ENVIRONMENTAL ASSESSMENT OF NIMR ASSET - 2002 REVIEW AND UPDATE

PETROLEUM DEVELOPMENT OMAN

SULTANATE OF OMAN

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- 2002 REVIEW AND UPDATE

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EXECUTIVE SUMMARY

Introduction

This report updates the environmental assessment of Nimr asset (including Rima), which is under the oil south directorate within PDO's concession area in the Sultanate of Oman. The first environmental assessment for Nimr asset was carried out in June 1999. Since then, several changes with respect to the facilities, processes and procedures have taken place in the asset. In order to review the impacts on the environment due to these changes, the environmental hazards and effects associated with the activities in the asset are reassessed in this study. This study is conducted, on behalf of PDO by HMR Environmental Consultants during the period of June-December 2002.

Overview of Asset Activities and Facilities

PDO operates over 113,550 km^2 of concession area consisting of about a hundred fields, 2,454 oil producing wells and 72 gas producing wells. Currently, PDO produces 843,490 barrels/day of crude and 44 million Sm^3 of gas on average per day. Nimr is the largest asset in PDO, covering a land area of 16,160 km^2 and consisting of 6 major operating fields and 20 small oil fields and 710 producing wells.

The Nimr asset currently produces 35,669 bpd of crude (26.6% of PDO) and 780,000 Sm^3/d of associated gas (1.8 % of PDO). The total power generation in the asset is 76.7 MW and the total abstraction of groundwater in the asset is 2,988 m^3/d. The total length of flow lines in the asset is 607 km.

The asset releases about 3511 tpd of CO_2, 6 tpd of NO_x, 8 tpd of CO and 184 tpd of SO_2 and 33 tpd of HC into the atmosphere. The liquid effluents generated in the asset include 313,105 m^3/d of produced water and 601 m^3/d of sewage. The total hazardous waste produced is about 36,238 tpa. The total volume of accidental oil spills and leaks reported in the asset is 116 m^3 per year.

Description of Environment

Nimr asset (under oil south directorate) is located in the southeast part of PDO's concession area. The Rima and Al Noor assets are now a part of Nimr asset. The northern half of the asset area is quite arid, but several wadis drain through the southern part. The elevation of the asset is about 200 m above the mean sea level. The Nimr area is located on the eastern edge of the Nejd, which consists of undulating sand and gravel plains in the central and northern areas of the region, the geological setting of which consists of limestones with shale, dolomite and sandstone. The main prolific aquifer in the asset is the UeR, which is prolific but the groundwater is quite saline.

The region has an arid climate with mean monthly temperatures ranging from 17°C (January) to 35°C (June), and extreme temperatures ranging from a maximum of 45°C to a minimum of 6°C. The rainfall in scanty with an annual average of 34 mm, which is highly variable in time and space.

The vegetation is composed of desert plants and grasses, and there are no major trees in the asset except in those places irrigated by PDO using treated wastewater.

The fauna includes mammals and reptiles, which contribute substantially to the biological diversity of the region. Bird surveys at Nimr show an estimate of 43 species the majority of which are migratory. The Arabian Oryx Nature Reserve is an ecologically significant area adjacent to the asset area. Rima area falls within the nature reserve, but just outside the boundaries of an environmentally sensitive zone.

The total population in the asset is 492. The number of persons currently accommodated in PDO and contractor camps in the asset is about 1,560. The asset area is a thinly populated area and therefore has limited social infrastructure.

Groundwater is the only water resource in the region. Most of the potable water requirement for the population in Nimr asset, including the PDO and contractor camps is met with demineralised water from PDO's RO plants.

There is a cemetery on the south-eastern end, 5 km from the boundary of the Rima Asset. No other significance sites of cultural heritage are present in the Nimr Asset Area. However, the area of Al Zakhier in the south of the Asset is unexplored and may contain historical artifacts and other features of cultural importance.

Significant Environmental Effects

Based on the existing activities and the current status of the environment in the asset, the environmental hazards and potential effects are identified. The potential environmental effects are assessed based on the HEMP methodology outlined in PDO's document GU-195 "Environmental Assessment Guideline". The effects with a risk rating level of medium or higher are short-listed and the necessary additional mitigation measures are recommended. The following table summarizes the recommended additional mitigation measures against each of the environmental specifications of PDO, *viz.*, SP-1005 to SP-1012 and SP-1170.

Specification	Areas of Non-compliance or Concern	Recommended Additional Mitigation Measures
SP-1005: Specification for Emissions to Atmosphere	• Stationary sources of air emissions are not monitored to check compliance with emission standards. • Positive assurance of unlit flares is not available. In case of unlit flare, very high concentration of toxic H2S gas is vented to atmosphere leading to very high concentration of H2S at ground level • Ambient air is not monitored to check compliance with air quality standards.	• H2S laden off gases from the stripper in Al Noor shall be injected into the reservoir, instead of flaring. • All continuous air emission sources shall be monitored periodically, at least on quarterly basis. • Ambient air quality shall be monitored in accommodation camps periodically, at least on quarterly basis.
SP-1006: Specification for Aqueous Effluents	• Disposal of produced water into shallow aquifer is in practice. • The operation of some STPs is not satisfactory. The treated effluent quality often exceeds the standards. • The application of Standard A-2 for treated sewage quality is questionable since the irrigated areas are accessible to public. Application Standard A-1 will lead to repeated non-compliance. • Current STP monitoring frequency and schedule are inadequate. Once a day or once a week monitoring cannot detect if standards are breached during peak load times. • Technical proficiency of STP operators and supervisors is below par.	• Shallow water disposal shall be discontinued. • The issue relating to the application of Standard A-2 needs to be resolved, in consultation with MRME&WR. • STP monitoring frequency and schedule need to be revised to ensure compliance at all times. Monitoring frequency may be increased to 4 times per day for on-site measurements and composite samples may be taken for laboratory analysis. • All STP operators and supervisors shall be provided continuing education and training on STP operation and monitoring.

SP-1007: Specification for Accidental Releases to Land and Water	• Appropriate storage area for chemicals is not provided inside the Nimr production station. • No improvement in oil spill incidents has been achieved over the years. • It is likely that quantities of oil spills are under-estimated.	• Spillage containment and proper storage area shall be prepared for the chemical store inside the Nimr production station. • The oil spills / leaks shall be minimized through better pipeline and flow line integrity check. • All oil spill / leak incidents shall be responded to promptly to minimize quantities of release as well as quantity of soil contaminated. • More accurate methods for estimating the volumes of oil spills and the quantities of contaminated soil shall be evolved.
SP-1008: Specification for Use of Energy, Materials and Resources	• Optimal use of energy and water is not demonstrated as required in the specification.	• Avenues for minimization of water consumption shall be explored. • Monitoring of water wells shall be continued to ensure that there is no depletion of groundwater reserves.
SP-1009: Specification for Waste Management	• Waste consignments are not properly weighed or estimated. • Some wastes, such as rig site wastes are not segregated at source as required. • Waste compaction equipment is inadequate and some are non-functional. • Waste recycling is not significant. • There is no evidence of regular wetting of land farms.	• Compliance with waste handling procedures shall be enforced. • Waste operators shall be closely supervised. • Waste recycling avenues shall be explored at corporate level.
SP-1010: Specification for Environmental Noise and Vibration	• Ambient noise levels are not monitored to check compliance with the standards.	• Ambient noise levels shall be monitored in accommodation camps periodically, at least on quarterly basis
SP-1011: Specification for Flora and Fauna	• None	• None
SP-1012: Specification for Land Management	• There are several abandoned well sites, which require restoration.	• Site restoration shall be accelerated.
SP-1170: Specification for Management of Naturally Occurring Radioactive	• None	• None

Conclusion

Based on the present study, it is concluded that no change in PDO's existing HSE management system is required. However, it is necessary to modify the HSE plans and programmes in the asset by incorporating the additional mitigation measures recommended above. This will ensure that the potential environmental risks are minimized, non-compliances are eliminated and the overall environmental performance in the asset is significantly improved.

TABLE OF CONTENTS

Section		Title	Page
		EXECUTIVE SUMMARY	(i)
		TABLE OF CONTENTS	(iv)
		ABBREVIATIONS	(vii)
1		INTRODUCTION	
	1.1	Petroleum Development Oman	C1-1
	1.2	Environmental Impact Assessment	C1-9
	1.3	Objectives and Scope of Study	C1-9
	1.4	Method of Study	C1-10
	1.5	Structure of Report	C1-10
2		REGULATORY FRAMEWORK	
	2.1	Omani Regulations	C2-1
	2.2	Shell Group Environmental Guidelines	C2-2
	2.3	PDO Corporate Environmental Specifications	C2-2
	2.4	Environmental Standards	C2-3
3		ASSET DESCRIPTION	
	3.1	Asset Organisation	C3-1
	3.2	Activity Description	C3-4
	3.3	Gathering Stations	C3-5
	3.4	Production Stations	C3-5
	3.5	Power Stations	C3-9
	3.6	Water Treatment Plant	C3-10
	3.7	Auxiliary Facilities	C3-10
	3.8	Developmental and Construction Activities	C3-13
	3.9	Materials and Utilities	C3-15
4		RELEASES TO ENVIRONMENT	
	4.1	Introduction	C4-1
	4.2	Air Emissions	C4-2
	4.3	Liquid Effluents	C4-8
	4.4	Solid Wastes	C4-15
	4.5	Noise	C4-19
	4.6	Accidental Leaks and Spills	C4-20
5		ENVIRONMENTAL SETTING	
	5.1	General	C5-1
	5.2	Location and Topography	C5-1
	5.3	Geology and Soil	C5-2
	5.4	Hydrogeology and Groundwater Quality	C5-2
	5.5	Climate	C5-14
	5.6	Ambient Air Quality	C5-17
	5.7	Ambient Noise	C5-17
	5.8	Flora and Fauna	C5-17

5.9	Arabian Oryx Nature Reserve	C5-19
5.10	Human Settlements	C5-20
5.11	Land Use	C5-23
5.12	Social Infrastructure and Public Services	C5-24
5.13	Archaeological, Cultural and Recreational Resources	C5-25
6	ENVIRONMENTAL IMPACTS	
6.1	Methodology	C6-1
6.2	Potential Environmental Hazards and Effects	C6-1
6.3	Beneficial Impacts	C6-2
6.4	Impacts on Natural Resources	C6-3
6.5	Impacts on Air Environment	C6-5
6.6	Impacts on Water Environment	C6-7
6.7	Impacts on Land Environment	C6-8
6.8	Impact on Ecology and Wildlife	C6-10
6.9	Impact on Social Environment	C6-10
7	SUMMARY OF SIGNIFICANT EFFECTS AND MITIGATION MEASURES	C7-1
8	REFERENCES	C8-1

APPENDICES

1	Organisation Responsible for Preparation And Review of the Report	A1-1
2	Fuel Gas Analysis	A2-1
3	Details of Stacks	A3-1
4	PDO's Environmental Risk Evaluation Criteria	A4-1
5	Environmental Hazards and Effects Identification Matrix: Nimr Asset	A5-1

LIST OF TABLES

1.1	Description of Production Assets in PDO	C1-1
2.1	Environmental Laws and Regulations in Oman	C2-1
2.2	Shell Group Environmental Specifications	C2-2
2.3	PDO's Environmental Specifications	C2-3
2.4	Air Emission Standards	C2-3
2.5	Ambient Air Quality Standards	C2-4
2.6	Classification of Standards A-1 and A-2 for Re-use of Treated Wastewater	C2-7
2.7	Standards for Treated Wastewater Discharged on Land	C2-7
2.8	Maximum Permissible Metal Concentrations in Sludge	C2-8
2.9	Standards for Treated Wastewater Discharged into Marine Environment	C2-9
2.10	Applicable Requirements for the Use of Energy, Materials and Resources	C2-10
2.11	Classifications of Hazardous and Non-Hazardous Wastes	C2-10
2.12	Ambient Noise Standards	C2-11
2.13	Classification of Environmentally Sensitive Areas	C2-12
2.14	Land Management Requirements	C2-12
3.1	List of Facilities in Nimr Asset	C3-1
3.2	Details of Power Plants in Nimr Asset	C3-10
3.3	Details of Water Treatment Plant in Nimr	C3-10
3.4	Accommodation Facilities in Nimr Asset	C3-13
3.5	Consumption of Process Chemicals in Nimr Asset	C3-15
3.6	Consumption of Power, Fuels and Freshwater in Nimr Asset	C3-16
4.1	Inventory of Stacks in Nimr Asset	C4-3

4.2	Emission Loads from Stacks in Nimr Asset	C4-3
4.3	Inventory of Emissions from Flares / Vents in Nimr Asset	C4-5
4.4	Air Emissions from Area Sources in Nimr Asset	C4-7
4.5	Air Emissions from Mobile Sources in Nimr Asset	C4-8
4.6	Liquid Effluents Generated in Nimr Asset	C4-9
4.7	Design Specification of STPs in Nimr Asset	C4-11
4.8	Typical Characteristics of Treated Effluent Streams	C4-13
4.9	Details of Disposal of Produced Water and RO Plant Rejects + Backwash	C4-14
4.10	Treated Sewage Characteristics	C4-15
4.11	Solid Waste Generated in Nimr Asset	C4-16
4.12	Solid Waste Disposal Practice in Nimr Asset	C4-17
4.13	Details of Nimr Waste Management Centre	C4-18
4.14	Accidental Leaks and Spills in Nimr Asset	C4-20
5.1	Nimr Asset Boundary Coordinates	C5-1
5.2	Well Yield and Water Quality Data in Nimr Asset	C5-13
5.3	Human Settlements in Nimr Asset	C5-23
5.4	Land Use in Nimr Asset	C5-23
5.5	Environmentally Significant Areas in Nimr Asset	C5-25

LIST OF FIGURES

1.1	Geographical Map of PDO's Concession Area	C1-3
1.2	Organisation Structure in PDO	C1-5
1.3	Asset-wise Break-up of Land Area, Oil, Gas and Produced Water	C1-7
3.1	Asset Organization Structure for Nimr Asset	C3-2
3.2	Asset Management Structure for Nimr Asset	C3-3
3.3	Schematic Diagram of Major Production and Associated Activities	C3-6
5.1	Topographical Map of Nimr Asset	C5-3
5.2	Geological Cross Section in Nimr Asset Area	C5-5
5.3	Soil Map of PDO's Concession Area	C5-7
5.4	Salinity Maps of Fars Aquifers	C5-9
5.5	Salinity Maps of UeR Aquifers	C5-11
5.6	Climatic Charts for Nimr Asset	C5-15
5.7	Map of Arabian Oryx Nature Reserve	C5-21

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ABBREVIATIONS

µg	Micro-Gram
µm	Micro-Meter (Also Known As Micron)
µS/cm	Micro-Siemens Per Centimetre (Units Of Electrical Conductivity)
AP	Atmospheric Pressure
atm	Atmosphere
bar(g)	Unit Of Gauge Pressure (Equal To 101.3 Kpa Gauge)
bbl	Barrel (Equal To About 159 Liters)
BOD	Biochemical Oxygen Demand
bpd	Barrels Per Day
Bq	Bequerel, Unit For Measurement Of Radioactivity (One Nuclear Disintegration/Second)
$CaCO_3$	Calcium Carbonate
CFC	Chloro-Floro-Carbon
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COD	Chemical Oxygen Demand
CPI	Corrugated Plate Interceptor
d	Day
dB	Decibel
DGEA	Directorate General Of Environmental Affairs
DLN	Dry Low No_x
DWD	Deep Water Disposal
E	East
E&P	Exploration & Production
EIA	Environmental Impact Assessment
EPC	Engineering, Procurement And Construction
ESP	Electrical Submersible Pump
EU	European Union
GT	Gas Turbine
h	Hour
ha	Hectare
HC	Hydrocarbons
HCFC	Hydro-Chloro-Floro-Carbon
HEMP	Hazards And Effects Management Process
HFC	Hydro-Fluoro-Carbon
HMR	HMR Environmental Engineering Consultants
HP	High Pressure
HSE	Health, Safety And Environment
ISO	International Organization for Standardization
IUCN	International Union For The Conservation Of Nature And Natural Resources (The World Conservation Unit)
kg	Kilogram
km	Kilometer
km^2	Square Kilometer
kPa	Kilo Pascal, Unit Of Pressure (1 Atm = 101.13 Kpa)
Kpa	Kilopascal
L_{eq}	Equivalent Noise Level
LNG	Liquified natural gas
LP	Low Pressure
m^3	Cubic Meter
MAF	Mina Al Fahal
MD	Ministerial Decision
mg	Milligram
MJ	Mega-Joule
ml	Milliliter

MLPS	Main Line Pumping Station
MMPS	Nimr Main Production Station
MOL	Main Oil Line
mPa.s	Milli-Pascal-Second (A Unit Of Viscosity Equivalent To 1 Centipoise Or Cp)
MPN	Most Probable Number
MRME&WR	Ministry Of Regional Municipalities, Environment And Water Resources
MSDS	Material Safety Data Sheet
MW	Megawatt
MWh	Megawatt-Hour
N	North
NAAQ	National Ambient Air Quality
NH_3	Ammonia
Nm^3	Normal Cubic Meter (At 1atm And 0^oc)
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
NOCS plant	North Oman Crude Stabilization Plant
NORM	Naturally Occurring Radioactive Materials
NO_x	Oxides Of Nitrogen
^oC	Degree Centigrade
^oK	Degree Kelvin
PDO	Petroleum Development Oman LLC
PM_{10}	Particulate Matter Of <10 µm Size
$PM_{2.5}$	Particulate Matter Of <2.5 µm Size
ppm	Parts Per Million
ppmv	Parts Per Million, Volume Based
RD	Royal Decree
RMS	Remote Manifold Station
RO	Reverse Osmosis
SHOC	Safe Handling Of Chemicals
Sm^3	Standard Cubic Meter (At 1atm And 20^oc)
SO_2	Sulphur Dioxide
SOGL	South Oman Gas Line
STOIIP	Stock Tank Of Oil Initially In Place
STP	Sewage treatment plants
t	Metric Tonne (Equal To 1000 Kg)
TDS	Total Dissolved Solids
tpa	Tonnes Per Annum (Year)
tph	Tonnes Per Hour
TSP	Total Suspended Particulates
TSS	Total Suspended Solids
UeR	Umm Er Radhuma
UNEP	United Nations Environmental Program
UNESCO	United Nations Scientific And Cultural Organisation
USEPA	United States Environmental Protection Agency
Wadi	River Bed (Usually Dry)
WHO	World Health Organisation
Wilayat	Governing District

1 INTRODUCTION

1.1 Petroleum Development Oman

Petroleum Development Oman (PDO) is the largest petroleum exploration and production (E&P) company in the Sultanate of Oman, with over 113,550 km^2 of concession area, covering most of the central and southern parts of the Sultanate. The geographical map of PDO's concession area is shown in Figure 1.1. Presently, PDO's concession area is divided into two main directorates viz., North Oman and South Oman. The production assets within North Oman include Fahud, Lekhwair, Yibal and Qarn Alam, and those within South Oman include Bahja, Nimr (including Rima) and Marmul. The crude oil export facilities and the administrative head quarters are located on the coast in Mina Al Fahal. The current asset organisation structure in PDO is shown in Figure 1.2.

Currently PDO operates from about a hundred fields and has 2,454 oil producing wells and 72 gas producing wells. The total production of crude oil currently is about 843,490 barrels per day, and that of associated gas is 44 million Sm^3 per day. A network of 9,300 km of pipelines, 28 gathering stations and 18 production stations feed the produced crude oil into the main storage facility located at Mina Al Fahal near Muscat (at Muscat coastal area), from where the oil is loaded into tankers moored offshore. The produced gas is partly utilised within the assets and the rest processed in three gas stabilisation stations (located in Yibal, Saih Rawl and Saih Nihayda) and then exported. The asset-wise break-up for land area, crude oil production, gas production and production water is presented in Table 1.1 below for the current year (2002) and their percentages are given in figure 1.3.

