY**

A1: TITLE OF THE PROPOSED ACTIVITY

Proposed Construction of Rossing Uranium Mine Desalination Plant near Swakopmund, Erongo Region.

A2: DETAILS OF ASSESSMENT PRACTITIONER

SLR Environmental Consulting (Namibia)
Robyn Christians
Tel: 061 231287
Mobile: 081 4176560

A3: LOCATION OF PROPOSED ACTIVITY

(Annexure A – proposed site map)

B. RELEVANT LISTED ACTIVITIES

Legislation	Description of Listed Activity	Relevance to Proposed Activity
Regulation 29(sub-regulation 5) of Government Notice No. 29 of 2012	INFRASTRUCTURE 10.1 The construction of- (a) oil, water, gas and petrochemical and other bulk supply pipelines; (b) public roads; (c) railways and harbours; (d) airports and airfields; (e) any structure below the high water mark of the sea; (f) cableways; (g) communication networks including towers, telecommunication and marine telecommunication lines and cables; (h) motor vehicle and motorcycle racing and test tracks; (i) the outdoor racing sites of motor powered vehicles including - (i) motorcars; (ii) trucks; (iii) motorcycles; (iv) quad bikes; (v) boats; and (vi) jet skis; (j) masts of any material or type and of any height, including those used for telecommunication broadcasting and radio transmission, but excluding - (i) flag poles; and (ii) lightning conductor poles. 10.2 The route determination of roads and design of associated physical infrastructure where - (a) it is a public road; (b) the road reserve is wider than 30 meters; or (c) the road caters for more than one lane of traffic in both directions.	Proposed Construction of Rossing Uranium Mine Desalination Plant near Swakopmund, Erongo Region.

C. CONDITIONS

C1: Conditions of Approval

1. This certificate does not in any way hold the Ministry of Environment and Tourism accountable for misleading information, nor any adverse effects that may arise from these activities. Instead, full accountability rests with the proponent and its consultants.

2. This Ministry reserves the right to attach further legislative and regulatory conditions during the operational phase of the project.

3. Regular environmental monitoring and evaluations on environmental performance should be conducted. Targets for improvements should be established and monitored throughout this process.

4. This environmental clearance is valid for a period of 3 (three) years, from the date of issue unless withdrawn by this office.

C2: Clearance Certificate Validity

1. On expiry of the ECC, the proponent is required to submit within a period not exceeding one month, and in the prescribed form and manner an application to the Office of the Environmental Commissioner for the renewal of the ECC.
2. Failure to renew an expired environmental clearance certificate shall result in permanent termination of the environmental clearance certificate.

3. In terms of Section 3 (2)C of the Environmental Impact Assessment, you are instructed to, within 14 days of this notice issuance date, ensure that all registered interested and affected parties (" I&APs") are notified that an environmental clearance certificate has been issued in respect to your application and of their right to appeal

C3: Compliance with authorization under other laws

4. All other applicable and required permits or authorization from relevant competent authorities must be obtained prior to commencing the proposed activities and accordingly adhered to.

C4: Implementation and Monitoring

5. The granting of the Environmental Clearance Certificate (ECC) constitute, an approval for the implementation of mitigation measures proposed in your approved Environmental Management Plan (EMP), hence making the approved EMP legally binding document.

6. The proponent shall appoint a suitably experienced environmental control officer, or site agent where appropriate, before the commencement of any listed activities to ensure compliance with the conditions of approval and mitigation stipulated in the approved EMP

7. A copy of the Environmental Clearance Certificate (ECC), EMP, Environmental Audit and monitoring reports must be kept at the site of the authorized activity and readily available for inspection by officials of the Ministry and registered Interested and affected Parties (I&APs) on request.

8. Should any heritage remains be exposed during excavations or any other actions on the site, these must immediately be reported to the National Heritage Council of Namibia. Heritage remains uncovered or disturbed during earthworks must not be further disturbed until the necessary approval has been obtained from National Heritage Council.

9. Using the best and affordable methodology, the Proponent must ensure that all listed activity's operations footprints are thoroughly rehabilitated prior to closure of the operation. Wherever possible, the Proponent must proceed with the rehabilitation process concurrently with the progression of the project rather than wait until the damage is far beyond the available means of management.

10. The general standard for all rehabilitation processes must at all costs aim at restoring the natural character of the environment to the satisfaction of the Ministry of Environment and Tourism. Such rehabilitation processes shall be inspected and certified satisfactory or unsatisfactory by the Ministry of Environment and Tourism. Where a certificate of unsatisfactory is issued, the Proponent shall be advised to carry-out certain tasks to meet the

requirements. Failure to meet the basic rehabilitation requirements shall be regarded by this Ministry as a breach of this contract and of which serious consequences shall follow.

11. Officials of the environmental commissioner's office may from time-to-time conduct spot-inspection (non-auditing) without prior notice and or Auditing Inspection (dates to be agreed prior to arrival to the site), hence access to the site and the aforementioned documentation must be granted to any authorized official representing the Office of the Environmental Commissioner and Registered Interested and Affected Parties (I&APs)

12. Any changes to, or deviations from the scope of the alternative described in section B above must be accepted or approved, in writing, by the Office of the Environmental Commissioner before such changes or deviations may be implemented. In assessing whether to grant such acceptance/ approval or not, the Competent Authority may request information in order to evaluate the significance and impacts of such changes or deviations, and it may be necessary for the holder to apply for further authorization in terms of the applicable legislation.

13. Officials representing the Office of the Environmental Commissioner must be, in possession and or by request and for the purpose of inspection referred to in C4(11) present their staff identification card in order to gain entry to the premises

14. The proponent is required, from the date of commencing implementation of project activities, to compile and submit environmental monitoring reports (on project progress and the environmental management profile) on a bi-annual basis to Office of Environmental Commissioner

15. Any changes to, or deviations from the scope of project activities approved in respect to the assessment received and reviewed for the purpose or granting this ECC Number (**ECC- 00247**) are subject to an amendment application and approval by the Environmental Commissioner prior to adopting / implementing any such changes / deviations.

16. For the purpose of amending and or transferring the ECC, the proponent submit in the prescribed form and manner an application to the Office of the Environmental Commissioner, clearly indicating the need for amendment and or transfer of the ECC

17. Non-compliance with a condition of this Environmental Clearance Certificate or EMP may render the Proponent liable to criminal prosecution.

D. DISCLAIMER

1. The decision taken by the Office of Environmental Commission is based mainly on information provided by the proponent or their representative, therefore, it must be noted here that the proponent is accountable for any wrong and misleading information that may have been presented in the environmental assessment documents.