Table 1.1: Description of Production Assets in PDO

Production Asset	Land Area (km^2)	Crude Oil Production (m^3/d average)	Gas Production (10^3 x Sm^3/d average)	Produced Water (m^3/d average)
Fahud	11,580	14,670	5,007	11,239
Lekhwair Asset	3,560	14,601	1,550	21,977
Yibal Asset (Including Gas Asset)	5,830	31,134	31,995	154,970
Qarn Alam Asset	18,900	14,462	3,084	67,255
Bahja Asset	30,560	12,347	550	27,050
Nimr Asset (Including Rima and Al Noor)	16,160	35,669	780	313,105
Marmul Asset	26,960	11,221	900	41,937
Total for PDO's Concession Area	**113,550**	**134,104**	**43,866**	**637,533**

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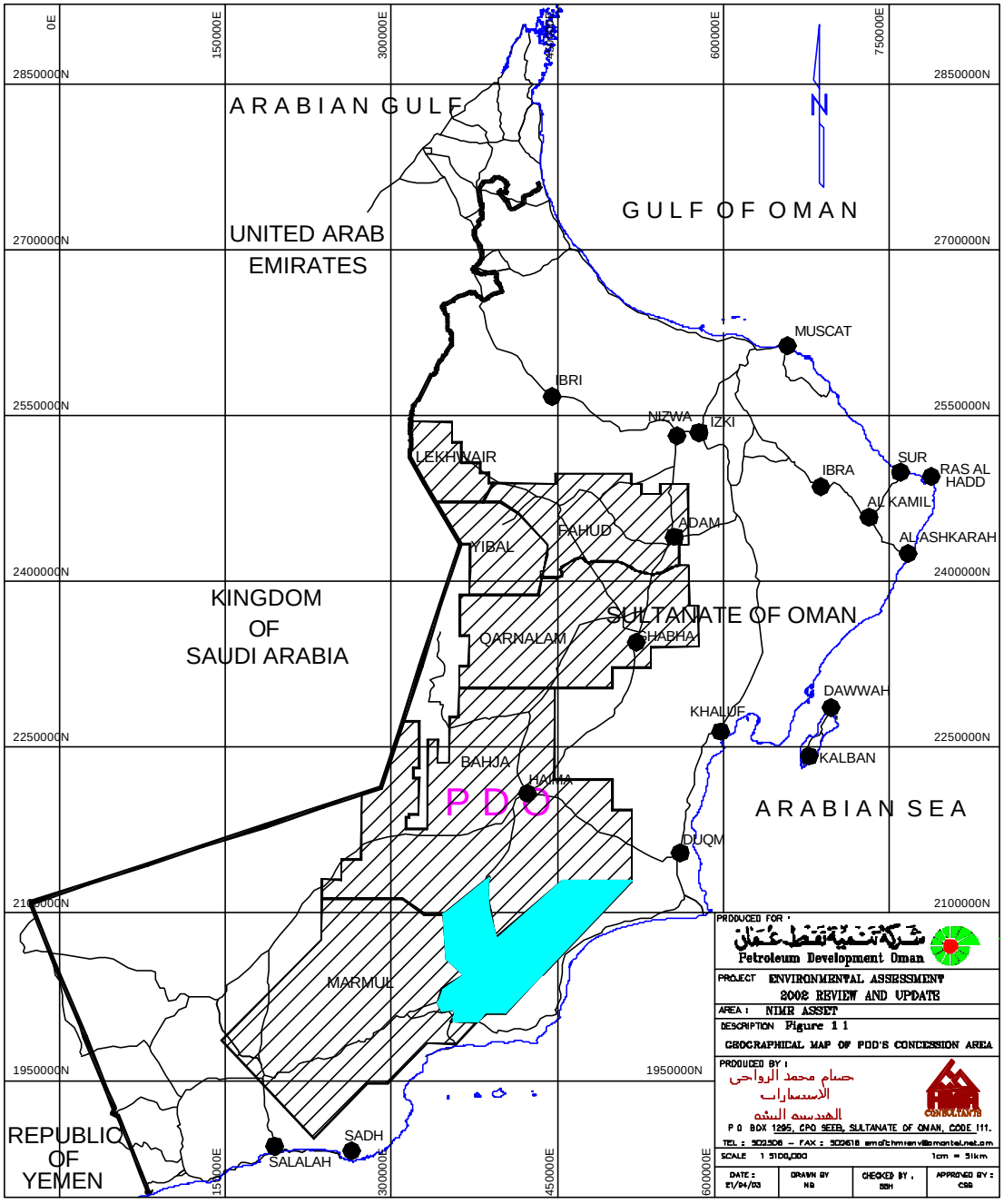

Figure 1.1: Geographical Map of PDO's Concession Area

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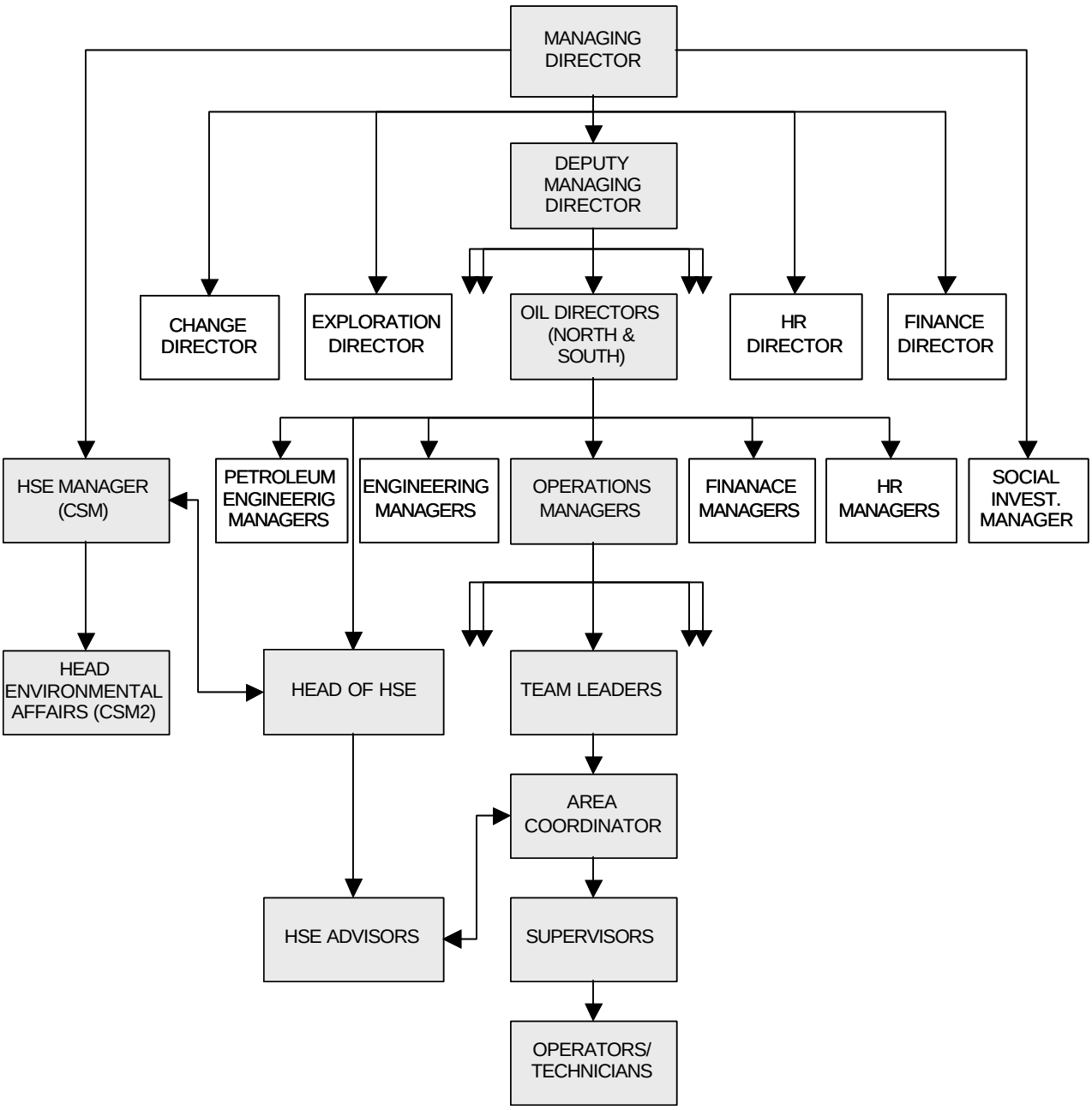

Figure 1.2: Organisation Structure in PDO

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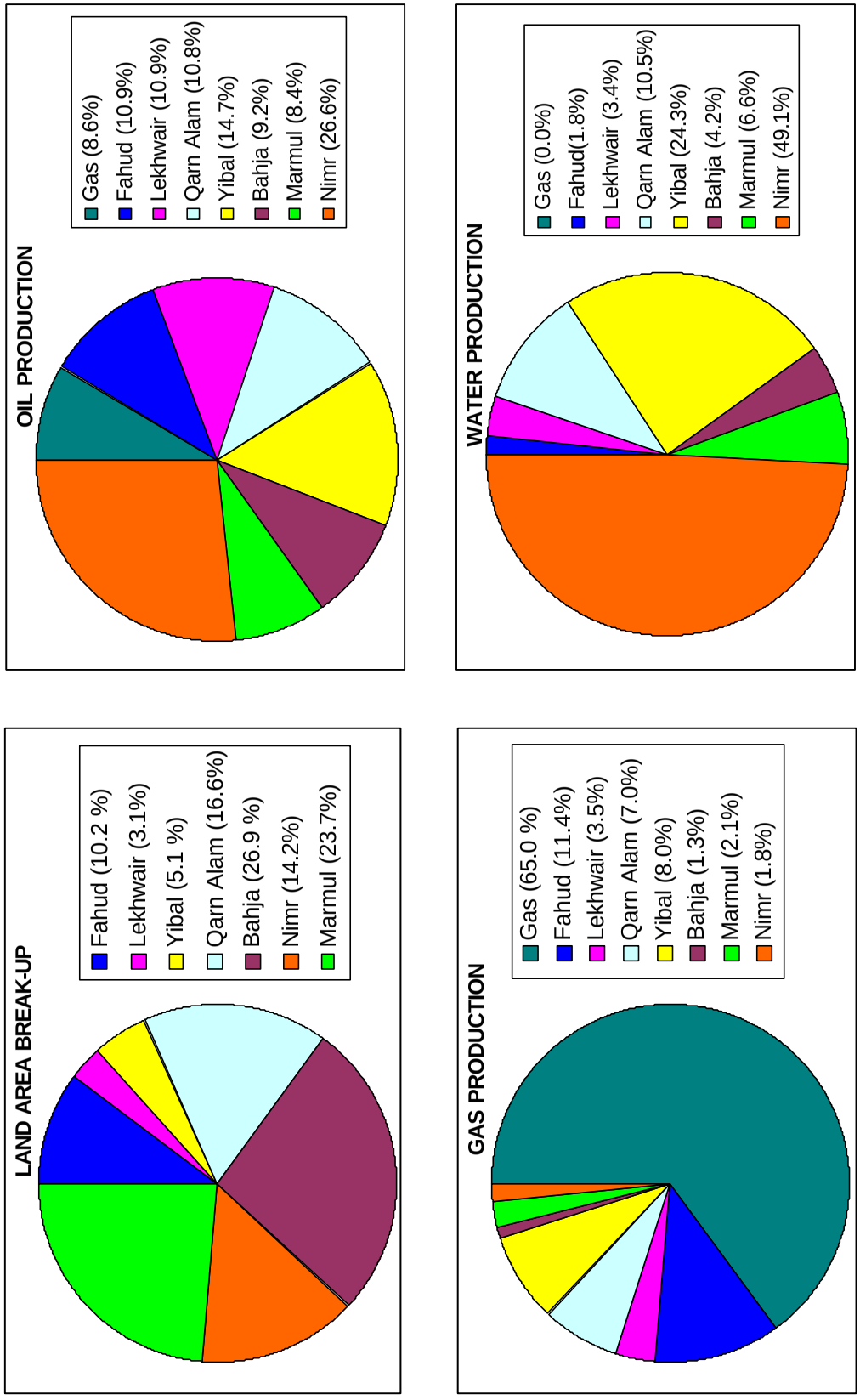

Figure 1.3: Asset-wise Break-up of Land Area, Oil, Gas and Produced Water

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1.2 Environmental Impact Assessment

The environmental impact assessment (EIA) for all the production and service assets was first conducted during the period of 1998–2000, and based on this the environmental management plans and programmes were developed.

It is an internal requirement in PDO to review and update the EIA once every three years, in order to periodically re-assess the environmental impacts and appropriately revise the environmental management plans and programmes. Accordingly, PDO has requested HMR Environmental Engineering Consultants (HMR Consultants) to carry out the first review and update of the EIA for all its assets. This study was conducted over the period of June – December 2002 and presents the review and update of the environmental assessment for the entire Nimr asset (including the Rima and Al Noor assets). The previous environmental assessment study for Nimr asset was completed in December 1999 (*Reference 1*).

1.3 Objectives and Scope of Study

The objectives of this environmental assessment were the following:

- Updating the environmental inventories in the asset, taking into consideration all developments and activities that have taken place since the last environmental assessment conducted in June 1999.
- Reviewing the environmental requirements in the asset, taking into consideration any recent changes in the legislative and corporate regulations and specifications
- Auditing the environmental performance for the current year.
- Updating the environmental baseline data, wherever required.
- Reviewing the significant aspects and re-assessing the environmental impacts, in view of the above.
- Revising the environmental mitigation measures and monitoring plan, wherever required.

The social and health impact assessment components were not included in this study. The quantitative risk analysis was also not included in this study.

1.4 Method of Study

This study was carried out in three stages. In the first stage, the previous EIA report (*Reference 1*) and other available environmental documents were reviewed. Based on this review, detailed and structured checklists were prepared for asset data verification and environmental performance audit. Subsequently, in the second stage, a site visit was undertaken to check the ground realities and to collect all necessary information. During the site visit, the key operating personnel in the asset including the Area Coordinator and the Area HSE Advisor were interviewed, and a detailed environmental audit of the various facilities in the asset was conducted. In the third stage, all the data collected were analysed and the significant environmental hazards (aspects) were identified. Then the environmental effects (impacts) were reassessed using PDO's "Hazards and Effects Management Procedure (HEMP)" as described in the PDO's document GU-195 "Environmental Assessment Guideline" (*Reference 2*). Following the reassessment, the environmental mitigation measures and the monitoring plans were revised as appropriate.

1.5 Structure of Report

This report is prepared based on the table of contents suggested for environmental assessment report in PDO's "Environmental Assessment Guideline" *(Reference 2)*. A non-technical executive summary is presented at the beginning of the report.

Section 1 overview of PDO activities and description of all the production assets. The scope and objective of the work is presented.

Section 2 presents the regulatory framework and outlines the environmental regulations governing the environmental aspects in the work.

Section 3 details the description of Nimr asset along with the consumption of utilities and materials in the asset.

Section 4 describes the various waste products and energies released to the environment from activities performed in Nimr asset. Characterisation and quantification of the various waste products released to the environment are presented in this section and their treatment and disposal practices are analysed.

Section 5 presents a detailed description of the environment status within the Nimr asset.

Section 6 provides a description of the significant environmental hazards associated with the asset activities identifying the environmental effects. These effects are assed based on the methodology outlined in PDO's document GU-195. The identified

potential environmental impacts were rated based on the PDO's environmental risk criteria attached in appendix.

Section 7 summarises the significant environmental effects and mitigation measures in the asset for adverse impacts. Additional mitigation measures aimed at minimizing the potential environmental risks and improvement of the overall performance were also suggested.

Section 8 lists the references used for this document.

Other useful information not included in the main text is presented in the appendices. The details of the personnel responsible in the preparation and review of the report are presented in *Appendix 1.*

2 REGULATORY FRAMEWORK

2.1 Omani Regulations

The Omani regulations on environmental protection, control and management are covered under two basic laws *viz*., the "Law for the Conservation of the Environment and Prevention of Pollution" first promulgated in 1982 as Royal Decree (RD) 10/82 and superseded in November 2001 as RD 114/2001 and the "Law on Protection of Sources of Potable Water from Pollution" promulgated in November 2001 as RD 115/2001. The responsibility for the implementation of this law rests with the Ministry of Regional Municipalities, Environment and Water Resources (MRME&WR), which issues regulations, standards and guidelines through "ministerial decisions (MDs)". Within MRME&WR, the authority responsible for environmental permitting, inspection and control in the Sultanate of Oman is the Directorate General of Environmental Affairs (DGEA).

The current Omani environmental laws and regulations are listed below in chronological order.

Table 2.1: Environmental Laws and Regulations in Oman

(Presented in Chronological Order)

Title	Reference Number
Protection of certain species of birds	MD 4/76
Law on the development of water resources and its amendments	RD 76/77, RD 82/88, RD 29/00
Omani drinking water standards	OS8/98
Law on national heritage protection	RD 2/80, RD 6/80
Law for the conservation of the environment and prevention of pollution and its amendments	RD 10/82 (superseded), RD 63/85, MD 5/86, RD 71/89, MD 2/90, RD 31/93, RD 114/2001
Regulations concerning the disposal of liquid effluents to marine environment	MD 7/84
Regulations for the discharge of industrial and commercial effluents	MD 8/84
Regulations for septic tanks and holding tanks	MD 5/86 (superseded), MD 421/98
Regulations for air pollution control from stationary sources	MD 5/86
Regulations for the registrations of existing wells and new well permits	MD 2/90
Regulations for the management of the solid non-hazardous wastes	MD 17/93
Regulation for the management of hazardous wastes	MD 18/93
Regulations for wastewater re-use and discharge	MD 145/93, RD 115/2001
Regulating issuance of environmental permits	MD 300/93
Regulation on the removal of vegetation	MD 128/93
Regulation on hunting, capture or firing at wild animals	MD 207/93
Regulations for noise pollution in public environment	MD 79/94
Regulations for noise pollution in the working environment	MD 80/94
Law on handling and use of chemicals	RD 46/95

Title	Reference Number
Regulations for the handling of toxic substances	MD 248/97
Regulations for control and management of radioactive materials substances	MD 249/97
Regulation on the use of desalination units on wells	MD 342/97
Law on protection of potable water sources from pollution	RD 115/2001

2.2 Shell Group Environmental Guidelines

The Royal Dutch Shell Group has a formulated an extensive HSE management system covering all Shell's activities including hydrocarbon exploration and production. The system includes a series of comprehensive set of guidelines, standards and procedures. These guidelines have been incorporated into PDO's series of specifications where applicable; yet remain as reference documents covering specific operations and activities.

The Shells Group environmental specifications (standards and guidelines) are listed below in Table 2.2.

Table 2.2: Shell Group Environmental Specifications

Reference Number	Title
EP 95-0110	Management of Contractor HSE
EP 95-0120	Competence Assurance for HSE-critical Activities
EP 95-0140	Exploration & Production HSE Strategy and Policy Implementation Guide
EP 95-0220	Concept Selection
EP 95-0300	Overview Hazards and Effects Management Process
EP 95-0330	Drinking Water Guidelines
EP 95-0352	Quantitative Risk Assessment
EP 95-0370	Environmental Assessment
EP 95-0371	Social Impact Assessment Guidelines
EP 95-0375	Environmental Quality Standards - Air
EP 95-0376	Monitoring Air Quality
EP 95-0377	Quantifying Atmospheric Emissions
EP 95-0380	Environmental Quality Standards - Water
EP 95-0381	Monitoring Water Quality
EP 95-0385	Environmental Quality Standards - Soil and Groundwater
EP 95-0386	Monitoring Soil and Groundwater
EP 95-0387	Contaminated Soil and Groundwater
EP 95-0390	Waste Management Guidelines
None	Guide for Risk Based Management of Potentially Contaminated Land

2.3 PDO Corporate Environmental Specifications

PDO has established a comprehensive health, safety and environment (HSE) management system, based on ISO 14001, the international standard for environmental management and EP: 95-0000, the Royal Dutch Shell group guidelines on HSE management. PDO has developed environmental specifications for application throughout its facilities within Oman, based on the Omani regulatory

standards and Shell Group guidelines. PDO's specifications, which are described in the following sections, fully comply with the Omani regulatory standards, and in most cases are more stringent. The list of PDO's environmental specifications SP-1005 to SP-1012 and SP-1170 version dated 7/2002 is presented below in Table 2.3.

Table 2.3: PDO's Environmental Specifications

Reference Number	Title
SP-1005	Specification for Emissions to Atmosphere
SP-1006	Specification for Aqueous Effluents
SP-1007	Specification for Accidental Releases to Land and Water
SP-1008	Specification for the Use of Energy, Materials and Resources
SP-1009	Specification for Waste Management
SP-1010	Specification for Environmental Noise and Vibration
SP-1011	Specification for Flora and Fauna Protection
SP-1012	Specification for Land Management
SP-1170	Specification for Management of Naturally Occurring Radioactive Materials

In the following sections, the various environmental standards given under the above specifications are summarized.

2.4 Environmental Standards

2.4.1 Emissions to Atmosphere

PDO specification SP-1005on emissions to atmosphere addresses both stationary and mobile sources and is largely based on MD 5/86 “Regulations for Air Pollution Control from Stationary Sources” and Shell Exploration and Production International best practices. These are presented below in Table 2.4.

Table 2.4: Air Emission Standards

Parameter	Maximum Permissible Concentration
Hydrogen chloride	200 mg/Nm^3
Hydrogen fluoride	100 mg/Nm^3
Oxides of nitrogen (as NO_2)	200 mg/Nm^3
Phosphorus as (P_2O_5)	50 mg/Nm^3
Hydrogen sulphide	5 ppmv (7 mg/Nm^3)
Total particulates	100 mg/Nm^3

Note: Nm^3 refers to volume at 0 ^oC and 1atm.

In addition to the above emission limits, PDO has specified the following requirements to minimise air pollution and fugitive emissions:

(a) There shall be no continuous venting of gas in new projects.

(b) Fugitive emissions occurring as a result of leaks from components (such as pipe connections, valves, rotating shafts and other packed components) shall be minimised through enhanced maintenance programs. There shall be no significant visible emissions of fugitive dust.

(c) No smoke emitted shall be as dark or darker than shade 1 on the Ringlemann scale (equivalent to 20% opacity).

(d) No odorous substances shall be emitted to the environment that are recognisable at residences for more than 150 hours per year.

(e) CFCs, HCFCs or HFCs shall not be knowingly vented to the atmosphere. They shall be recovered and re-used during servicing and maintenance. No equipment or product containing CFCs shall be selected for purchase or lease. Further, no equipment or product containing HCFCs shall be selected for purchase or lease, unless no alternatives are available in the market.

(f) There shall be no halon releases to the atmosphere for maintenance, testing or any other purposes. Halon releases are permitted under emergency situations only. No new halon fire fighting systems in new projects shall be purchased, and no virgin halons shall be used for recharging any existing halon fire fighting systems in use.

2.4.2 Ambient Air Quality

Presently, there are no Omani standards for ambient air quality. In their absence, MRME&WR recommends the use of United States Environmental Protection Agency's (USEPA) national ambient air quality (NAAQ) standards. PDO uses World Health Organisation (WHO) - European Union (EU) and Netherlands standards, which are more stringent than USEPA's NAAQ standards. PDO's ambient air quality standards are given as both limit values and guide values. The "limit values" are the maximum permissible concentrations in the ambient air, which if exceeded will result in non-compliance. The "guide values" are the desirable upper limits. PDO's ambient air quality standards are given in Table 2.5 below.

Table 2.5: Ambient Air Quality Standards

Parameter	Averaging Period	Limit Value ($\mu g/m^3$)	Guide Value ($\mu g/m^3$)
Oxides of nitrogen as NO_2	1 hour 4 hour 24 hour 1 year	400 - 150 -	- 95 - 30
Sulphur dioxide	10 minutes 1 hour 24 hours 1 year	500 350 125 50	- - 125 30

Hydrogen sulphide	30 minutes 24 hours	- 150	7 -
Carbon monoxide	1 hour 8 hour	40000 6000	- -
Benzene	1 hour 1 year	- 10	7.5 5
Total suspended particulate matter	1 year	120	-
Particulate products of incomplete combustion	24 hours 1 year	125 50	- -

2.4.3 Aqueous Effluents

PDO specification SP-1006 on aqueous effluent discharge is derived from a number of Ministerial Decisions (in particular, MD 7/84, MD 5/84 and MD145/93). The effluents include production water and other various process waters, sewage and storm water run-off. The specification covers both land and marine discharges. The details are presented below.

- **Production Water:**

The approved PDO Production Water Management Plan, which has been agreed upon with the government consists of five principles. These principles govern the disposal of production water (or other hyper saline brines), and are listed below in the order of preference.

(a) Minimise the volumes of water produced during oil extraction.

(b) Maximise reuse of such produced waters.

(c) Phase out the use of shallow disposal wells and prevent disposal into useable or exploitable aquifers.

(d) Return production water to the producing reservoir.

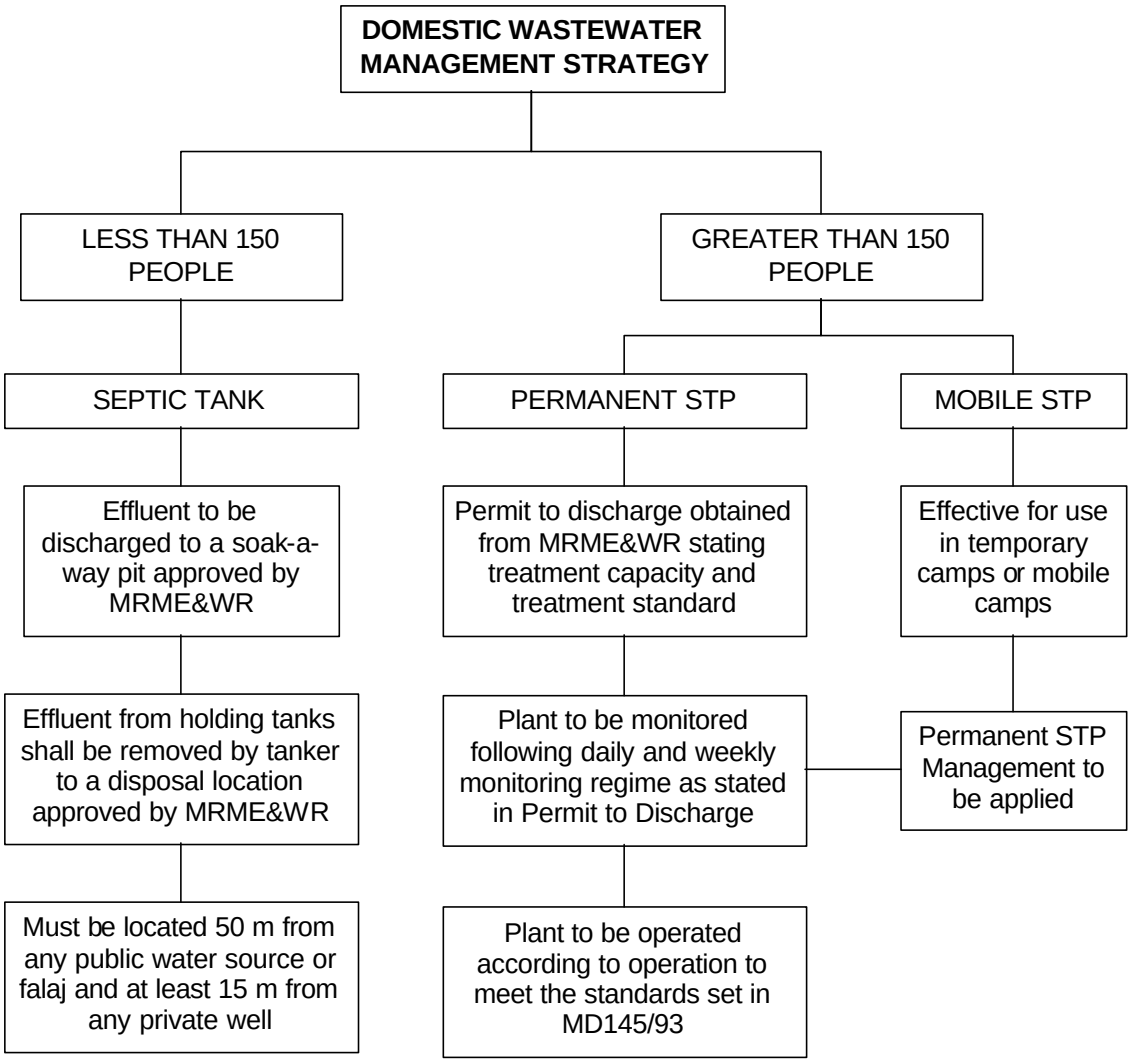
(e) Dispose surplus waters to formations, which have salinity greater than 35,000 mg/L, in conjunction with case-specific monitoring programs.

- **Other Process Effluents:**

The disposal of other process (such as reverse osmosis plants, hydrotest, maintenance etc.) effluents is dependent on the location and degree of the contamination. If the effluent is to be discharged to land then the quality of the water shall satisfy the water quality standards as identified in MD 145/93. Where the water is to be disposed of to the marine environment the effluent shall meet the water quality standards as per MD 7/84. In the event that the water quality standards are not met then the effluent discharge should be segregated and undergo treatment so as not to impact on the receiving environment.

- **Sewage Effluent:**

PDO have developed a strategy to select the wastewater treatment technology for various operations across the company. The strategy uses the population size of each camp as a basis for selecting a wastewater treatment option. This approach is summarised in the flowchart shown in below:



- **Storm Water Runoff:**

There are no legal requirements with respect to the discharge of storm water runoff uncontaminated by hydrocarbons. Potentially hydrocarbon contaminated storm water runoff shall be segregated and treated to the standards specified for on land discharge or marine disposal.

- **On Land Discharge:**

The following are PDO's standards for on land discharge and re-use of treated wastewater, which are the same as Omani standards (MD145/93 and RD 115/2001).

There are two types of standards (Standard A-1 and A-2), which differ from each other based on the intended re-use of treated sewage effluent. They are presented in Table 2.6.

Table 2.6: Classification of Standards A-1 and A-2 for Re-use of Treated Wastewater

Specification	Standard A-1	Standard A-2
Crops	- Vegetables likely to be eaten raw - Fruit likely to be eaten raw and within 2 weeks of any irrigation	- Vegetables to be cooked or processed - Fruit if no irrigation within 2 weeks of cropping - Fodder, cereal and seed crops
Grass and ornamental areas	- Public parks, hotel lawns recreational areas - Areas with public access. - Lakes with public contact (except place which may be used for praying and hand washing)	- Pastures - Areas with no public access

The treated wastewater if discharged on land shall meet the following specifications given In Table 2.7.

Table 2.7: Standards for Treated Wastewater Discharged on Land

Parameter	Units	Standard A-1	Standard A-2
Biochemical oxygen demand (5 days @ 20^0C)	mg/L	15	20
Chemical oxygen demand	mg/L	150	200
Suspended solids	mg/L	15	30
Total dissolved solids	mg/L	1500	2000
Electrical conductivity	µS/cm	2000	2700
Sodium absorption ratio	-	10	10
pH	-	6 - 9	6 -9
Aluminium (as Al)	mg/L	5	5
Arsenic (as As)	mg/L	0.100	0.100
Barium (as Ba)	mg/L	1	2
Beryllium (as Be)	mg/L	0.100	0.300
Boron (as B)	mg/L	0.500	1.000
Cadmium (as Cd)	mg/L	0.010	0.010
Chloride (as Cl)	mg/L	650	650
Chromium (total as Cr)	mg/L	0.050	0.050
Cobalt (as Co)	mg/L	0.050	0.050
Copper (as Cu)	mg/L	0.500	1.000
Cyanide (total as CN)	mg/L	0.050	0.100
Fluoride (as F)	mg/L	1	2
Iron (total as Fe)	mg/L	1	5
Lead (as Pb)	mg/L	0.100	0.200
Lithium (as Li)	mg/L	0.070	0.070
Magnesium (as Mg)	mg/L	150	150
Manganese (as Mn)	mg/L	0.100	0.500
Mercury (as Hg)	mg/L	0.001	0.001
Molybdenum (as Mo)	mg/L	0.010	0.050
Nickel (as Ni)	mg/L	0.100	0.100

Parameter	Units	Standard A-1	Standard A-2
Nitrogen: Ammoniacal (as N) : Nitrate (as NO_3) : Organic (Kjeldahl) (as N)	mg/L	5 50 5	10 50 10
Oil and grease (total extractable)	mg/L	0.500	0.500
Phenols (total)	mg/L	0.001	0.002
Phosphorus (total as P)	mg/L	30	30
Selenium (as Se)	mg/L	0.020	0.020
Silver (as Ag)	mg/L	0.010	0.010
Sodium (as Na)	mg/L	200	300
Sulphate (as SO_4)	mg/L	400	400
Sulphide (total as S)	mg/L	0.100	0.100
Vanadium (as V)	mg/L	0.100	0.100
Zinc (as Zn)	mg/L	5	5
Faecal coliform bacteria	Number per 100 mL	200	1000
Viable nematode ova	Number per L	<1	<1

The sludge generated from the treatment of domestic wastewaters may be applied on land for agricultural use, subject to the conditions set in Table 2.8. After spreading the sludge, there must be at least a three-week period before any grazing or harvesting of forage crops. Sludge application on land prohibited in the following cases:

- On soils while fruits or vegetable crops, other than fruit trees, are growing or being harvested
- For six months preceding the harvesting of fruit or vegetables that are normally eaten raw, and grown in contact with the soil
- On soils with pH less than 7

Table 2.8: Maximum Permissible Metal Concentrations in Sludge

Metal	Maximum Permissible Concentration (mg/kg dry solid)	Maximum Application Rate (kg/ha/yr)	Maximum Permissible Concentration in Soil (mg/kg dry solid)
Cadmium	20	0.150	3
Chromium	1000	10	400
Copper	1000	10	150
Lead	1000	15	30
Mercury	10	0.100	1
Molybdenum	20	0.100	3
Nickel	300	3	75
Selenium	50	0.150	5
Zinc	3000	15	300

Any sludge containing metal concentration above the following prescribed limits shall be disposed in sanitary landfills or to other facilities with approval from MRME&WR.

- **Marine Disposal:**

Any effluent discharged into the marine environment shall meet the specifications given below in Table 2.9, which are same as or more stringent than the discharge limits into the marine environment as per MD 7/84.

Table 2.9: Standards for Treated Wastewater Discharged into Marine Environment

Parameter	Discharge limit
Arsenic	0.05 mg/L
Cadmium	0.05 mg/L
Chromium	0.50mg/L
Copper	0.50 mg/L
Cyanide	0.10 mg/L
Iron	2.00 mg/L
Lead	0.10 mg/L
Mercury	0.001 mg/L
Nickel	0.10 mg/L
Selenium	0.02 mg/L
Silver	0.005 mg/L
Zinc	0.10 mg/L
Chlorine (salt)	2.50 mg/L (minimum)
Hydrogen ions	6-9 units
Sulfide salts	0.10 mg/L
Sticking solid particles	30.0 mg/L
Sludge	75.0 Jackson sight unit
BOD	30.0 mg/L
Oil & grease	5.0 mg/L
Carbolic acids (phenols)	0.10 mg/L
Ammonium nitrates	40.0 mg/L
Phosphates	0.10 mg/L
Faecal coliforms	100 MPN/100 mL (80% samples)
Faecal streptococci	100 MPN/100 mL
Salmonella	Zero MPN/L

2.4.4 Accidental Releases to Land and Water

PDO specification SP-1007 on accidental releases to land and water focuses on minimising the effect on groundwater, and soil. The requirements are outlined below:

- Equipment, processes, pipelines etc. containing material harmful to the environment shall be designed, maintained, operated and abandoned to prevent accidental releases to the environment
- In case of a loss of containment to the environment, the contamination shall be assessed and the soil and groundwater shall be cleaned to a level compatible with the environmental quality standard of the receiving environment (available EP 95-0385)

2.4.5 Use of Energy, Materials and Resources

PDO specification SP-1008 on the use of energy, materials and resources attempts on the efficient use of natural resources. The requirements under this specification are outlined in Table 2.10.

Table 2.10: Applicable Requirements for the Use of Energy, Materials and Resources

Indicators	Requirement
Energy	- Efficient use of energy at all times shall be demonstrated
Water Resources	- RD 82/88 controls the exploitation of groundwater in the interest of agricultural and development plans - MD 2/90 requires all wells used for the detection or extraction of groundwater be registered with MRME&WR - Efficient water use shall be demonstrated for hydrocarbon production
Land Use	- Under PDO's concession agreement, land no longer necessary for operations shall be handed back to the government
Use of Chemicals	- The manufacture, import, storage, handling and use of any chemical substance shall comply with RD 46/95 - Under RD/248/97, the manufacture, export, transport, storage, handling use, and disposal of any chemical substance will require a permit from MRME&WR - Chemicals shall only be bought with valid Safe Handling of chemicals (SHOC) card. The chemicals shall be stored with the SHOC card visible

2.4.6 Waste Management

PDO specification SP-1009 on waste management defines what are hazardous and non-hazardous wastes, and outlines the waste management strategy in PDO. This specification complies with Omani regulations MD 17/93 and MD 18/93 dealing with non-hazardous and hazardous waste management. The classification of non-hazardous and hazardous wastes is specified under SP 1009 as below in Table 2.11.

Table 2.11: Classifications of Hazardous and Non-Hazardous Wastes

Hazardous Wastes	Non-Hazardous Wastes
Hazardous empty drums	Kitchen refuse
Waste lubricants	Domestic waste
Pigging sludge	Tree/grass cuttings
Tyres	Water-based drilling mud and cuttings
Batteries	Office waste
Clinical waste	Non-hazardous waste chemicals
Naturally occurring radioactive material	Non-hazardous empty drums
Sewage sludge	Scrap metal
Oil-based drilling mud and cuttings	
Hazardous waste chemicals and lab waste chemicals	
Oily sand /soil	
Oily sludge	

PDO's waste management hierarchy is as below:

- Pollution prevention: elimination, change or reduction of operating practices, which result in wastes
- Source reduction: generation of less wastes through more efficient processes
- Re-use: the use of materials or products that are reusable in their original form
- Recycling/recovery: the conversion of waste into usable materials, or the extraction of energy or materials from the waste
- Treatment: the destruction, detoxification and/or neutralisation of residues
- Responsible disposal: depositing wastes using appropriate methods for a given situation

Based on the above hierarchy, the detailed waste handling and disposal procedures are given in the specification SP-1009. The procedures for the handling and disposal of NORM wastes are given under the specification SP-1170. These are discussed in Section 2.4.10 in this chapter.

2.4.7 Environmental Noise and Vibration

PDO specification SP-1010 on environmental noise and vibration is based on Omani standards MD 79/94 and MD 80/94. PDO standards on ambient noise, which are the same as Omani standards (MD 79/94) are summarized in Table 2.12 below.

Table 2.12: Ambient Noise Standards

Type of District	Maximum Permissible Noise Level [as L_{eq} in dB (A)]		
	Workdays – Day time (7am –6pm)	Workdays – Evening (6pm –11pm)	Workdays Night time (11pm- 7am) and Holidays
Rural, residential, recreational	45	40	35
Suburban residential	50	45	40
Urban residential	55	50	45
Urban residential with some workshops or business	60	55	50
Industrial and commercial	70	70	70

2.4.8 Flora and Fauna

PDO specification SP-1011 on protection of wildlife is developed in response to several Omani royal decrees and ministerial decisions on environmental protection.

The specification outlines specific ecological zones and based on their importance, defines specific requirements for carrying out projects. These are summarized in Table 2.13 below.

Table 2.13: Classification of Environmentally Sensitive Areas

Ecological Zone	Description	Requirements
Zone 1: Areas of Concern	National reserves or sanctuaries	Activities shall be restricted
	Areas that provide habitat to particularly sensitive wildlife	
	Areas containing high proportions of endemic flora or fauna	
	Woodlands	
	Areas of exceptional natural beauty	
Zone 2: Areas of Interest	Areas having significant natural features and beauty	Activities shall be restricted for those not compatible with the protection of the area
	Areas showing features of geological or climatic history	
	Artificially created areas to attract wildlife and migratory birds	
Arabian Oryx Sanctuary	Area defined by RD 9/94	Case-specific approval from MRME&WR

2.4.9 Land Management

There is currently no specific Omani legislation on land management (site preparation, abandonment and restoration). PDO's policy on abandonment requires that redundant assets shall be removed where appropriate and the environment restored to, or as near as reasonably practicable, to its original state. PDO specification SP-1012 on land management is summarized below in Table 2.14.

Table 2.14: Land Management Requirements

Project Stage	Requirements
Site Selection	- Selection of a site shall be carried out in accordance with PDO's procedure on HEMP and environmental assessment guideline
Site Preparation	- Earthmoving shall be conducted to minimize environmental effects - Trees shall not be felled or removed - Borrow pits shall not be excavated more than 2m in depth - Borrow pits shall not be excavated in wadis, in areas used by grazing livestock or in areas which would cause nuisance to local inhabitants - A 20m wide right-of-way shall be provided for all pipelines (10m each side) - Where pipelines or roads cross wadis, earthmoving shall be carried out to minimize flow or characteristics of shallow aquifers

Project Stage	Requirements
Site Abandonment and Restoration	- Restored land shall be visually similar to the surrounding landscape - All waste materials shall be removed - Hydrocarbon shall be removed from site if concentrations greater than 1% weight - Areas having less than 1% weight hydrocarbon contamination shall be covered with 0.6m of clean sand within 6 months of abandonment - All pipelines, process equipment and instrumentation shall be removed - All camp facilities shall be removed and site re-graded. Any soak pits shall be backfilled - Borrow pits shall be filled with 0.3m of clean sand and graded to match the surrounding contours

2.4.10 NORM Waste Disposal

Oil sludges, pigging wastes, tubulars and water/well accessories from reservoir locations are known to contain NORM materials. The monitoring, handling, transport, storage, treatment and disposal of NORM wastes are specified under SP-1170 "Specification for Management of Naturally Occurring Radioactive Materials". This specification conforms to MD 249/97, " Regulations for the Control and Management of Radioactive Materials". Any waste having radioactivity greater than 100 Bq/g (for solids) and 100 kBq/L (for liquids) is classified as radioactive waste. Such waste shall be sent to PDO's dedicated storage facility in Zauliyah as soon as possible. Normal transport vehicles can be used. However, the waste shall be packaged as per the detailed procedures given in the specification. Any recyclable items shall be released only after they are decontaminated by an authorised contractor at the designated site, such that the radioactivity level is reduced to <100 Bq/g. If decontamination is not possible, the wastes shall be retained at the storage site until the radioactivity level drops to <100 Bq/g.

3 ASSET DESCRIPTION

3.1 Asset Organisation

Geographically, Nimr asset is located in the southeast part of PDO's concession area. The erstwhile Rima and Al Noor assets are now a part of Nimr asset. The asset currently covers a total land area of 16,160 km^2 and accounts for 14.2% of the total PDO concession area. There are 6 major operating oil fields and 20 small oil fields in Nimr area, 9 fields in Rima area and one field in Al Noor area. Currently there are 710 producing wells in Nimr area, 167 in Rima area and 7 in Al Noor area. Nimr field was discovered in 1980 and initially brought on stream in 1985. Nimr field was discovered in 1978 and initially brought on stream in 1985. Rima field was discovered in 1979 and initially brought on stream in 1982. The asset organisation structure is shown in Figure 3.1. The asset management structure including the health, safety and environment (HSE) management structure as shown in Figure 3.2.

This asset (including Rima and Al Noor) produces 35,669 m^3/d of net crude (26.6 % of PDO's total crude oil production) and 780,000 Sm^3/d of associated gas (1.8% of PDO's total gas production) as reported for the year 2002. The asset also produces 313,105 m^3/d of produced water. The total power generation in the asset is 76.7 MW and the total abstraction of groundwater in the asset is 2,988 m^3/d excluding water used by rigs. The total length of flow lines is 607 km.