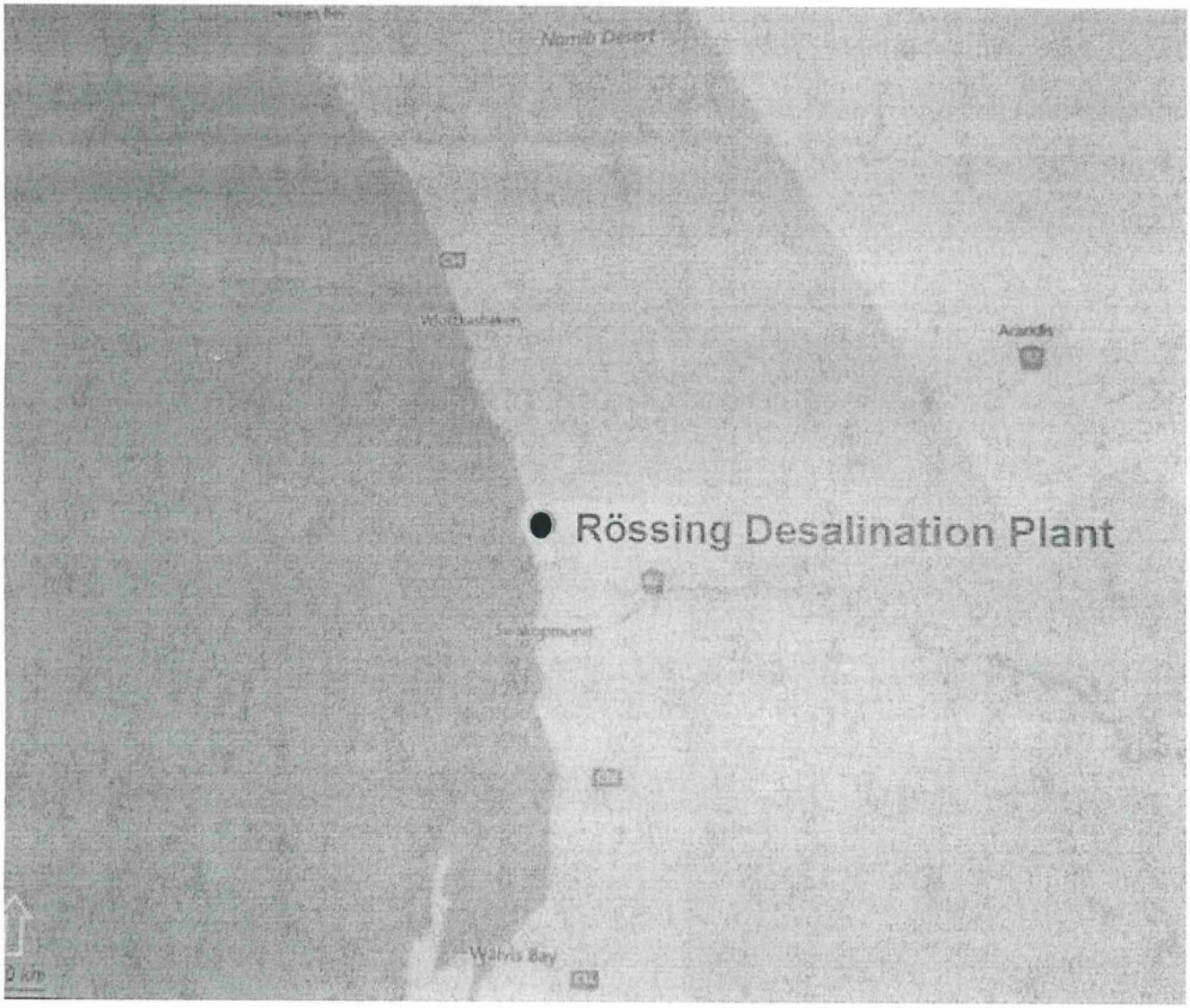
Yours sincerely,

MINISTRY OF ENVIRONMENT, FORESTRY AND TOURISM
Private Bag 13306
WINDHOEK, NAMIBIA
21 OCT 2022
ENVIRONMENTAL COMMISSIONER
REPUBLIC OF NAMIBIA

Timoteus Mufeti
ENVIRONMENTAL COMMISSIONER

ANNEXURE A: SITEMAP / SITE LAYOUT

Renewal of Environmental Clearance certificate for the proposed Rossing Uranium mine desalination plant near Swakopmund, Erongo Region



Stamp

CURRICULUM VITAE

Of

Stefaans Amandus Mu Antago Gaeseb

P.O. Box 5336
Mondesa
Swakopmund
Namibia

Cell phone: +264 812002769
Tel: +264 64 520 2741
Email: Stefaans.Gaeseb@rossing.com.na

PROFILE

Hardworking, team player, self-motivated, good communicator and dedicated Environmental Scientist with over 15 years working experience in Environmental Management, Hydrogeology, Hydrochemistry, Engineering & Economic Geology. Academically I hold a Bachelor of Science with Honours in Hydrogeology (University of the Free State) and Bachelor degree in Geology & Chemistry (University of Namibia). Have excellent computer skills, familiar with GIS and may adapt easily with any other software's. Have very good experience in project management in several sectors. Have strong interpersonal character, very good communication skills at all levels, adaptable to all weather conditions and enjoy travelling and field work. I have a valid driver's license (Code B).