The facilities currently available in the asset are listed in Table 3.1 below

Table 3.1: List of Facilities in Nimr Asset

Name of Facility	Number of Units
Production stations	3 (Nimr, Rima and Al Noor)
Crude stabilisation plants	None
Gathering stations	1(Amal)
Power stations	2 (Nimr and Rima)
Water treatment plants	2 (Nimr and Rima)
Booster stations	None
Permanent PDO camps	1 (Nimr)
Permanent contractor camps	7 (Six in Nimr and one in Rima)
Permanent sewage treatment plants	4 (Three in Nimr and one in Rima)
Mobile sewage treatment plants	None
Central chemical stores	1 (Nimr)
Waste management centre	1 (Nimr)
Drilling rigs	5 (currently)

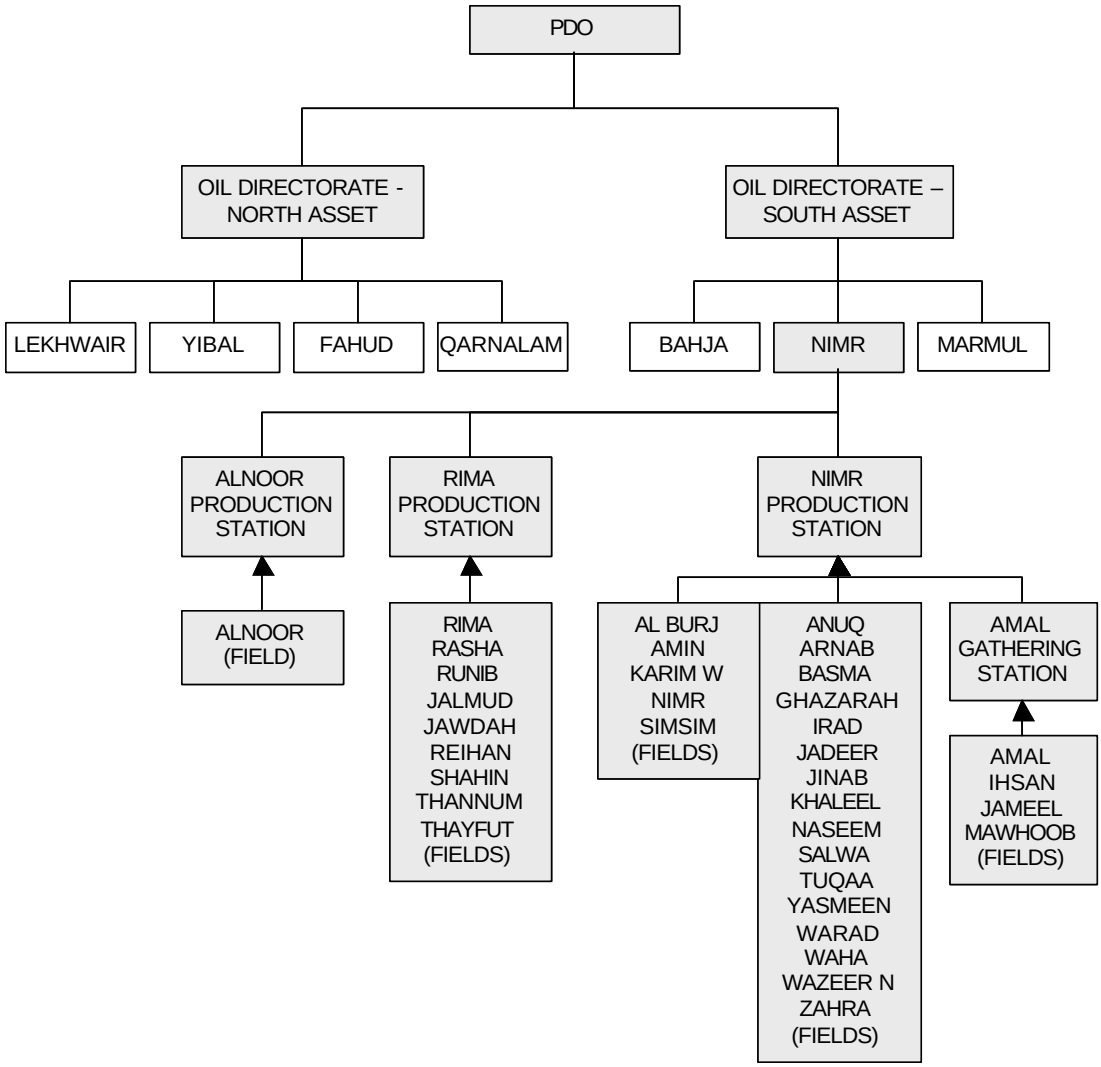


Figure 3.1: Asset Organization Structure for Nimr Asset

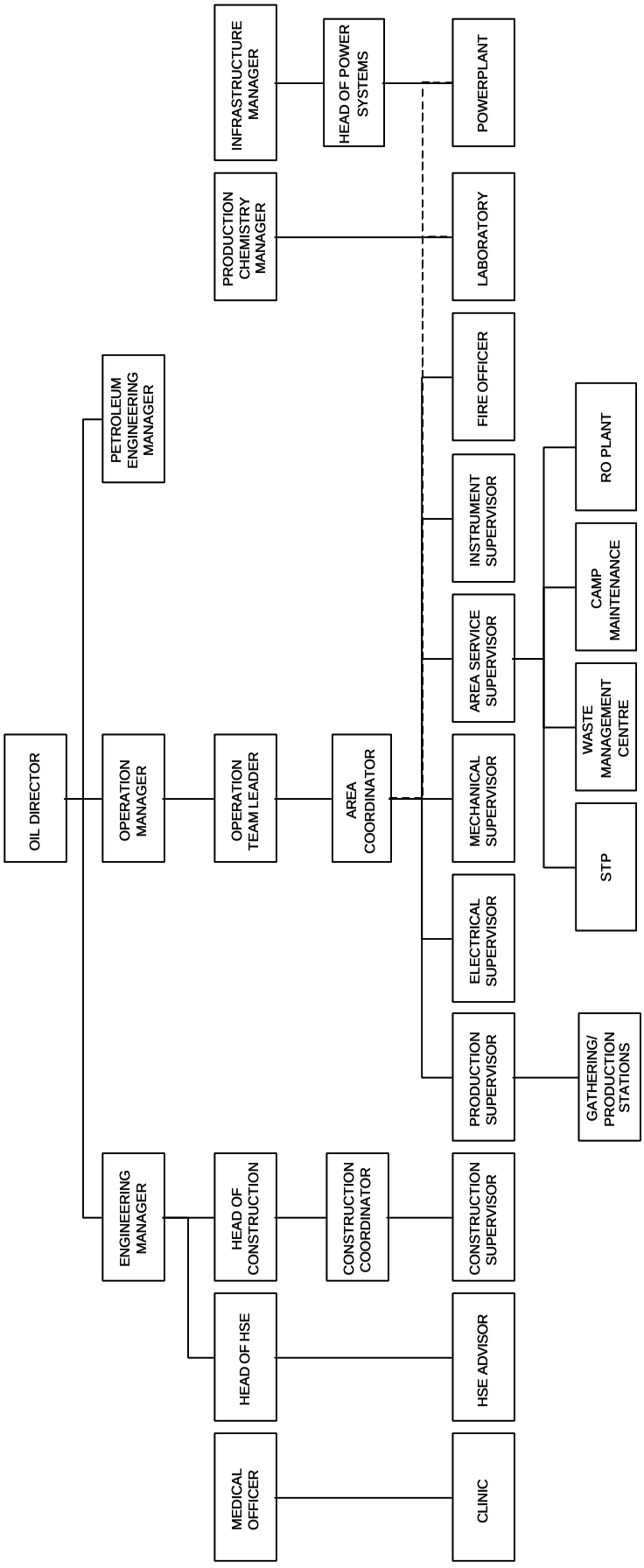


Figure 3.2: Asset Management Structure for Nimr

There are three production stations in the asset, located in Nimr, Rima and Al Noor. There is only one gathering station in this asset, which is located at Amal. There is one gas fired gas turbine power station located in Nimr. There is a central chemical store and a permanent laboratory facility in Nimr. There are two water treatment plant based on reverse osmosis (RO) process, one located in Nimr and another in Rima.

There are eight permanent accommodation camps in the asset, one exclusively for PDO staff (located in Nimr) and seven for contractor staff (six in Nimr and one in Rima). There are four permanent sewage treatment plants (STPs), three in Nimr and one in Rima. There is a central waste management centre in the asset, located in Nimr.

3.2 Activity Description

The major production related and associated activities performed in the asset may be summarised as below:

- Extraction of reservoir fluid from oil fields and transporting it to gathering stations/ production stations
- Separation of associated gas from the reservoir fluid in the gathering station/ production station
- Separation of produced water and crude oil and stabilisation of crude oil at the production station
- Exporting of crude oil to Mina Al Fahal storage tank through booster stations.
- Compression of associated gas
- Abstraction of groundwater and demineralisation
- Generation of power using gas fired gas turbines
- Disposal of produced water by injection into deep aquifers
- Treatment of liquid effluents
- Disposal of solid waste
- Flaring of unutilised associated gas

In addition to the above, the following developmental and construction activities are performed at some location or the other within the asset throughout the year:

- Seismic survey
- Drilling
- Well construction

- Pipeline construction and maintenance
- Road construction and maintenance
- Power line construction and maintenance
- Well closure and site restoration

A schematic diagram illustrating the major production related and associated activities performed in the asset is shown in Figure 3.3. A brief description of the major facilities and activities in the asset are discussed in the following sections.

3.3 Gathering Stations

Currently, crude oil is extracted from 35 operating fields and 884 wells in the asset. Out of the 884 wells, only seven are natural flow wells, all of which are located in the Rima area. The pumped wells include 236 using electrical submersible pumps (ESP), 622 using beam pumps and 19 using screwed pumps. There is only one gathering station in the asset, which is located in the Amal field for the degassing of reservoir fluid extracted from Amal, Ihsan, Jameel and Mawhoob fields. The reservoir fluid extracted from all other fields in the asset is directly sent through flow lines to one the three production stations located in the asset for degassing and dehydration.

In the Amal gathering station, the reservoir fluid extracted from the Amal, Ihsan, Jameel and Mawhoob fields is degassed before it is sent to Nimr production station for dehydration. The facilities in the gathering station consist of a bulk separator, a surge tank and an atmospheric flare. The associated gas in the reservoir fluid is separated in the bulk separator and the surge tank. The percentage of associated gas in the reservoir fluid in this field is quite small and is uneconomical to recover. Therefore the separated gas is flared in an atmospheric flare. Gas required for surge tank blanketing is imported from the gas grid. The degassed oil water mixture is sent to Nimr production station for dehydration and export to main oil line.

3.4 Production Stations

3.4.1 General

There are three production stations in the asset. They are located in Nimr, Rima and Al Noor. In Nimr production station, the reservoir fluid extracted from five major fields *viz.*, Al Burj, Amin, Karim West, Nimr and Sim Sim and several other small fields including Anuq, Arnab, Basma, Ghazarah, Irad, Jadeer, Jinab, Khaleel, Naseem, Salwa, Tuqaa, Yasmeen, Warad, Waha, Wazeer North and Zahra is handled.

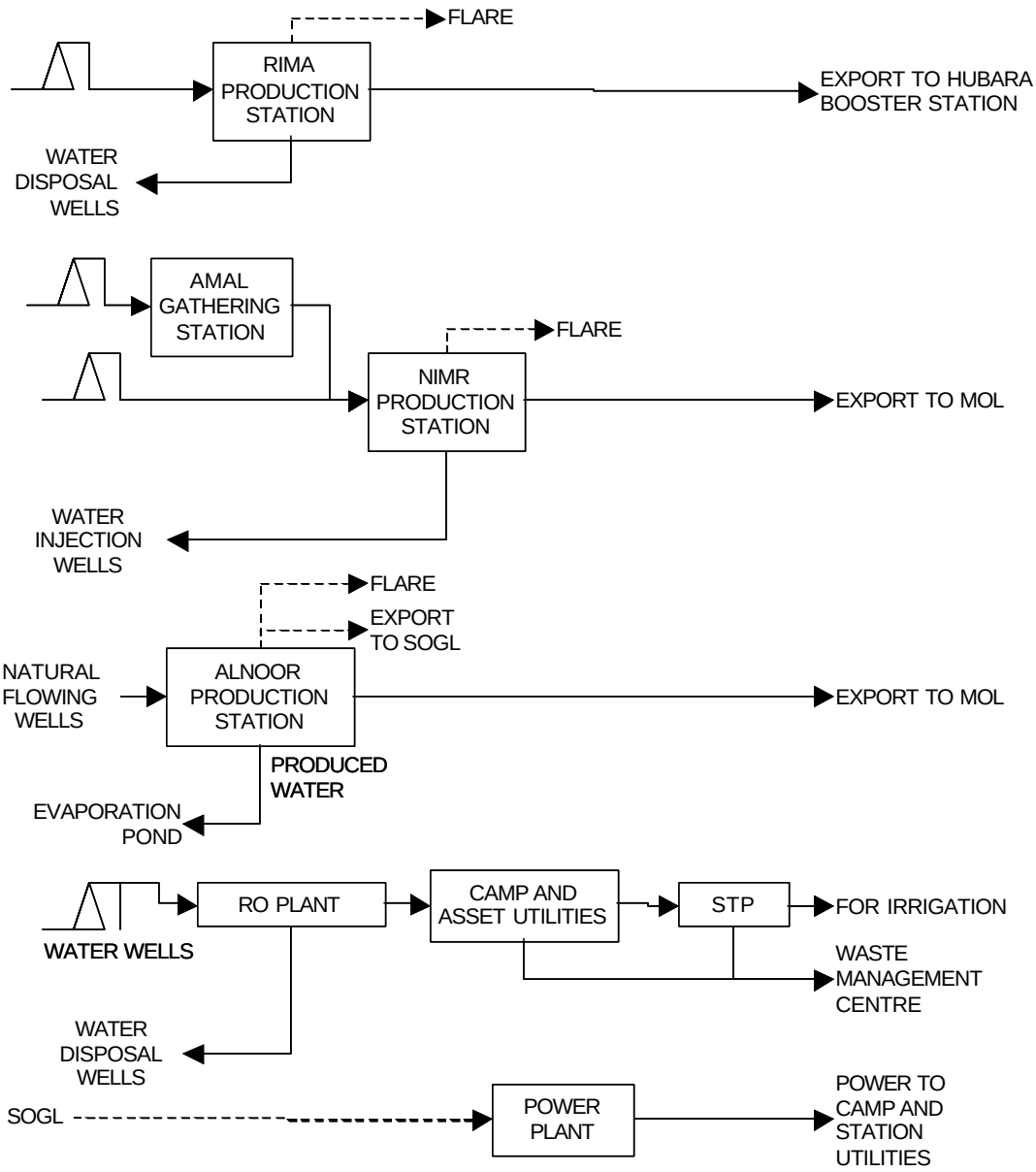


Figure 3.3: Schematic Diagram of Major Production and Associated Activities

In addition, the degassed fluid from Amal gathering station is also processed in this production station. In the Rima production station, the reservoir fluid extracted from Rima, Runib, Jawdah, Jalmud, Jalmud North, Reihan, Shahin, Thayfut, Rasta and Thannum fields is degassed and dehydrated. In Al Noor production station, the reservoir fluid extracted from Al Noor field is degassed and dehydrated. A brief description of each production station in the asset is presented below.

3.4.2 Nimr Production Station

Nimr production station, known as the Nimr Main Production Station (NRPS) is located adjacent to PDO's Nimr main camp. This production station receives well fluid from five major fields (Al Burj, Amin, Karim West, Nimr and SimSim fields) and 16 small fields (Anuq, Arnab, Basma, Ghazarah, Irad, Jadeer, Jinab, Khaleel, Naseem, Salwa, Tuqaa, Yasmeen, Warad, Waha, Wazeer North and Zahra fields) along with degassed well fluid from Amal gathering station (Amal, Ihsan, Jameel and Mawhoob fields). The facilities in the production station include four parallel process trains, each consisting of free water knock out tank (FWKO), heat exchanger, concentric wash tank, oil storage tank and oil export pumps. In addition, there are 12 corrugated plate interceptor (CPI) separators in the production station for de-oiling of separated produced water and four hot water heaters for heating the oil-water emulsion entering the concentric wash tanks.

The well fluid is received FWKO tanks where free water is removed by gravity under interface level control. The free water removed from the bottom of the tanks is sent for de-oiling and disposal. The associated gas present in the well fluid is separated from the top of the tank and sent to the flare.

The partially dehydrated oil leaving knock-out tanks will be in oil-water emulsion phase. This emulsion is broken in concentric wash tanks. In order to break the emulsion, the fluid is heated to about 80^{o}C before it enters the concentric wash tanks. The oil emulsion is heated in counter-current heat exchangers. The heat transfer medium is recirculating water, which is heated in gas fired heaters. From the concentric wash tanks, the dehydrated hot oil is sent to the crude oil storage tanks via preheaters. In the preheaters, the heat in the hot oil is exchanged to the oil emulsion (inlet stream to concentric tanks).

The separated produced water is mixed with the free water separated in the knock-out tanks and then treated in CPI separators for de-oilng. The oil recovered from the CPI separators and any oil sludge periodically removed from the various process tanks are sent to an oil sludge storage tank for disposal. The de-oiled produced water (~ 250 ppm oil in water) is disposed using the deep-well disposal pumps. If the volume of

produced water exceeds the pumping capacity of the deep-well disposal pumps, then the excess water is shallow-well disposed.

3.4.3 Rima Production Station

The Rima production station is located about 60 km northeast of Nimr main camp. This production station receives well fluid from Rima, Runib, Jawdah, Jalmud, Jalmud north, Reihan, Shahin, Thayfut, Rasta and Thannum fields. The process activities in this production station are similar to those of Nimr production station. However, there are only two parallel process trains in the production station. There are two hot water heaters, which are currently non-operational.

The associated gas separated from the well fluids in this production station is not utilised and hence flared. The de-oiled produced water disposed of to either deep-well or shallow-well disposed. The dehydrated crude is pumped via a 30 km line to the Hubara Booster Station, from where it is fed into the main oil line for export.

3.4.4 Al Noor Production Station

Al Noor production station is located approximately 40 km southwest of Nimr main camp. This production station receives the well fluid from seven free flowing wells in Al Noor field. Unlike the other two production stations in this asset, this production station includes gas recovery and treatment facilities. The gas produced from the wells in the field is classified as high-risk sour gas with H_2S concentration in the gas as high as 125,000 ppm.

In this production station, the combined well fluid first enters a 3-phase (gas-oil-water) high-pressure separator, which operates at 7,900 kPa(g). This is a first stage bulk separator, where the gas separation is achieved by velocity reduction and water is separated by gravity. The separated gas flows to the gas treatment train and the separated water flows into a sour water stripper. The oil phase flows into the second stage medium pressure separator via a pre-heater. The medium pressure separator operates at 1,900 kPa(g) and is similar to the high pressure separator in operation. The gas and water separated in this separator flow to the gas treatment train and sour water stripper respectively.

The degassed and dehydrated crude oil from the medium pressure separator flows to the crude stabiliser system, which consists of a stabiliser column, re-boiler and water draw-off vessel. The purpose of the crude stabiliser system is to remove and recover, by distillation, the volatile components in the crude before it is fed into the main oil line. The heat for crude stabiliser reboiler, a horizontal kettle type heater, is supplied

by re-circulating hot oil from hot oil heater. The gas exits from the top of the column and flows into the low pressure compressor suction. The stabilised crude oil from the bottom of the column flows via medium pressure separator pre-heater into the product oil tank from where it is pumped to the main oil line for export.

The gas separated in the 3-phase separators is compressed to high pressure and then taken to a gas conditioning train, consisting of an H_2S removal package, a dehydration package and a hydrocarbon dew point package. The removal of H_2S from sour gas is achieved through chemical absorption in an amine absorber. The amine absorber is designed for selective removal of H_2S and mercaptans to less than 10 ppm. In the absorber, the sour gas is counter-currently contacted with lean amine solution (amine: sulfolane : water = 40 : 40 : 20). The rich amine solution is sent to amine stripper via a flash vessel for regeneration, cooled and then recycled. The off-gases from the flash vessel and stripper are flared.

Wet gas from the amine absorber enters the glycol contactor where lean glycol flows counter-currently with the rising wet gas. Water is removed from the gas by absorption into the glycol. Rich glycol flows into the glycol regenerator and is recycled after cooling. The dry gas from the glycol absorber is chilled to about 4°C in the hydrocarbon dew point package to condense the low boiling hydrocarbons in the gas. The cooling is achieved with chilled water entering at -5°C. The sweet gas is exported to the gas grid. The condensate is exported to Nimr production station.

3.5 Power Stations

The electrical power is required in the asset for production activities, auxiliary activities and accommodation facilities. The total electrical power requirement in the asset is presently about 31 MW. There are two power plants in the asset with a total generating capacity of 90 MW. After meeting the internal power requirement in the asset, excess power is exported to PDO grid for use in other power deficient assets. It may be seen that currently, over 65% of the power generated in the asset is exported.

The two power plants in the asset are located in Nimr and Rima. Both power plants are based on open cycle gas turbine technology, with no waste heat recovery. The associated gas imported from the gas grid is used as the fuel gas in the power plants. The details of the power plant are given below in Table 3.2.

Table 3.2: Details of Power Plants in Nimr Asset

Specifications	Power Plant in Nimr	Power Plant in Rima
Total generating capacity	60 MW	30 MW
Number of gas turbines	2	2
Make and model of gas turbines	Frame 6	Frame 5
Fuel used	Associated gas	Associated gas
Fuel consumed per day	349,000 m^3	247,000 m^3
Emission control system used	Standard combustion system with no NO_X control	Standard combustion system with no NO_X control
Number of stacks	2	2
Stack height	15 m (approx.)	15 m (approx.)
Stack exit diameter	4.3m (approx.)	2.2 m (approx.)
Stack gas exit temperature	560-595^oC	482^oC

3.6 Water Treatment Plant

The groundwater in the asset is saline and therefore it needs to be demineralised for process and domestic use. The total treated water requirement in the asset is presently 1,050 m^3/d, out of which Nimr station requires 960 m^3/d and at Rima requires 90 m^3/d. The demineralisation is done by reverse osmosis (RO). The net feed water to the RO plant is currently 1,500 m^3/d. There are two RO plants, one in Nimr and other in Rima. Groundwater is abstracted from Fars and Dammam formations for demineralisation. Details of the existing water treatment plants are given in Table 3.3 below.

Table 3.3: Details of Water Treatment Plant in Nimr

Specifications	Nimr RO Plant	Rima RO Plant
Total freshwater production capacity	975 m^3/d	350 m^3/d
TDS of treated water	473 mg/L	212 mg/L
Type of demineralisation	Reverse osmosis	Reverse osmosis
Number of units	One	One
Total flow rate of inlet stream	1500 m^3/day	550 m^3/day
TDS of feed water	6816 mg/L	8894 mg/L
Total flow rate of reject stream	525 m^3/day	200 m^3/day
TDS of reject stream	19155 mg/L	25766 mg/L

3.7 Auxiliary Facilities

3.7.1 Overview

The major auxiliary facilities in the asset include the following:

- Water disposal system
- Sewage treatment plants

- Waste management centre
- Production chemistry laboratory
- Maintenance workshop
- Accommodation facilities
- Miscellaneous facilities

A brief description of these facilities is presented below.

3.7.2 Water Disposal System

The total produced water generated in the asset is currently 291,939 m^3/day. The production of water is 191,265 m^3/day (66%) from Nimr station, 100,652 m^3/day (34%) from Rima station and very little (22 m^3/day) from Al Noor production station. In Nimr, about 75% of the produced water is disposed into deep water disposal wells and about 25% is disposed of into shallow water disposal wells. There are seven deep water disposal pumps and eight shallow water disposal wells in Nimr. In Rima, about 35% of produced water is disposed into deep water wells while 65% is disposed into shallow water disposal wells. In Al Noor, there are no water disposal wells. Instead, the produced water is disposed into an evaporation pond for solar evaporation.

3.7.3 Reed Beds

Nimr asset has experimental reed beds for the treatment of production water. The native strains of Phragmites australis reeds are proven to withstand high concentrations of salinity and oil-in-water and breakdown a host of organic pollutants including hydrocarbons in the root zone by bacterial action. In addition, the about 25% reduction in water volume is also achieved in the reed beds due to transpiro-evaporation. In February 2000, two plots of reed beds of 3,000 m^2 area each were established in Nimr to treat 1,500 m^3/d of produced water with an average oil-in-water content of 200 ppm. While the initial results were encouraging, due to several operational and maintenance deficiencies, the performance of the reed beds suffered. Currently, only 250 m^3/d of produced water with an average oil-in-water content of 60 ppm is treated in the Nimr reed beds.

3.7.4 Sewage Treatment Plants

There are four sewage treatment plants (STP) at the asset. One STP of 55 m^3/day capacity is dedicated for the treatment of sewage generated from the PDO camp in Nimr. Two STPs of 400 m3/day and 270 m^3/day capacity respectively are provided

for treating the sewage generated from the contractor camps in Nimr. There is another STP of 38 m^3/day capacity is provided for treating the sewage generated from the Rima camp. The details of these facilities are presented in Chapter 4.

3.7.5 Waste Management Centre

Nimr asset has a centralised waste management centre for the disposal of both non-hazardous and hazardous wastes. It also consists of a land farm and a landfill for kitchen refuse. This facility does not handle NORM wastes or clinical wastes. NORM wastes are sent to a dedicated storage /disposal site in Zauliyah. The clinical wastes are sent to an incinerator in MAF. The details of the waste management centre are presented in Chapter 4.

3.7.6 Production Chemistry Laboratory

Nimr asset has a laboratory facility for the analysis of oil and gas quality, produced water quality, groundwater quality, treated water quality and effluent quality. This facility, known as production chemistry laboratory is located within the administrative area. Necessary laboratory equipment required for chemical, thermo-physical and biological analysis are available in the facility with resident analytical staff.

3.7.7 Workshops

A general maintenance workshop and an automotive maintenance workshop are located within the asset. In addition, there are also several small workshop units at work sites. Oily wastes from these workshops are collected separately and send to the waste management centre.

3.7.8 Accommodation Facilities

There are four permanent accommodation camps located within the asset. There is a PDO camp in Nimr, which is exclusively for the accommodation of PDO staff and their visitors. There two other permanent camps in Nimr for the contractor staff and their visitors. A small camp is located in Rima for the use by the contractor staff. All these camps are having catering and laundry facilities and all the rooms are fully furnished and air-conditioned. The details of accommodation facilities are summarised below in Table 3.4.

Table 3.4: Accommodation Facilities in Nimr Asset

Item	Description
Total number of permanent camps	Eight including one PDO main camp in Nimr, six contractors camps in Nimr (Two PACs and four portacabin camps for Haliburton, HES, Bhaker Oil Tools and Al Rabi) and one in Rima.
Total number of mobile camps	Presently five (for Rig 1, Rig 29, Rig 30, Rig 70, Rig 53).
Total number of housing units and total number of PDO staff (and visitors) accommodated at any time in PDO main camp	Rooms: 176 Current occupancy: 150
Total number of housing units and total number of contractor staff (and visitor) accommodated at any time in contractors camps	Rooms: 630 (only in PACs) Current occupancy : 1160 (only in PACs) In addition, there are about 80 poratcabins in four contractors camps accommodating about 200 people.
Typical number of staff accommodated at any time in each mobile camp	60
Total number of canteens in the permanent camps	PDO camp – 1 Contractor camps – 8 (PAC-4, Other contractor camp-4)
Total number of laundries in the camps	One laundry at each camp
Recreation facilities available in PDO main camp	Playing area (tennis, volleyball etc.) Swimming pool Gymnasium and Indoor games area Auditorium, conference rooms, TV room and reading room Mosque

3.7.9 Miscellaneous Facilities

The administrative offices are located in a large building called the Camp Main Office. Other facilities available within asset include a medical clinic, shops, ROP station, fire station, airstrip, vehicles for transportation etc.

3.8 Developmental and Construction Activities

3.8.1 Overview

Developmental and construction activities are carried out in the asset throughout the year, at some location or the other. At a site, these activities are of short duration ranging from a few days to a few weeks. These activities include seismic survey, drilling and well completion, pipeline construction and maintenance, road construction and maintenance, power line construction and maintenance, well closure and site restoration. The detailed description of these activities is presented in the individual EIA report for each of the service assets. A brief description is provided below.

3.8.2 Seismic Survey

Seismic survey is carried out for locating the new oil fields. This survey is carried out by the Exploration Asset Team. The seismic survey involves the mobilization and operation of survey equipment such as vibrator trucks and geophones, any site preparation work and management of on-site accommodation camps (mobile camps). Typically, the survey activity at a site lasts for 4-12 weeks.

3.8.3 Drilling and Well Completion

Drilling of exploration and production wells is a major construction activity with significant environmental aspects. Contractors under the supervision of the Exploration Asset Team carry out exploration drilling, while contractors under the supervision of the Well Engineering Asset Team carry out the drilling of producing wells. Drilling and well completion process involves the following sub-processes.

- Well pad preparation, which included site levelling, construction of access road for the rigs, construction of water and waste pits etc.
- Mobilization of drilling rig by road using over 20 trucks
- Setting up of rotary drilling rig on well pad with ancillary facilities (power generation unit, fuel storage, waste oil storage, drilling mud / chemical storage, accommodation / office and sewage treatment / handling)
- Preparation of water based or oil based muds for well drilling
- Continuous drilling, with drill string casing and cementing for protection of shallow aquifer
- Discharge of drilling mud and drill cuttings into a dedicated, fenced waste pit at each well pad
- Well completion and installation of wellhead (Xmas tree)

Typically, well pad preparation takes 4-7 days, rig mobilization up to 10 days, drilling about 2 weeks and well completion about 1-2 days. The drilling team stays on-site in mobile camps. Up to 150 personnel may be involved in the drilling team.

3.8.4 Pipeline, Road and Power Line Construction and Maintenance

The laying of new pipelines and the repair / replacement of defective pipelines is undertaken by the Infrastructure Asset Team. Laying of new pipelines may involve site preparation including removal of vegetation, to lay out the pipes as well as to provide access roads. For a new pipeline, hydrotesting is carried out prior to commissioning.

Road laying and maintenance involve the use of construction equipment such as bulldozers, road rollers etc. and may require importing to site construction materials such as gravel, stone aggregates, asphalt etc. This process also requires significant quantity of water for wetting and dust suppression.

Laying of new power lines and the maintenance of existing power lines is supervised by the Infrastructure Electrical Team. This activity normally does not involve major site preparation since the power lines are normally laid along the pipeline access roads.

3.8.5 Well Closure and Site Restoration

As wells dry out over a period of time, well closure is also a continuing activity in the assets. The Well Engineering Asset also conducts this activity.

Well closure involves the removal of both surface and sub-surface structures from the well site. The surface structures include the production and auxiliary equipment, flow lines, storage tanks, above ground steelwork and concrete. The sub-surface structures include the foundations, well casings etc.

The site restoration first involves the removal of any soil found to be contaminated oils or chemicals, then sending these soils for remediation or disposal. After the removal of structure and the equipment from the site, all efforts will be made to restore the landscape of the site, so that it integrates well with the surroundings. Where possible, the site will be restored to a level so that it can be put to a useful purpose.

3.9 Materials and Utilities

The production of oil does not require any raw materials. However, a large number of process chemicals are used in drilling, dehydration of crude, water treatment, scale control, corrosion control and wastewater treatment. The various process chemical used in the asset are grouped together based on their application and the quantities consumed during the year 2002 are given in Table 3.5 below.

Table 3.5: Consumption of Process Chemicals in Nimr Asset

Name of Process Chemical	Physical State and Chemical Nature	Purpose	Quantity Consumed (2002)
Water based muds		For drilling	Quantity unknown
Oil based muds		For drilling	Quantity unknown

Name of Process Chemical	Physical State and Chemical Nature	Purpose	Quantity Consumed (2002)
Demulsifier	Liquid; mixture of aliphatic and aromatic hydrocarbons; surface active agents	Used in dehydration of crude and deoiling of production water	4000 L/d
Defoaming agents	Liquid; mixture of aliphatic and aromatic hydrocarbons; surface active agents	Used in dehydration of crude and deoiling of production water	350 L/d
Scale inhibitors	Liquid; mostly organic phosphates	Used in RO plant for scale control	30 L/month
Corrosion inhibitors	Liquid; surface active agents in alcohols	Used in RO plant pipelines for corrosion control	Not used
Oxygen scavengers	Liquid; surface active agents in alcohols	Used in pipelines for corrosion control	400 L/month
Acids, alkalis and chelating agents	Liquid or solid; reactive and corrosive	Used in RO plant for membrane cleaning	EDTA: unknown Caustic soda: 800 L/month
Chlorine or hypochlorite solution	Liquid or tablets; strong oxidant	Used in RO plant and STPs for disinfection	10 kg/month in RO plant
Biocides	Liquid	Used in pipeline during pigging for control of fungal growth	Not in use
Flammable gases in cylinders	Pressurised gas, flammable	Cooking gas	Quantity unknown
Inflammable gases in cylinders	Pressurised gas	Welding gas	Quantity unknown
Solvents	Liquid	Painting	Quantity unknown

Note: All these chemicals are transported by road in trucks

The quantities of electrical power, fuels and freshwater consumed in the asset for the year 2002, are given below in Table 3.6.

Table 3.6: Consumption of Power, Fuels and Freshwater in Nimr Asset

Utility	Consumer	Average Quantity Consumed per Day during 2002
Electrical power	Oil fields, gathering stations, water injection plant, NRPS and accommodation and auxiliary facilities	3,020 MWh
Associated gas	Nimr power plant for power generation	349,200 Sm^3
	Rima power plant for power generation	246,620 Sm^3
	Nimr production station for heaters	67,310 Sm^3
	Rima production station for heaters	0
	Alnoor production station for heaters	23,440 Sm^3
	Total	686,570 Sm^3
Groundwater	For injection	1,488 m^3/ d
	For demineralisation	1,500 m^3/ d
	Total	2,988 m^3/ d
Treated (demineralised) water	For process + domestic use - Nimr	960 m^3/ d
	For process + domestic use - Rima	90 m^3/ d
	For process + domestic use – Al Noor	Negligible
	Total	1,050 m^3/ d

4 RELEASES TO ENVIRONMENT

4.1 Introduction

In this section, the various waste products and energies released into the environment from the various activities performed within the Nimr asset are discussed. The activities in the asset may be classified into the following groups, based on their nature:

- Activities related to production
- Activities related to generation of utilities
- Activities related to support services
- Activities related to construction, maintenance and decommissioning

The ***production related activities*** include all the activities performed in the oil fields, remote manifold stations, gathering stations, production stations and pipelines. The ***activities related to utilities*** include the activities performed in the power stations, sewage treatment plants and water treatment plants. The ***activities related to support services*** include catering, laundry, air conditioning etc. performed within the PDO and contractor camps; waste handling, treatment and disposal activities; and other activities such as transportation and workshops. All the activities are more or less continuous in nature and are site-specific.

The ***activities related to construction, maintenance and decommissioning*** include seismic survey, drilling, well construction, laying and repairing the pipelines, laying and repairing the roads, well closure etc. These activities are carried out almost throughout the year at some site or the other within the asset. However, at a particular site, these activities are essentially temporary (short duration) in nature and of very localized impact. Therefore, any waste generated from these activities is not discussed here unless they have a long resident time (ex: drilling wastes). However, a detailed analysis of wastes arising for these wastes are considered separately under the relevant EIA study for the service asset.

The wastes released into the environment from all the activities related to the above activities might be classified into the following groups, based on their physical state as well as nature:

- Air emissions
- Liquid effluents
- Solid wastes

- Noise
- Accidental leaks and spills

In order to quantify and characterize these releases, the currently available database is used. In cases where data are not available or insufficient, an attempt is made to estimate the quantities and characteristics using theoretical or empirical equations. Where estimates based on theoretical or empirical equations are considered not reasonably accurate, recommendations are made for direct measurement.

4.2 Air Emissions

4.2.1 Overview

The air emissions in the asset for the purpose of this report are classified into the following categories:

- Stack emissions
- Flare / vent emissions
- Area source emissions
- Mobile source emissions

While most of these emissions are continuous and long term, there are other several temporary sources from which the emissions are intermittent and of short duration. These sources, such as the equipment used for exploration, drilling, construction or maintenance purposes are operated for a short duration at any given site. As stated earlier (refer Section 4.1), the emissions from the temporary sources are discussed elsewhere and are not included in this report. The discussion on the various emission sources in the asset, their quantification, characterization and emission control is presented in the following sections.

4.2.2 Stack Emissions

Stack emissions are the most dominant air emissions in any asset by virtue of their number and quantity. The sources of stack emissions include the gas turbines (used in power stations for power generation and in booster stations and production stations for mechanical drive), heaters used in the production stations and the standby diesel generators used for emergency power supply. The emissions from standby diesel generators are very infrequent and hence of no significance. Hence, they are not considered further in this report.

The inventory of stacks in the asset is presented below in Table 4.1.

Table 4.1: Inventory of Stacks in Nimr Asset

Location	Gas Turbine Stacks	Heater Stacks	Total Number of Stacks
Nimr Production Station	0	4	4
Rima Production Station	0	0	0
Al Noor Production Station	0	2	2
Amal Gathering Station	0	0	0
Nimr Power Station	2	0	2
Rima Power Station	2	0	2
Asset Total	4	6	10

Note: Minor stacks such as standby diesel generator stacks are not included, since emissions from these stacks are very infrequent and emissions loads are relatively insignificant.

The fuel burned in all the above systems is the associated gas produced in the asset. The detailed analysis of the fuel gas used in the asset is shown in *Appendix 2*. The emissions are the products of combustion. The pollutants of concern in these emissions are sulphur dioxide (SO_2), oxides of nitrogen (NO_X), carbon monoxide (CO) and particulate matter (PM), which is primarily due to unburnt hydrocarbons (HC), which are released as fine particulates of <10µm size (PM_{10}) with a significant fraction under 2.5µm size ($PM_{2.5}$). Further, the emissions also contain significant quantity of carbon dioxide (CO_2), which is a greenhouse gas.

The detailed information on the stack design specifications, exit temperature, exit velocity, total gas flow rate, heat emission rate and the emission rates of individual pollutants for each stack is presented in *Appendix 3*. It may be noted that the stack emissions are not regularly monitored in the asset. Instead, the emission rates are estimated based on empirical emission factors, as described in *Appendix 3*. The emission inventories for all the assets are summarized in Table 4.2 below.

Table 4.2: Emission Loads from Stacks in Nimr Asset

Area	Fuel Consumed in 1000 Sm^3/d	Quantity of Emissions					
		Heat (10^6 MJ/d)	CO_2 (tpd)	SO_2 (tpd)	NO_X as NO_2 (tpd)	CO (tpd)	PM_{10} including HC (tpd)
Nimr Production Station	67.31	NA	168.4	0.00	0.2	0.0	<0.01
Al Noor Production Station	23.44	NA	96.0	0.00	0.10	0.0	0.0
Nimr Power plant	349.20	NA	825.9	0.00	2.0	0.8	0.1
Rima Power plant	246.62	NA	583.3	0.00	1.4	0.6	0.1
Asset total from all stacks	686.57	NA	1673.6	0.00	3.7	1.5	0.3

Note: For the cells marked NA, data are not available and not reported

Particulate emission controls are required only for fuels such as solid fuels and heavy petroleum residues with significant ash content. Particulate emissions (due to unburnt HC) from the stacks are not significant. The HC emissions along with CO emissions are minimised due to high combustion efficiency. SO_2 emissions depend on the sulphur content in the fuel. The fuel gas fired in the gas turbines and the heaters do not have sulphur in it and the SO_2 concentration in the stack emissions is nil.

Particulate emissions are not significant for gas-fired systems. Particulate emission controls are required only for fuels such as solid fuels and heavy petroleum residues with significant ash content. The HC emissions along with CO emissions are minimised due to high combustion efficiency of the fired systems, and therefore do not need any specific control systems.

SO_2 emissions depend on the sulphur content (or the hydrogen sulphide concentration) in the fuel gas. The associated gas produced from Al Noor field highly sour and the hydrogen sulphide concentration in the associated gas ranges up to 125000 ppm. Therefore the gas from Al Noor field is sweetened in an amine absorber to bring down the hydrogen sulphide concentration to <10 ppm. The description of the amine absorber is presented in Section 3.4.4 in Chapter 4. There is no Omani regulatory standard or PDO specification for maximum permissible SO_2 concentration in the stack emissions. However, PDO specification SP-1005 requires that SO_2 emission load be such that the ambient air quality standards (refer Table 2.5 in Chapter 2) are not breached.

NO_x emissions from standard combustion systems in the gas turbines can be quite significant. While there are no Omani specifications presently, PDO specification SP-1005 requires that NO_x emission concentration shall not exceed 200 mg/Nm^3. No data are available on NO_x concentrations in the stack emissions and no NO_x emission control systems are provided for any of the combustion systems.

4.2.3 Flare / Vent Emissions

Flares and vents are installed in the asset to release into the atmosphere any associated gas that cannot be utilised or re-injected into the reservoir. PDO has a “no continuous venting” policy, which requires that gases are flared (combusted at the flare tip) such that no unburned hydrocarbons are released into the atmosphere. Venting is permitted only under abnormal conditions such as insufficient gas pressure or quantity to support the flame. In PDO’s terminology, vent is an unlit (cold) flare and as such, there is no physical difference between a vent and a flare. Three types of flares / vents exist in PDO, *viz.*, high pressure (HP) flare / vent, low pressure (LP) flare / vent and

atmospheric pressure (AP) flare / vent. The principal difference is that the gas pressure is greater than 150 kPa(g) for HP flare / vent, 0.5 to 150 kPa(g) for LP flare / vent and 0 to 0.5kPa(g)for AP flare / vent.

The constituents in the flare emissions are not different from those of stacks, except for their composition. Generally, the emission factors (tonnes emission per tonne of gas flared) for CO and HC from the flares are substantially higher than those for stacks. The SO_2 emissions depend on the sulphur content in the gas flared. NO_x emissions will be slightly higher than that from a gas turbine fitted with DLN burner. The emission factors for flares in PDO are estimated based on Tier 3 emission factors given in the Shell group specification EP 95-0377 on "Quantifying Atmospheric Emissions" (Reference X), as below:

CO_2	: 27.5 x E kg per tonne of gas flared
CO	: 8.7 kg per tonne of gas flared
NO_x as NO_2	: 1.5 kg per tonne of gas flared
SO_2	: 20 x S kg per tonne of gas flared
HC	: 3 x (100 - E) kg per tonne of gas flared
Smoke index	: Ringlemann 1

where E is the flare efficiency (assumed to be 95%) as percentage and S is the mass percentage of sulphur in the fuel gas. In the case where the flare is unlit (cold vent), the emissions have the characteristics as the vented gas.

The concentrations of pollutants, mainly HC, CO and NO_x in the flare emissions are controlled by proper design of the flare tip. The basic principle is to ensure near complete combustion through good entrainment of air for combustion, good fuel-air mixing and flame stability. All the flares are currently designed such that the smoke index, which a measure of combustion efficiency is Ringlemann 1 or lower. The details of flares / vents in the asset are presented below in Table 4.3.

Table 4.3: Inventory of Emissions from Flares / Vents in Nimr Asset

Area	Number of Flares / Vents	Quantity of Gas Flared / Vented (10^3 Sm^3/d)	Number o Hours Vented pe Year	Heat Emission Rate (10^5 MJ/d)	CO_2 Emissio Rate (tpd)
Nimr Production Station	2 (1 HP +1 LP)	48.9	0	17.7	116.3
Rima Production Station	2 (1 HP +1 LP)	65.6	0	41.1	269.1
Al Noor Production Station	2 (1 HP +1 LP)	341.6	0	186.6	1329.7
Amal Gathering Station	2 (1 LP + 1 AP)	Not reported	Not reported	Not reported	Not reported
Asset total	8 (3 HP + 4 LP + 1AP)	456.1+		245.4+	1715

4.2.4 Area Source Emissions

The area sources for air emissions in the asset include bulk storage tanks, waste disposal sites, sewage treatment plant (STP) sites, wastewater lagoons and excavation sites.

For area sources, ***bulk storage tanks*** account for most of the air emissions. The air emissions from bulk storage tanks are basically the hydrocarbon vapour losses into the atmosphere due to evaporative pressure build-up in the tanks and their purging during tank fillings. Among the bulk storage tanks, only the crude oil and associated gas storage tanks are considered as significant area sources, while the storage tanks of small capacities for petroleum products are disregarded.

The ***waste disposal sites*** include the dumpsites / landfill sites, land farms for contaminated soils and drilling waste pits. The emissions from these sites may include hydrocarbon vapours (due to surface evaporation), dust (due to wind dispersal) and other noxious gases (due to waste decomposition). The ***emissions from STP sites and the wastewater lagoons*** are basically the odorous vapours such as sulphides and amines. They are released only under septic conditions, which rarely exist in the asset. The ***excavation sites*** are basically associated with well pad construction. The emissions are basically dust risings and temporary in nature. Hence they are not considered in this report.