WORK EXPERIENCE – FULL TIME

Timeline: *2016 – Present*
Company: Rössing Uranium Limited
Positions: Project Hydrogeologist (2016 - 2021)
Specialist Environment (2022 - present)

Task / Main Responsibilities:

Health, safety and environmental leadership; People management; Lead environmental develop plans and translate strategies into actions; Determine environmental footprint and improvements; Groundwater monitoring governance; Groundwater monitoring network designs, drilling projects supervision through all phases; Manage all environmental and asset resource information; Assess environmental aspects and impacts; Identify and manage impact assessments, projects and programmes; Risk management and audits; Land use management; Costing & budgeting and Drive business improvement.

Timeline: *2010 – 2016*
Company: Namib Hydrosearch cc
Position: Hydrogeologist

Task / Main Responsibilities:

Groundwater exploration (various geophysical techniques); Drilling supervision for groundwater (air percussion and mud rotary); Drilling supervision for mineral exploration (RC drilling, chip logging and sampling); Borehole rehabilitation supervision; Pumping test (supervision, data capture, evaluation/interpretation and reporting); Environmental Impact Assessments (EIA); Hydro census and water quality sampling for environmental work; Acid Base Accounting (ABA) sampling

Major projects:

Annual Drilling Tender 2010 in Caprivi & Erongo Regions (MAWF); Mineral Exploration Drilling Supervision at Swakop Uranium / Husab (2011); Test pumping of the Oanob aquifer in Rehoboth (2011); Groundwater Quality baseline hydro census survey at Okanjande Graphite (2012 – 2013); Quarterly groundwater quality monitoring for Tschudi Mine (2013 -2015); Borehole Rehabilitation Supervision 2013 in Kunene Region (MLR); Borehole Rehabilitation Supervision 2014 in Omusati Region (MAWF); Drilling and Test Pumping Supervision in Etosha National Park (MET); Annual Drilling Tender 2014 in Erongo Region (MAWF); Borehole siting in Omaheke Region (MET under Kalahari Namib Projects); Siting, Drilling and Test Pumping Supervision in Khaudum National Park (MET); Annual Drilling Tender 2015 in Erongo Region (MAWF).

EDUCATION AND QUALIFICATIONS

Bachelor of Science (with Hons) in Geohydrology (2012)
University of the Free State (UFS)
Institute for Groundwater Studies (IGS)

Bachelor of Science in Geology & Chemistry (2009)
University of Namibia (UNAM)

GRADE 12 - SENIOR CERTIFICATE (H/IGCSE) IN 2000
Delta Secondary School Windhoek (DSSW)

GRADE 10 - JUNIOR CERTIFICATE (JCSE) in 1998
Delta Secondary School Windhoek (DSSW)

REFERENCES

i. Jacklyn Mwenze
Manager: HSE & PS
Rössing Uranium Limited
Telephone: +264 81 140 5893
Email: jacklyn.mwenze@rossing.com.na

ii. Dr Danie Vermeulen
Head of Department
Institute for Groundwater Studies (IGS)
Telephone: +27 51 401 2317
vermeulenD@ufs.ac.za

iii. Diganta Sarma
Chief Geohydrologist
Namib Hydrosearch cc
Telephone: +264 81 275 3927
Email: diganta@geonamibia.com

iv. Prof. Benjamin Mapani
Professor: Mining Engineering
Namibia University of Science and Technology
Telephone: +264 81 298 7534
Email: bmapani@nust.na

PERSONAL DETAILS

Surname:	Gaeseb
First Names:	Stefaans Amandus Mu Antago
ID Number:	83072910650
Nationality:	Namibian
Gender:	Male
Religion:	Christian
Driving License:	Code B
Postal Address:	P.O. Box 5336
	Swakopmund, Mondesa
Contact Details:	gaeseb@gmail.com
	+264 81 2002769
	+264 81 1626191
Health:	Very Good
Spoken & Written Languages:	Damara Nama, English, Afrikaans