Only hydrocarbon emissions are considered significant in quantity from area sources in PDO. The hydrocarbon vapour emissions from all significant area sources are estimated based on Tier 3 emission factors given in the Shell group specification EP 95-0377 on "Quantifying Atmospheric Emissions" (*Reference 3*):

Fixed roof tank	: 131.765 grams per tonne of throughput
Internal floating roof tank	: 0.235 grams per tonne of throughput
External floating roof tank	: 1.000 grams per tonne of throughput

The above emission factors are based on USEPA's AP-42 methods. It is assumed in PDO that 15% of the total hydrocarbons emissions are methane and the remaining 85% are non-methanes.

Crude oil storage tanks are identified as the principal area sources of air emissions, and the emissions from these sources are hydrocarbon vapours. The details of the crude oil storage tanks in the asset and the estimated hydrocarbon vapour emissions from these sources are presented in Table 4.4 below.

Table 4.4: Air Emissions from Area Sources in Nimr Asset

Description of Source	Tank type	Tank Capacity (m^3)	Throughput Rate (Tonnes per day)	Total Hydrocarbon Emission Rate (Tonnes per Year)
Storage tank in Nimr Production Station	Fixed Roof	4 tanks each of 6000 m^3	9.75	0 (See Note 1)
Storage tank in Rima Production Station	Fixed Roof	2 tanks each of	2.23	0 (See Note 1)
Product Tank in Al Noor Production Station	Fixed Roof	One tank of 1200 m^3	2.65	0 (See Note 1)

Note 1: All fixed roof ranks are provided with vents for collection of vapours and these vapours are routed to the flare. Hence there will be no direct emissions to air from fixed roof tanks

4.2.5 Mobile Source Emissions

Motor vehicles used within the asset for the transportation of materials and men constitute mobile air emission sources. The types of motor vehicles used may be classified as light duty petrol vehicles (cars and 4-wheel drives), medium duty diesel vehicles (buses and vans) and heavy duty diesel vehicles (trucks). The significant pollutants present in these emissions are NO_x, CO and PM_{10}, which includes the unburnt HC. The emission factors (mass of pollutants emitted per running kilometre) depend on the type of the motor vehicle, type of the fuel, running speed, load conditions and environmental conditions.

In PDO, the air emissions from mobile sources are estimated based on Tier 3 emission factors given in the Shell group specification EP 95-0377 on "Quantifying Atmospheric Emissions" (Reference X). These are based on USEPA's AP-42 methods. However, for the sake of simplicity, EP 95-0377 specification uses common emission factors for all categories of land transport vehicles, as shown below:

CO_2	:	3200 kg per tonne of fuel consumed
CO	:	27 kg per tonne of fuel consumed
NO_x as NO_2	:	38 kg per tonne of fuel consumed
SO_2	:	8 kg per tonne of fuel consumed
HC	:	5.6 kg per tonne of fuel consumed

In the above estimates, it is assumed that all vehicles are diesel driven, moderately aged and the sulphur content in the fuel is 0.4% by mass.

The estimated total emissions from mobile sources in the asset are as given in Table 4.5.

Table 4.5: Air Emissions from Mobile Sources in Nimr Asset

Parameter	Quantity
Total number of land vehicles operating in the asset (PDO and Contractors)	Not available
Total quantity of fuel consumed – petrol	585.11 tpa
Total quantity of fuel consumed – diesel	13,409.57 tpa
Total quantity of fuel consumed – all fuels	13,994.68 tpa
Total emission of CO_2	44,782.97 tpa
Total emission of CO	377.86 tpa
Total emission of NO_x	531.80 tpa
Total emission of HC	78.37 tpa

4.3 Liquid Effluents

4.3.1 Overview

The liquid effluents in the asset may be classified into three groups *viz.*, continuous, intermittent and accidental. The different effluent streams in each group include the following:

- Produced water (continuous)
- Water treatment plant rejects (continuous)
- Sewage (continuous)
- Vessel washings (intermittent)
- Hydrotest water (intermittent)
- Drilling wastewater (intermittent)
- Leaks and spills of oils and chemicals (accidental)

Quantity-wise, the most significant streams are produced water, water treatment plant rejects and sewage, which are continuously generated. ***Produced water*** refers to the water separated from the crude and then disposed. ***Water treatment plant effluents*** refer to the concentrated brine rejects from reverse osmosis (RO) plants and the backwash of softening plants. ***Sewage*** refers to the domestic effluents generated from accommodation facilities, canteens, laundries and the wastewater generated from the various washrooms and toilets in administrative areas. Sewage generated from mobile camps used by the seismic survey and drilling teams are not considered here, since these camps stay at a site for typically 1-2 weeks only and they are handled separately.

With respect to the intermittent effluents, the ***vessel washings*** refer to the occasional washings from process tanks and vessels. *Hydrotest water* refers to the wastewater

that is finally disposed after hydrotesting of pipelines. ***Drilling wastewater*** refers to the wastewater that is finally disposed after the completion of oil well drilling.

The ***oil and chemical leaks and spills*** occur only accidentally due to pipeline failure, storage tank failure and road accidents. The leaks and spills usually result in the contamination of soils and are discussed separately under Section 4.6. The leaks and spills involving water or treated sewage are not considered as waste streams, and hence not discussed in this section.

4.3.2 Quantification and Characterisation of Liquid Effluent

The quantities of the various liquid effluent streams generated in the asset are presented in Table 4.6 below, along with a brief description of their nature.

Table 4.6: Liquid Effluents Generated in Nimr Asset

Liquid Effluent	Source of Generation	Streams	Quantity Generated (m^3/d)	Typical Nature and Characteristics of Raw Effluent
Produced water (Continuous)	Production stations	Nimr Rima Al Noor Total	215,181 97,912 12 313,105	Water from the reservoir with high dissolved inorganic salts, traces of oil and virtually free of organic matter
Water treatment effluents (Continuous)	RO plants and softening plants	RO plant reject + backwash Softening plants Total	450 0 450	Backwash with high dissolved inorganic salts and virtually free of organic matter
Sewage (Continuous)	Accommodation facilities, canteens, laundries, toilets and wash basins	STP-PDO STP-Contractor 1 STP-Contractor 2 Total	84 314 203 601 (see note)	Wastewater from domestic activities with mostly biodegradable nutrients as suspended and dissolved matter
Vessel washings (Intermittent)	Process tanks and vessels	All	Negligible	Occasional washings with traces of oil and detergents, and virtually free of organic matter
Hydrotest water (Intermittent)	Pipeline under testing	All sources in the asset	Negligible	Wastewater after hydrotesting with traces of oil and virtually free of organic matter
Drilling wastewater (Intermittent)	New drilling sites	All sources in the asset	Not available	Wastewater from drilling activities with traces of oil, heavy metals and virtually free of organic matter

Note: Some raw sewage is occasionally released into lagoons due under-capacity of sewage holding tanks in the Contractors STP. The sewage generated from mobile camps is not included, since mobile camps do not stay for more than 1-2 weeks at a site and the effluents are separately handled.

4.3.3 Effluent Treatment

- **Overview**

The produced water, after de-oiling is disposed mostly into deep aquifer and some is disposed into the shallow aquifer. A very small quantity of produced water that is generated in Al Noor production station is evaporated in a solar evaporation pond. The RO plant rejects and backwash are collected in the wastewater pit and then disposed into shallow disposal well. Sewage is treated by biological oxidation in STPs based on activated sludge process for removal of organic nutrients. With respect to the intermittent streams, they are either mixed with other compatible effluents or appropriately disposed as discussed in the following sections.

- **Produced Water**

Produced water is separated from the crude in a three-phase separator in the production station. The separated water is then de-oiled in CPI separators to reduce the residual oil content to the order of 250 mg/L. About 75% of produced water from Nimr production station is deep well disposed into Haima formation in Nimr Field. The remaining 25% is shallow well disposed into UeR formations. It is however proposed to replace shallow well disposal with deep well disposal by the end of year 2003. A small quantity of produced water (currently 250 m^3/d) is also used for the experimental reed beds (refer Section 3.7.3).

At Rima production station, about 35% of the produced water is deep well disposed into Haima formation and remaining 65% is shallow well disposed into UeR formation. The residual oil content in the de-oiled water from the Rima production station is in the order of 50 mg/L. Al Noor production station produces only small quantity (about 12 m^3/d) of produced water. This water is evaporated in solar evaporation pond of 120 m by 120 m size. This production water is characterized by high H_2S content. The H_2S detectors are installed near the evaporation pond area to raise an alarm whenever the H_2S concentration in the air exceeds 10 ppm.

- **RO Plant Rejects and Backwash**

RO plant rejects and backwash in Nimr are collected in a wastewater pit and disposed into Dammam formation using two water disposal wells. RO plant rejects and backwash in Rima are disposed into UeR formation.

- **Sewage**

Sewage generated in the asset is treated in four STPs, three of which are located in Nimr and one in Rima. The STPs are based on activated sludge process. The detailed

treatment process description is presented in the environmental audit report of the STPs in PDO (*Reference 4*). A brief description is provided below.

Raw sewage from the various points of generation is pumped to STP lifting station. From the lifting station, raw sewage is pumped to the aeration tanks, passed through bar screens to trap large objects. In the aeration tank, submerged air diffusers supply the oxygen necessary for oxidation. The sewage in the aeration tanks is internally re-circulated to ensure good mixing and to eliminate the settling of solids in the aeration tank. From the aeration tank, the effluent is transferred to a settling tank for the removal of sludge (excess biomass generated due to biological oxidation of the nutrients) by gravity settling. The sludge settled in the bottom of the settling tank is returned to the aeration tank to maintain a healthy biomass concentration (about 4000 mg/L) in the aeration tank. Excess sludge generated in the system is removed periodically from the settling tank to the sludge drying bed.

The clarified effluent from the settling tank is passed through a sand filter to remove any remaining fine suspended particles. The sand filter is periodically backwashed with treated sewage to remove the filtered particles, and the backwash is then pumped back to the aeration tank. The filtrate from the sand filter is then disinfected before it is pumped to the storage tank. The sludge removed from the settling tank is dried in sludge drying before it is sent to the waste management centre.

In the asset, there are three STPs in Nimr area, one in Rima area and none in Al Noor area. The first STP (STP/NMR-1) of 55 m^3/d design capacity is dedicated for treating the sewage generated from PDO's main camp in Nimr and the other two STPs (STP/NMR-2 and STP/NMR-3) of 400 m^3/d and 270 m^3/d design capacity are dedicated for treating the sewage generated from contractor camps in Nimr. STP/NMR-4 of 38 m^3/day design capacity is dedicated for treating the sewage generated from the contractor camp in Rima. The design details of all the STPs in the asset are presented below in Table 4.7.

Table 4.7: Design Specification of STPs in Nimr Asset

Design Specifications	STP/NMR-1 (PDO Camp)	STP/NMR-2 (Contractor Camp)	STP/NMR-3 (Contractor Camp)	STP/NMR-4
Hydraulic flow rate (m^3/d)	55	400	270	38
Loading rate (kg/d) - TSS	Unknown	Unknown	Unknown	Unknown
Loading rate (kg/d) - BOD	Unknown	Unknown	Unknown	Unknown
Raw sewage holding tank capacity (m^3)	4 tanks of 35 m^3	167	120	Unknown
Aeration tank volume (m^3)	120	410	280	Unknown
Type of aeration mechanism in aeration tank	Submerged air diffusers	Submerged air diffusers	Submerged air diffusers	Submerged air diffusers

Design Specifications	STP/NMR-1 (PDO Camp)	STP/NMR-2 (Contractor Camp)	STP/NMR-3 (Contractor Camp)	STP/NMR-4
DO maintained in aeration tank (mg/L)	Not available	Not available	Not available	Not available
MLSS maintained in aeration tank (mg/L)	Not available	Not available	Not available	Not available
Sludge settling tank volume (m^3)	63	374	92	Not available
Sand filter diameter (m) and height (m)	Not available	Not available	Not available	Not available
Type of chlorination provided	Chlorine powder and Tablets	Chlorine powder and Tablets	Chlorine powder and Tablets	Chlorine powder and Tablets
Treated sewage tank volume (m^3)	138	802	280	Unknown
Size of sludge drying beds (m x m x m)	1 bed of 9m x 5m x 0.4m	8 beds each of 8m x 5m x 0.4m	3 beds each of 9m x 5m x 0.4m	Unknown
STP outlet concentration (mg/L) - TSS	2-31	4-110	5-233	4-35
STP outlet concentration (mg/L) - BOD	2-20	2-20	3-30	2-13
STP outlet concentration (mg/L) - COD	21-85	6-68	5-67	13-59
STP outlet concentration (mg/L) – NH_3	0-8	0-7	0-10	0-4

- **Intermittent Effluents**

The major intermittent effluents include the hydrotest water and the drilling wastewater. Hydrotesting is performed only for the new pipelines. Since no new pipelines are laid out in the asset recently, no effluent is generated from hydrotesting in the asset. Following the standard practice in PDO for the disposal of hydrotest water, it will be drained into the desert if the quality meets the discharge standards (refer Table 2.7). If not, it will be sent to the production station for disposal along with the produced water.

The total quantity of wastewater generated from drilling activities in the asset depends on the frequency and duration of drilling. The standard practice in PDO for the disposal of drilling wastewater is to collect the wastewater in a waste pit and allow it to slowly evaporate by solar radiation. The sludge generated after drying will be disposed off as oily sludge or contaminated soil, if the oil content is greater than 10g/kg.

4.3.4 Effluent Disposal

- **Quality of Treated Effluents**

The typical characteristics of the treated effluent streams are presented in Table 4.8 below. The characteristics of production water and water treatment plant effluents are based on the analysis of periodic samples collected and analysed by PDO during the year (2002). The characteristics of sewage are based on the analysis of periodic samples collected and analysed by the STP operator during the year 2002. The intermittent effluent streams are not routinely analysed. Hence their characteristics presented below are based on limited analysis. The detailed analytical results of the continuous effluent streams are presented in the environmental audit reports for the year 2001-2002 (*Reference 4*).

Table 4.8: Typical Characteristics of Treated Effluent Streams

Parameter	Units	Typical Characteristics		
		Produced Water	RO Plant Rejects	Sewage
pH	No units	7.3-7.6	6.7-6.8	6.1 - 10
Total suspended solids (TSS)	mg/L	Not reported	Not reported	2.0 - 233
Total dissolved solids (TDS)	mg/L	6800-15000	19000-26000	Not reported
Total salinity	mg/L	Not reported	Not reported	Not reported
Total hardness as $CaCO_3$	mg/L	17-150	2200-6500	Not reported
Total chloride as Cl	mg/L	3100-8400	9500-13500	Not reported
Oil and grease (O&G)	mg/L	50-250	Not reported	Not reported
Biochemical oxygen demand (BOD)	mg/L	Negligible	Negligible	2 - 30
Chemical oxygen demand (COD)	mg/L	Negligible	Negligible	5 - 85
Total ammoniacal nitrogen	mg/L	Negligible	Negligible	0 - 10
Faecal coliform count	per 100 mL	Negligible	Negligible	0 - 1500

- **Disposal of Produced Water and RO Plant Rejects Backwash**

The Omani regulations (RD 115/2001, MD 145/93, MD7/84) as well as PDO's specifications (SP-1006) do not permit the discharge of these effluents into either marine water or onto the land, principally due to the high TDS content. Therefore, SP-1006 recommends their disposal into the deep aquifers where the salinity is above 35,000 mg/L. The specification also requires that shallow disposal (where salinity is <35000 mg/L) to cease by year 2000.

The details of produced water and RO plant rejects + backwash are as below in Table 4.9.

Table 4.9: Details of Disposal of Produced Water and RO Plant Rejects + Backwash

Parameter	Description
Deep disposal (produced water)	
Nature of formation:	Haima formation in Nimr Haima Mahwis formation in Rima
Depth from ground level:	900 m
Salinity of aquifer:	6800 mg/L in Nimr 15000 mg/L in Rima
Number of disposal pumps:	Nimr - 10 Rima - 4
Total volume disposed per day (2002):	Nimr – 159,127 m^3/d Rima – 31,726 m^3/d
Shallow Disposal (Produced water)	
Nature of formation:	Dammam formation
Depth from ground level:	100 m
Salinity of aquifer:	Unknown
Number of disposal pumps:	Nimr – 10 Rima – 4
Total volume disposed per day (2002):	Nimr – 56,054 m^3/d Rima - 66,186 m^3/d
Shallow Disposal (RO reject)	
Nature of formation:	Dammam formation in Nimr UeR formation in Rima
Depth from ground level:	Nimr – 125 m Perforation in the well Rima –369 m Perforation in the well
Salinity of aquifer:	Nimr – Unknown Rima –10000-15000 mg/l
Number of disposal pumps:	Nimr – 1 Rima –1
Total volume disposed per day (2002):	Nimr – 477 m^3/d Rima – 50 m^3/d

- **Disposal of Treated Sewage**

Land application of treated sewage is practised throughout PDO. SP-1006 as well as RD 155/2001 (also MD 145/93) permit land irrigation provided the following conditions :

- In areas with no public access: pH is 6-9, O&G O.5 mg/L, TSS 30 mg/L, TDS 2000 mg/L, BOD 20 mg/L, COD 200 mg/L and faecal coliform count 1000 per 100 mL
- In areas with public access: pH is 6-9, O&G O.5 mg/L, TSS 15 mg/L, TDS 1500 mg/L, BOD 15 mg/L, COD 150 mg/L and faecal coliform count 200 per 100 mL.

In Nimr asset, the treated sewage after filtration and chlorination is used for the irrigation of lawns and trees using a network of PVC pipes and sprinklers, some with timing devices. The characteristics of the treated effluent from the STPs as monitored during the year 2002 are summarised below:

Table 4.10: Treated Sewage Characteristics

Parameter	Units	NMRSTP-PDO	NMRSTP-Contr.1	NMRSTP-Contr.2
Volume of sewage treated	m^3/d	Average: 88 Max: 111	Average: 338 Max: 453	Average: 209 Max: 243
Biological oxygen demand	mg/L	Range: 2-20 Average: 7 XN: 0/50	Range: 2-20 Average: 7 XN: 0/49	Range: 3-30 Average: 8 XN: 1/50
Chemical oxygen demand	mg/L	Range: 21-85 Average: 41 XN: 0/50	Range: 6-68 Average: 36 XN: 0/50	Range: 5-67 Average: 33 XN: 0/50
Total suspended solids	mg/L	Range: 2-31 Average: 13 XN: 0/50	Range: 4-110 Average: 16 XN: 2/50	Range: 5-233 Average: 16 XN: 1/50
pH	None	Range: 6.6-7.8 Average: 7 XN: 0/50	Range: 6-7.7 Average: 7 XN: 0/50	Range: 6.6-7.6 Average: 7 XN: 0/50
Faecal coliforms	Nos./ 100 ml	Range: 0-1000 Average: 115 XN: 0/50	Range: 0-1500 Average: 154 XN: 1/49	Range: 0-1500 Average: 173 XN: 1/50
Ammoniacal nitrogen	mg/L	Range: 0-8 Average: 1 XN: 0/50	Range: 0-7 Average: 1 XN: 7/50	Range: 0-10 Average: 1 XN: 3/50

Notes: XN = Number times regulatory standards exceeded per total number of times monitored.
- = Data not available

4.4 Solid Wastes

4.4.1 Overview

Several types of solid wastes are generated in the asset. Based on the sources of generation, they may be classified as industrial, domestic and construction wastes. Some of these wastes are non-hazardous while some are hazardous.

The non-hazardous wastes include the following groups:

- Domestic and office waste
- Water based drilling mud and cuttings
- Non-hazardous industrial waste

The hazardous wastes include the following groups:

- Oil based mud and cuttings
- Sewage sludge
- Waste lubricants
- Oily sludge
- Oily sand
- Pigging sludge
- Non-recyclable batteries
- Recyclable hazardous batteries
- Transformers and transformer cooling fluids

- Clinical wastes
- NORM wastes
- Chemical wastes (including miscellaneous hazardous wastes)

The quantities of the waste generated in the asset during the year 2001-2002 and their disposal are discussed in the following sections.

4.4.2 Waste Generation

The quantities of the various solid wastes generated in the asset during the year 2001-2002 are given in Table 4.11 below.

Table 4.11: Solid Waste Generated in Nimr Asset

Waste Group	Classification	Units	Quantity Generated for Jan - Sept 2002
Domestic and office waste	Non-hazardous	tonnes	3,204
Water based drilling mud and cuttings	Non-hazardous	tonnes	Not reported
Non-hazardous industrial waste	Non-hazardous	tonnes	4,392
Total non-hazardous wastes			7,596
Oil based mud and cuttings	Hazardous	tonnes	Not available
Sewage sludge	Hazardous	tonnes	<1 (not reported)
Waste lubricants	Hazardous	tonnes	73.5
Oily sludge	Hazardous	tonnes	9,456
Oily sand	Hazardous	tonnes	26,082
Pigging sludge	Hazardous	tonnes	0
Non-recyclable batteries	Hazardous	pieces	0
Recyclable hazardous batteries	Hazardous	pieces	87
Transformers and transformer cooling fluids	Hazardous	tonnes	0
Clinical wastes	Hazardous	tonnes	0
NORM wastes	Hazardous	tonnes	0
Chemical wastes (including miscellaneous hazardous wastes)	Hazardous	tonnes	626
Total hazardous wastes		tonnes	36,238

Among the solid waste, both the clinical and NORM wastes are of prime importance due to their handling and disposal special requirements. Clinical wastes generated in the PDO clinic comprises used syringes, cotton / dressing containing blood and other body fluids, human tissue etc.. This waste requires special handling and disposal due to their nature and presence of pathogens. NORM wastes are the wastes containing naturally occurring radioactive materials (NORM), which are commonly encountered during well services operations. Some oil sludge, pigging wastes, tubulars and water/well accessories from reservoir locations may contain NORM. Any waste having radioactivity greater than 100 Bq/g (for solids) and 100 kBq/L (for liquids) is classified as radioactive waste.

4.4.3 Waste Disposal

The above wastes are disposed according to the requirements of SP-1009. The waste disposal practice in the asset is described in Table 4.12 below:

Table 4.12: Solid Waste Disposal Practice in Nimr Asset

Waste Group	Waste Disposal Practice
Domestic and office waste	- Kitchen waste is packed in black bins / plastic bags and send to the sanitary landfill in the asset. Green waste is also sent to the sanitary landfill. - Recyclable domestic and office waste (paper, plastic, cans etc) is segregated at source, packed in yellow bins / plastic bags and sent to an external recycling facility. - Non-recyclable waste is sent to the sanitary landfill.
Water based drilling mud and cuttings	- Unless total petroleum hydrocarbon content is >10 g/kg, they are disposed in a dedicated landfill in the Nimr waste management centre. - Otherwise, they are treated as oily sand
Non-hazardous industrial waste	- Iron scrap, electrical cable, wood, paper, metal/plastic drums are segregated at source and sent to sent to an external recycling facility. - Metal / plastic containers of non-hazardous chemicals are punctured, crushed and sent to an external recycling facility. - Non-recyclable waste is sent to the sanitary landfill.
Oil based mud and cuttings	- Sent to the waste management centre for land filling separately.
Sewage sludge	- Sewage from septic tanks is sent to STPs for drying along with STP sludge. - Dry sludge is disposed off on land if it meets the specifications (SP-1006), otherwise sent to landfilling as hazardous waste in the waste management centre.
Waste lubricants	- Sent to the oil saver pits for recycling into crude oil system.
Oily sludge	- Liquid fraction is sent to an external facility for recycling. - Solid fraction is sent to waste management centre for bio-remediation.
Oily sand	- Sent to land farm in the waste management centre for bio-remediation.
Pigging sludge	- Sent to waste management centre for landfilling, if it is not a NORM waste. - Otherwise, sent to NORM waste management centre in Zauliyah for storage and disposal.
Non-recyclable batteries	- They are packaged in refuse bags and disposed in the landfill with domestic waste.
Recyclable hazardous batteries	- The terminal are taped, electrolytes are drained and then sent to an external facility for recycling.
Transformers and transformer cooling fluids	- If they are PCB free (<50ppm), cooling fluids are drained and recycled to the crude oil system and the container is disposed as non-hazardous waste. - Otherwise, they are segregated and stored in the waste management centre for final disposal by a specialist
Clinical wastes	- All wastes are packaged in special yellow bags or cartons and sent to the incinerator in MAF for treatment.

Waste Group	Waste Disposal Practice
NORM wastes	- All NORM waste is sent to the waste management centre in Zauliyah for storage and disposal.
Chemical wastes (including miscellaneous hazardous wastes)	- Unused chemicals, if possible sent back to the supplier - Containers of hazardous chemicals are decontaminated, punctured / crushed and sent for recycling at an external facility - All other wastes are disposed in a dedicated landfill in the waste management centre.

4.4.4 Waste Management Centre

Nimr has a centralised waste management centre for the disposal of both non-hazardous and hazardous wastes. Further, Nimr has a dedicated land farming facility and kitchen waste dumpsite. The waste management centre does not handle NORM wastes, which are sent to a dedicated storage /disposal site in Zauliyah in Bahja. Further, this facility does not handle clinical waste, which is sent to Mina Al Fahal for incineration. The complete details of the waste management centre are presented in the environmental audit report in PDO's waste management centres (*Reference 5*). They are summarized below in Table 4.13.

Table 4.13: Details of Nimr Waste Management Centre

Item	Description
Year of commissioning	Unknown
Types of waste handled	Hazardous and non hazardous waste.
Total site area (m^2)	Kitchen waste dump site: 36.5 ha Scrap yard: 34.2 ha Land farm: 108 ha
Facilities available	The site consists of a waste handling area, waste oil and sludge pits and a sanitary landfill for kitchen wastes and non-hazardous non-recyclable wastes. There is also a land farm for bio-treatment of oily sands. There is no weighing bridge. Drum crusher and a shovel are available at site for waste compacting.
Storage (holding) area for non-hazardous wastes	Open space is available for non-hazardous wastes.
Storage (holding) tank for waste oils and oil sludge	Two oil recovery pits are available.
Storage (holding) area for chemical wastes	No chemical wastes are handled here.
Storage (holding) area for other miscellaneous hazardous wastes	A separate hazardous waste storage area is provided with drainage facility for any leaks and spills.
Sanitary landfill	Unlined 60m x 3 m x 3m trenches for kitchen wastes.
Hazardous waste landfill	There is no hazardous landfill.
Land farm	There are about 122 windrows for contaminated sand treatment. Each windrow is about 60m x 6m x 0.5m size. Approximately $30m^3$/d of water is used for wetting the land farm. Treated sewage is utilised for wetting.

4.5 Noise

4.5.1 Sources of Generation

The noise sources in the asset may be classified into the following categories:

- Continuous sources
- Intermittent sources
- Mobile sources

The major noise generating sources are present mainly in the production station, gathering stations, power stations, booster stations, RO plants, production water disposal sites and STPs. Both continuous and intermittent sources are present. The continuous sources include rotary pumps, compressors, electrical motors, burners, stacks, flares and other rotating equipment. All these sources are outdoor, stationary point sources. The intermittent sources include the pressure relief valves, standby diesel generators and some intermittently operated pumps and motors.

There are no significant noise sources in the oil fields. In all other areas such as accommodation facilities, administrative building, waste management centres, workshops etc., there are only intermittent noise sources.

The mobile sources include the normal transportation vehicles such as cars, vans, bus, trucks and construction equipment such as earth moving machines (excavators, dumpers, bulldozers etc.), rotary drilling rigs, lifting equipment (cranes and hoists), concrete mixers etc.

4.5.2 Noise Levels

Due to the presence of a large number of noise generating sources in process areas (particularly Production Station and Power Stations), it is not possible to measure the noise level at the source point for the equipment. Therefore, instead of considering all the individual sources as distinct point sources, a group of them may be treated as an area source.

Currently, no data are available on the noise levels for either point sources or area sources. It is however noticed during the site visits that at several places the noise levels are greater than 85 dB(A), which is the permissible workplace noise level.

4.5.3 Noise Control

All the major noise generating equipment such as pumps, motors, compressors, burners etc. are provided with standard noise control systems such sound insulation, vibration control and acoustic packages where necessary.

4.6 Accidental Leaks and Spills

In PDO, all accidental leaks and spills shall be promptly reported. There are three categories of accidental leaks and spills, as below:

- Oil leaks and spills
- Chemical leaks and spills
- Water leaks and spills
- Release of ozone depleting substances (ODS)

While water leaks and spills do not lead to any environmental consequences, they are reported as a matter of water conservation issue. ODS include CFCs, halons, HFCs and HCFCs. The use of these substances is currently phased out in PDO due to their high ozone depletion potential. Some inventories of such substances may still be found in some air-conditioners and portable fire extinguishers According to PDO's specification SP-1005, these substances are not permitted to be released into the atmosphere except in uncontrollable situations or emergencies.

For the year (2002), the leaks and spills are reported in Nimr asset are summarized in Table 4.14.

Table 4.14: Accidental Leaks and Spills in Nimr Asset

Description	Incidents Reported in 2002			
	Oil Leaks and Spills	Chemical Leaks and Spills	Water Leaks and Spills	Releases of ODS (CFCs and Halons)
Total number of incidents	22	0	2	Unknown
Number of spills into wadis	0	0	0	-
Total volume leaked / spilled (m^3)	116	0	30	0
Total land area impacted (m^2)	3,504	0	Not reported	-
Total quantity of soil contaminated (t)	Data not available	0	Not applicable	-

Generally, it is observed throughout PDO that incident reporting is not accurate. Therefore, it is likely that the leaks and spills volume, impacted areas and contaminated soil quantities are under-reported.

5 ENVIRONMENTAL SETTING

5.1 General

In this chapter, the existing environmental conditions in Nimr asset is described and analysed. The description is largely based on the information provided in the previous EIA report (*Reference 1*). Additional information is sourced from site reconnaissance surveys conducted as apart of the present environmental assessment study (refer Section 1.3). Brief description and analysis are presented in this chapter for the environmental aspects subjected to very little change since the last environmental assessment due to the activities in the asset. Detailed description and analysis are limited to the environmental aspects that are likely to have undergone a noticeable change since the last environmental assessment. The areas where specific data are required but not available are identified.

The environmental aspects likely to have undergone noticeable change due to the asset activities include the following:

- Groundwater availability and groundwater quality
- Ambient air quality and noise
- Land use and human settlements

5.2 Location and Topography

Geographically, Nimr asset is located in the southeast part of PDO's concession area. The Rima and Al Noor assets are now a part of Nimr asset. The asset currently covers a total land area of 16,160 km^2 and accounts for 14.2% of the total PDO concession area. Currently there are 710 producing wells in Nimr area, 167 in Rima area and 7 in Al Noor area. The asset consists of sand and gravel plains, low gravel hills and rocky outcrops. The northern half of the asset area is quite arid, but several wadis drain through the southern half. Wadi Rawnab, Wadi Shaybun and Wadi Ghadun are important and influence the main vegetated features in the Nimr asset area. The mean altitude of the asset is about 200 m above the mean sea level. The asset boundary co-ordinates are given in Table 5.1 below:

Table 5.1: Nimr Asset Boundary Coordinates

Site Boundaries	Clarke 1880 System (Easting or Northing in m)
Northern limit	2172019 N
Eastern limit	517515 E
Southern limit	2001141 N
Western limit	342053 E

The natural topography of the region is altered by the manmade structures such as production facilities and accommodation facilities erected by PDO. There are very few human settlements in the asset. The natural vegetation is composed of desert plants and grasses, and there are no major trees in the asset except in those places irrigated by PDO using treated wastewater. The topographical map of the asset is shown in Figure 5.1

5.3 Geology and Soil

The Nimr area is located on the eastern edge of the Nejd, which consists of undulating sand and gravel plains in the central and northern areas of the region, the geological setting of which consists of limestones with shale, dolomite and sandstone.

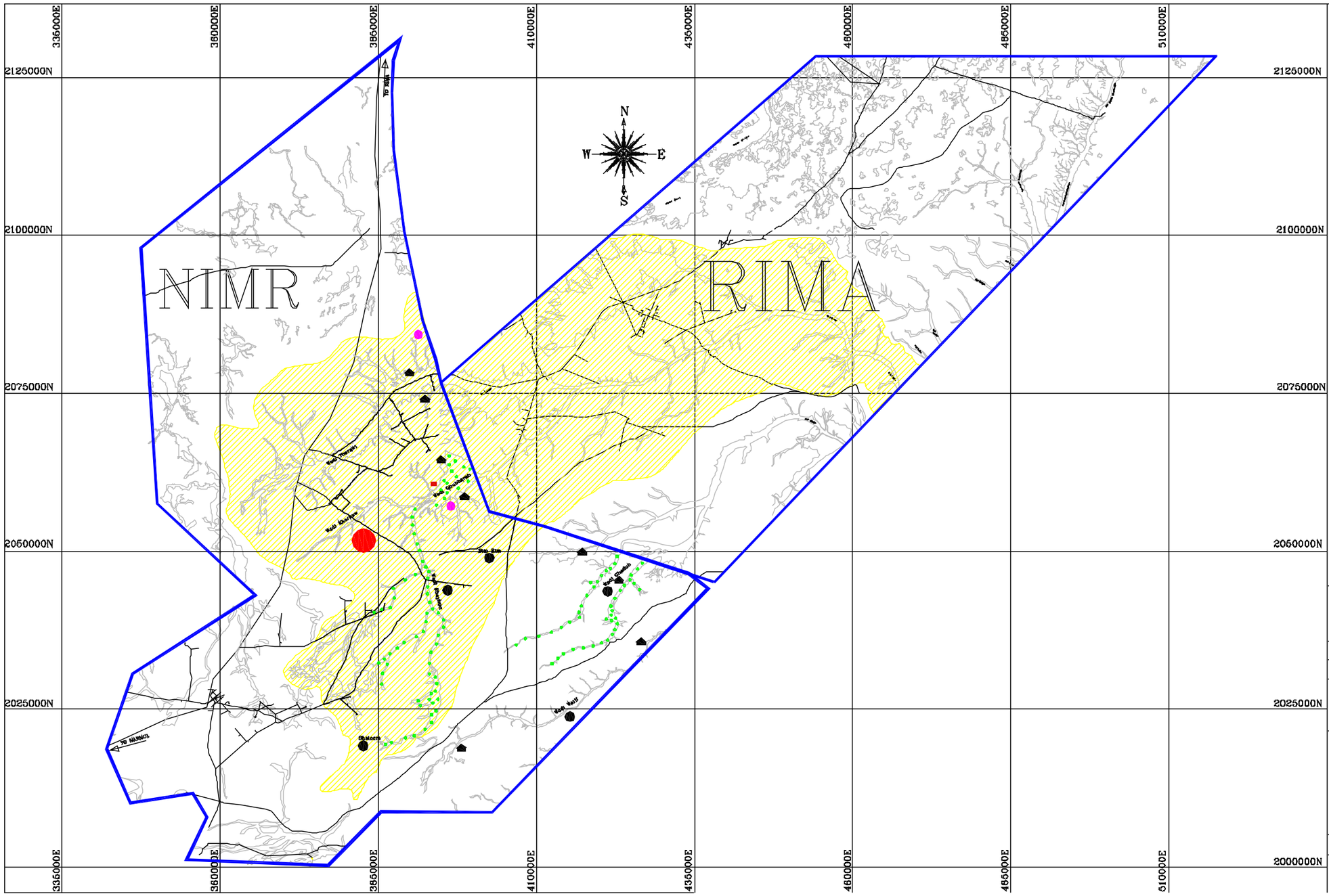
The shallowest formations are the Quaternary alluvium and aeolian sand, which occupy the low-lying areas. The area is underlain by up to 600 m thickness of tertiary rocks. They comprise in downward sequence the Fars formations followed by Dammam, Rus and UeR formations. The geological cross section in Nimr asset area is shown in Fig 5.2

No site-specific data are available on the soil quality. Generally, the soils in the asset are classified as unsuitable for agricultural purposes, as per the Ministry of Agriculture and Fisheries “General Soil Map of Oman". The soil map of PDO’s concession area is shown in Figure 5.3.

5.4 Hydrogeology and Groundwater Quality

The asset area, and much of the Nejd, is underlain by up to 600m thickness of tertiary rocks, primarily carbonate sediments. They comprise, in upward sequence, the Shammar shale, UeR, Rus, Dammam and Fars formations. It is in these carbonates that the major shallow aquifer zones of the Nejd exist. These aquifers are based on highly transmissive karst features such as solution-enlarged fissures and joints.

The main prolific aquifer in the asset area is the UeR formation consisting of marl and limestone. Rus formation is sometimes in hydraulic connection with UeR formation. Dammam formation is of limited thickness and is more accurately described as an aquitard. These tertiary aquifer systems in Oman are recharged from the flow from the Oman mountains to the north and Dhofar mountains to the south during the monsoon from July to September. The regional flow direction is to the north, The UeR water quality ranges between 5000 – 14000 mg/l. The Fars water has a TDS ranging from 600 – 7000 mg/l. The salinity maps of Fars and UeR aquifers are shown in Figure 5.4 and Figure 5.5 respectively.



LEGEND

- Permanent Human Settlements
- Bedouin Areas
- Boundary of Groundwater Protection Site (YELLOW ZONE)
- Richly Vegetated Sites
- Wild Life Sites
- Archeological Sites
- Cultural Sites (Cemetary)
- Recreational Sites
- PDO Camp
- Road
- Wadi
- Industrial Site (Crusher)

PRODUCED FOR:
شركة تنمية نفط عمان
Petroleum Development Oman

PROJECT :	EIA UPDATE FOR PDO
AREA :	NIMR ASSET

DESCRIPTION : Figure 5.1

Topographical Map of Nimr Asset

PRODUCED BY :

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SCALE : 1 : 700,000 — 1cm =7km

DATE :	DRAWN :	CHECKED BY :	APPROVED BY :
21/12/02	SSH	CMS	Dr.LMA

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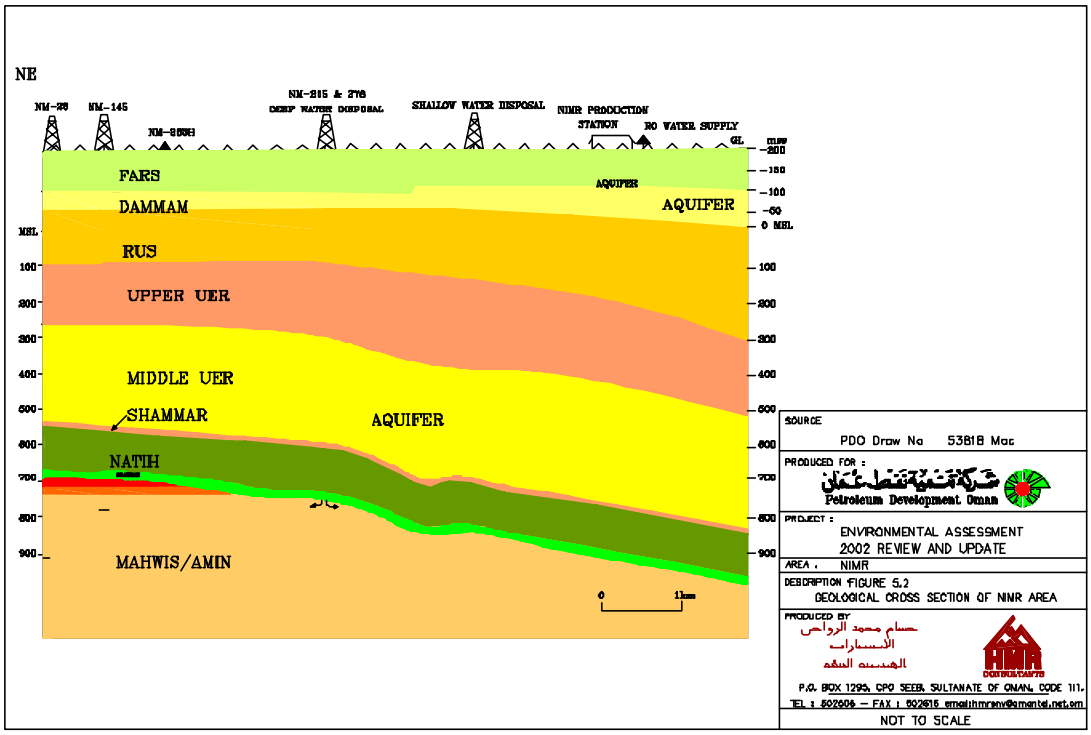

Figure 5.2: Geological Cross Section in Nimr Asset Area

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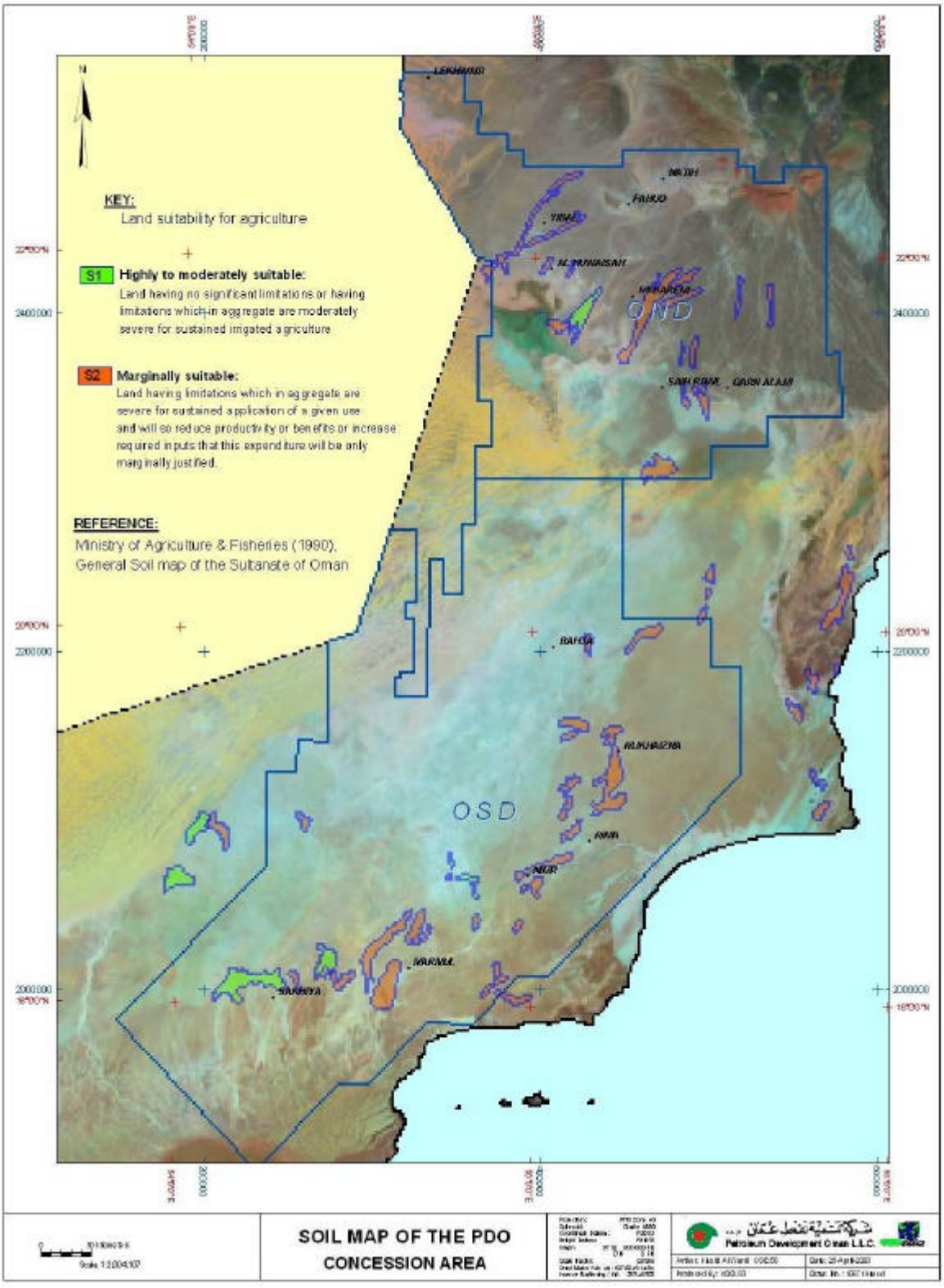

Figure 5.3: Soil Map of PDO's Concession Area

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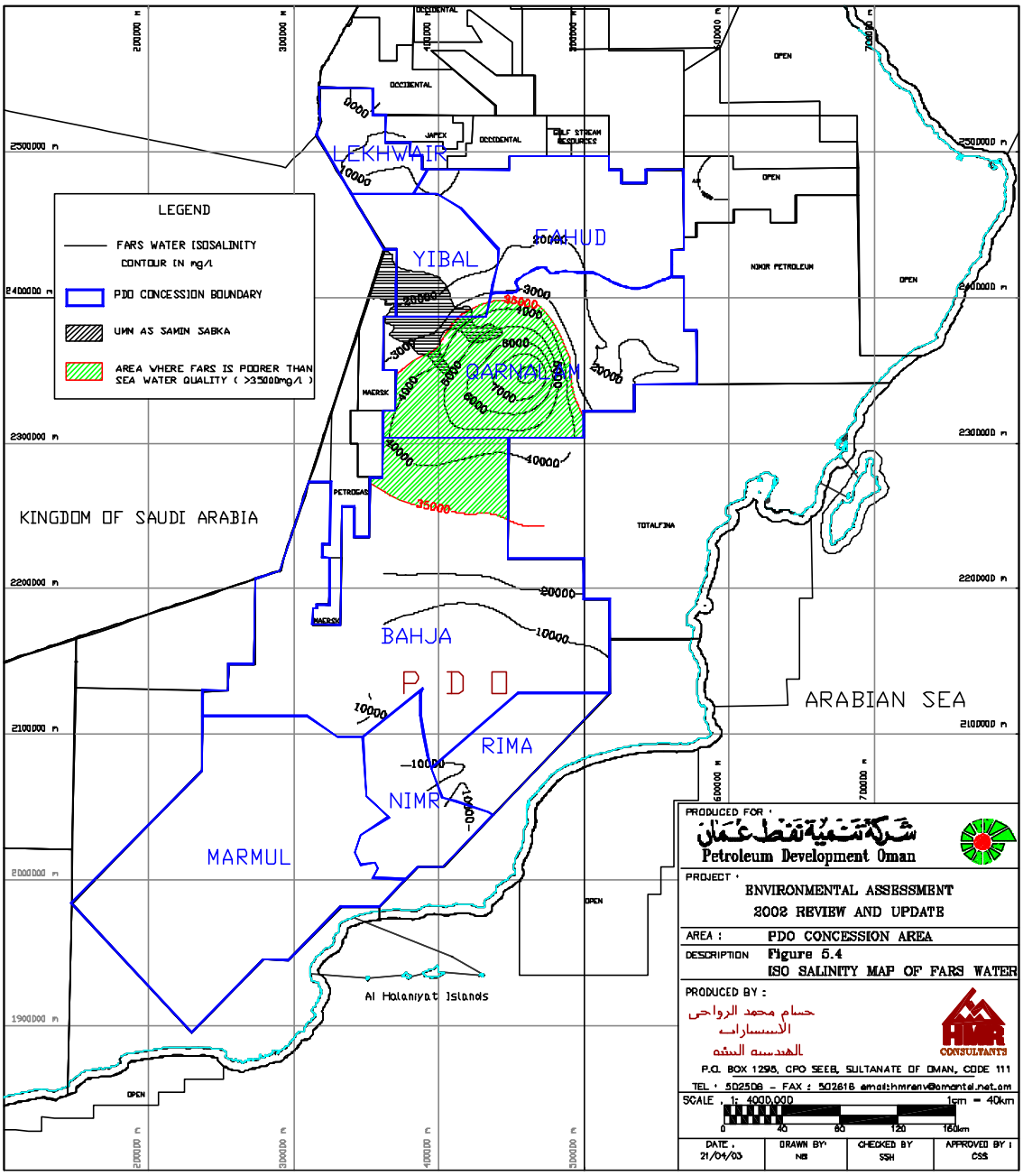

Figure 5.4: Salinity Maps of Fars Aquifers

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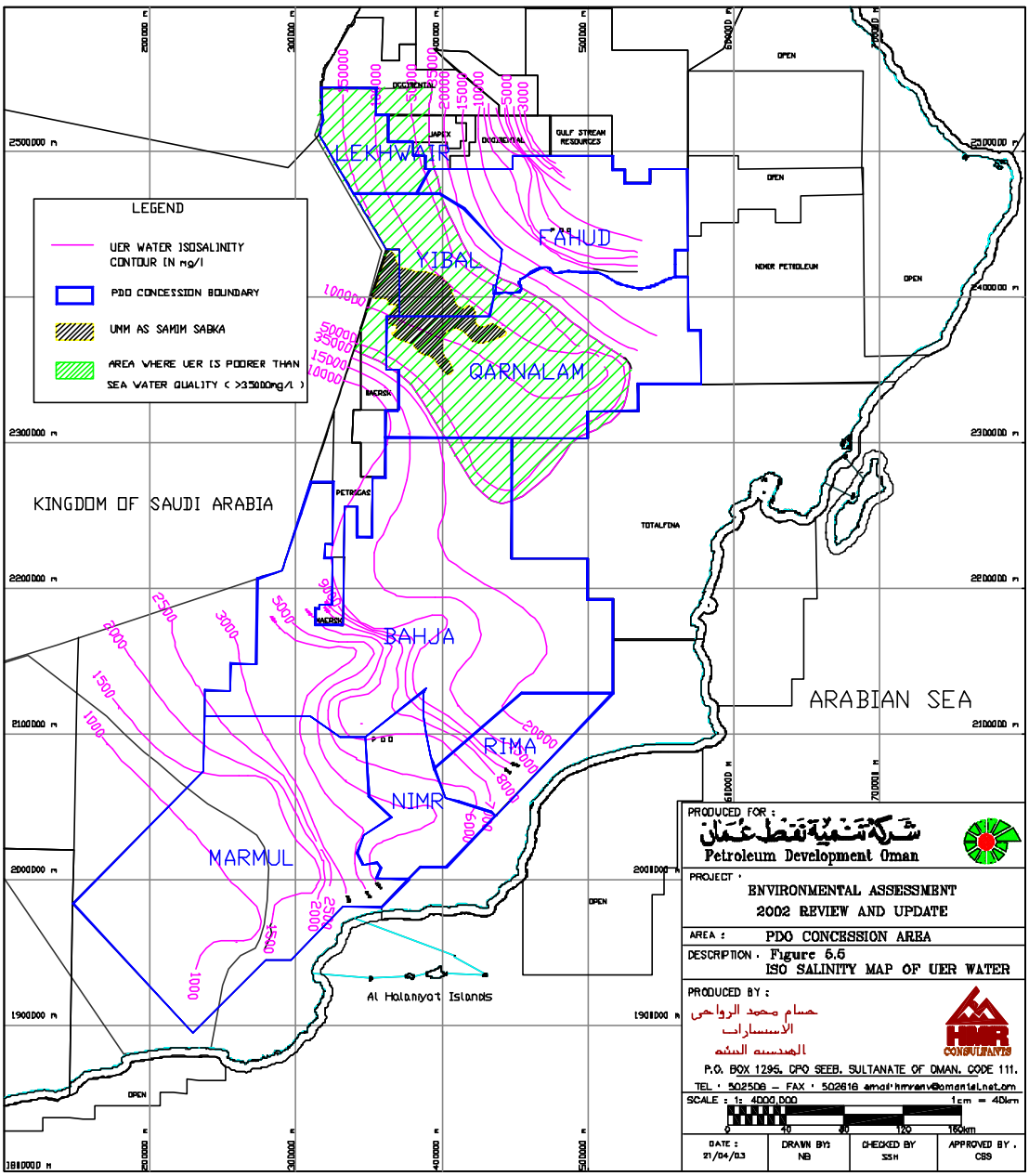

Figure 5.5: Salinity Maps of UeR Aquifers

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The well yield and water quality data for different locations within the asset are summarised below in Table 5.2. The change in water level and water quality over the past 5 years has also been shown.

Table 5.2: Well Yield and Water Quality Data in Nimr Asset

Location	Represent-ative Water Well	Name of Aquifer	Water level		Total Dissolved Solids (TDS)		Yield	
			(m)	Date	(g/L)	Date	m3/hr	Date
Al Burj	Al Burj WSW-2	UeR	104.72 111.12	Jul'88 Aug'99	8.134 9.787	Mar'88 Aug'96	20.0	Aug'96
Amal	Amal WSW-8	UeR	99.4 95.1	Jun'90 Jun'02	5.069 3.848	Dec'82 Mar'91	-	-
Amin	Amin WSW-2	Rus+ UeR	82.24 80.25	Nov'92 Aug'99	4.392 4.41	Dec'82 Aug'89	-	-
Anuq	Anuq WSW-2	Rus+ UeR	134.84 142.9	Jul'87 May'97	5.249 6.631	Sep'84 Dec'94	-	-
Ihsan	Ihsan WSW-1	UeR	117.52 118.85	Feb'92 Jan'02	5.067 10.95	Apr'88 Dec'92	35.0	Sep'93
Irad	Irad WSW-3	Dammam + Rus	97.61 96.97	Nov'91 Jan'02	10.226 13.324	Apr'87 Feb'88	28.57	Dec'00
Irad	Irad WSW-5	Rus	97.02 90.55	Feb'88 Jan'02	4.341 4.468	Oct'87 Jun'91	-	-
Karim	Karim WSW-4	Rus+ UeR	93.91 83.61	Feb'92 Jan'02	7.655	Jun'90	-	-
Mawhoob	Mawhoob WSW-1	UeR	94.65 95.43	Oct'89 Oct'00	5.815	Mar'88	-	-
Nimr	Nimr WSW-4	Dammam + Rus	139.83 125.55	Jan'92 Jan'02	5.587 6.223	Feb'81 Sep'89	-	-
Nimr	Nimr WSW-5	Rus	128.34 128.34	Aug'99 Jan'02	3.664 4.535	Feb'81 Dec'82	-	-
Nimr	Nimr WSW-6	Rus+ UeR	138.86 139.6	Aug'92 Dec'02	5.418	Jan'81	-	-
Nimr	Nimr WSW-10	Dammam	-	-	5.905 7.059	Jun'85 Sep'94	-	-
Simsim	Simsim WSW-1	UeR	168.71 152.32	Mar'92 Feb'02	5.447 5.548	May'86 Jan'91	70.0	Aug'95
Zahra	Zahra WSW-1	Rus+ UeR	91.64 81.26	Jan'88 Jan'97	7.456 11.63	Jun'86 Oct'89	-	-
Zahra	Zahra WSW-2	Dammam + Rus	91.37 80.59	Jan'88 Jan'97	6.196 8.962	Jun'86 Aug'92	-	-
Aseel	Aseel WSW-1	Rus+ UeR	118.6 131.96	Mar'87 May'02	9.042	Mar'87	-	-
Aseel	Aseel WSW-2	Dammam + Rus+ UeR	142.05 136.32	Jun'87 May'97	10.283	Mar'87	-	-
Jalmud	Jalmud North WSW-1	Fars	146.34 141.44	Jun'90 Aug'99	6.54 5.383	Jul'80 Jun'91	-	-
Maha	Maha WSW-1	Dammam	123.89 127.04	Feb'87 May'97	1.781	Sep'80	-	-
Reihan	Reihan WSW-1	UeR	128.0 124.57	Apr'89 Oct'99	7.055	Oct'86	-	-

Rima	Rima WSW-1	UeR	107.3 115.45	Sep'92 Jun'02	27.487 8.152	Nov'81 May'82	-	-
Rima	Rima WSW-3	Fars+ Dammam	167.0	Feb'81	5.383 10.845	Jul'80 Jul'91	33.5	Feb'81
Rima	Rima WSW-6	Rus+ UeR	139.42	Sep'92	8.005 10.634	Nov'81 Jun'88	-	-
Runib	Runib South WSW-1	Dammam + Rus	128.34 127.34	Aug'99 Feb'02	1.317 1.995	Jun'80 May'92	-	-
Tannum	Tannum WSW-1	UeR	152.02 150.5	Jul'88 Jul'98	5.73 7.391	Dec'87 Jan'95	24.0	Jul'98
Thayfut	Thayfut WSW-1	Rus+ UeR	164.23 165.57	Sep'89 Aug'99	6.33 6.57	Sep'81 Sep'91	72.0 91.37	Dec'93 May'97

5.5 Climate

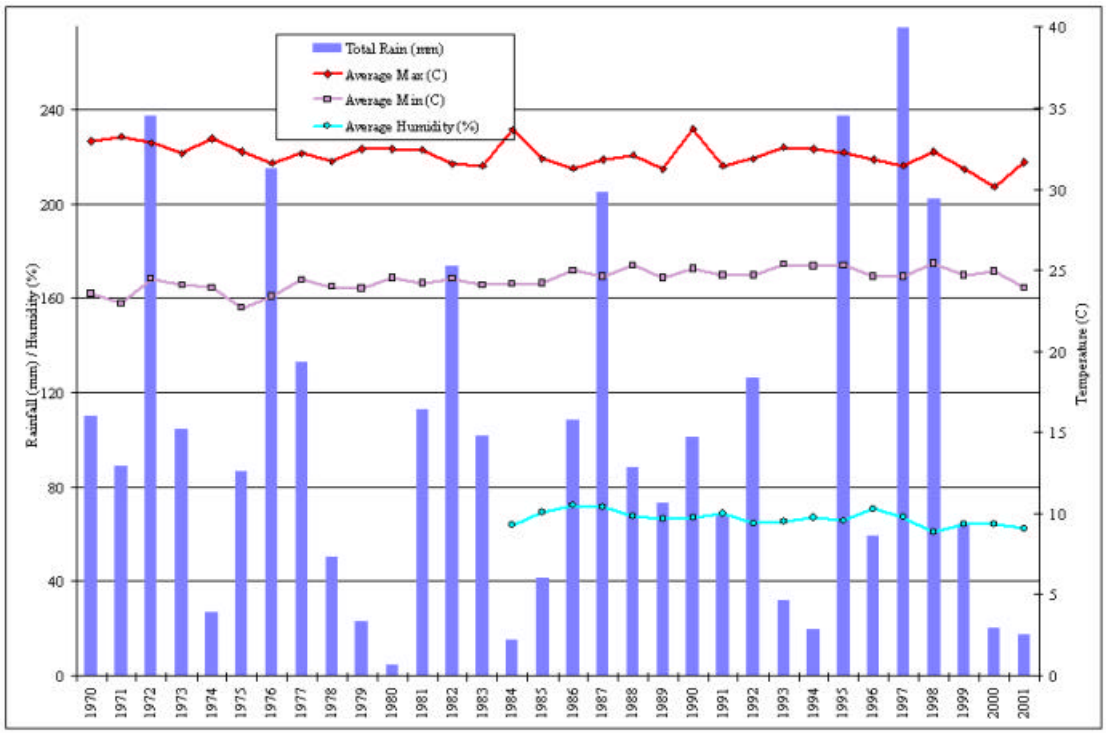
The region has an arid climate, with very low rainfall. No historical site-specific climatic data was available. The nearest meteorological station to the site is located at Marmul Airstrip approximately 90 km southwest of Nimr.

The climate of the region is typically hot with significant fluctuations between maximum and minimum temperatures. The hottest temperatures occur throughout summer months (May – August). The mean monthly temperatures range from 17^{o}C in January (with mean minimum 10^{o}C of and mean maximum of 24^{o}C) to 35^{o}C in June (with mean minimum 26^{o}C of and mean maximum of 43^{o}C).

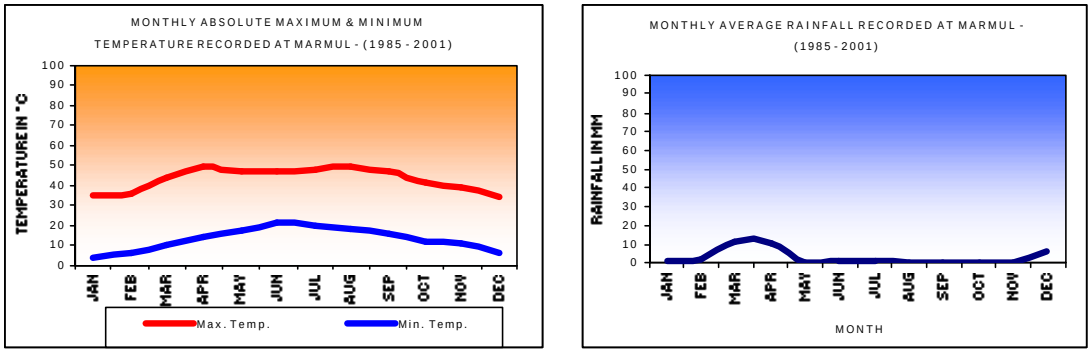
Rainfall in this region is scanty and is highly variable in time and space. Historical data give an average of 34 mm per annum. Although the annual average rainfall is very low, flash floods are known to have occurred in the area. Most of the rainfall occurs during the winter season (December - February) with secondary peaks expected in late summer. Little rainfall is expected throughout the rest of the year. Data on the annual mean number of days of fogs was not available for Nimr, but fog is known to occur during the summer months (June to August), and also intermittently during the spring months.

Wind speeds vary considerably from calm to strong gusts. The dominant wind directions are from the north or east. Due to the close proximity to the sea, southerly winds from the Arabian Sea also influence the area.

The climatic charts are presented in Figure 5.6.



Climatic Variation in Oman
(Recorded at Muscat)



Monthly Variations
(*Recorded at Marmul)*

Figure 5.6: Climatic Charts for Nimr Asset

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5.6 Ambient Air Quality

Very limited air quality studies have been conducted anywhere in PDO concession area since PDO's exploration and production activities started. For the Nimr asset, no data are available on the ambient air quality from the previous EIA report (*Reference 1*). It is generally believed that ambient air quality within PDO concession area is of no significance due to two reasons. Firstly, there are no human settlements close to any operational facilities in the entire PDO concession area. Secondly, there are not many air emission sources in PDO and the emission loads are not considered very significant.

However, in the absence of any measurements, the significance of ambient air quality cannot be established. Based on the uneven distribution of the emission sources, relatively shorter stack heights and atmospheric inversion conditions expected during winter nights, the concentration of some pollutants in ground level air may be elevated in certain locations and in PDO camps at certain times. Therefore, it is necessary that air quality surveys be undertaken at periodic intervals at selected locations to determine whether the air quality in the asset is within the permissible limits.

5.7 Ambient Noise

No data are available on the ambient noise levels within the asset. It is believed that the ambient noise levels in this region are of no significance due to the fact that there are no human settlements close to any operational facilities. The high noise generating sources in the facilities such as production station, power station, gathering stations, and RO plant are unlikely to have any impact on the human settlements. However, they may have an impact on the noise levels in the PDO and contractor camps. Therefore, it is necessary that noise surveys be undertaken at periodic intervals at selected locations to determine whether the noise levels in the accommodation areas are within the permissible limits.

5.8 Flora and Fauna

5.8.1 Flora

The northern gravel plains of the Nimr asset are sparsely vegetated with a low diversity of species. The southern wadis are well vegetated with trees, large and small shrubs, and perennial grasses. The main trees found throughout the asset are "ghaf" *Prosopis cineraria* and "samra" *Acacia tortilis*. Large shrubs of *Acacia ehrenbergiana* and

Ziziphus leucodermis are common in shallow wadis, and amongst the smaller shrubs, *Convolvulus hystrix, Cornulaca aucheri, Heliotropium spp., Pulicaria glutinosa, P.undulata, Rhazya stricta, Vernonian spp.* and *Zygophyllum spp*. are common.

The vegetation of Nimr asset area can be broadly classified as *Acacia-Zygophyllum-Heliotropium* vegetation type, which is typical of the central plains of Oman. The influence of fog has increased the species richness especially that of wadis. Overgrazing by camels has severely deformed the Acacia trees and several show a two-tier growth pattern and all trees of Prosopis show browse lines. A dominance of unpalatable species is evident in the vegetation of the wadis. The Zygophyllum-Pulicaria sub-shrub community and Acacia communities are the dominant of species in the asset.

5.8.2 Fauna

The central desert and its wadis are important habitats for wildlife. In particular, there are the large mammals and reptiles, which contribute substantially to the biological diversity of the region. Many species of resident and migratory birds that breed and visit the central desert also add to the diversity of wildlife. In particular Wadi Rawnab in the Rima area is one of three areas in Oman with a large diversity of wildlife including large mammals. A number of mammals are found in the Nimr asset area. Mammals recorded include the Arabian gazelle, red fox, Arabian wolf, hyaena, hedgehog, porcupine, gerbils, jird, jerboa, mice, fruit-bat and hare. Honey badger and hyrax are not recorded but expected to be present in this area. The mountain gazelle is a medium sized gazelle, which is endemic to Arabia. Bird surveys at Nimr show an estimate of 43 species the majority of which are migratory. There are 13 species that are recorded as breeding in the area, including the Golden Eagle and the South Arabian Wheatear.

A number of reptiles groups occur in the Nimr asset area, including agamid lizards, monitor lizard, skink, geckoes and snakes, with geckoes being are one of the most common types. About 30 species are recorded in the Nimr asset area, representing about 40% of the reptile species present in Oman. A single species of amphibian, the toad Bufo dhuforaensis, is likely to be present within the Nimr area. There are two endemic species, the spiny-tailed lizard (*Uromastyx thomasi*), and *Acanthodactylus masirae*, present in the central gravel desert. *Acanthodactylis masirae* is recorded to be uncommon in Oman.

5.9 Arabian Oryx Nature Reserve

The Arabian Oryx Nature Reserve is an ecologically significant area adjacent to the asset area. Rima area falls within the nature reserve, but just outside the boundaries of an environmentally sensitive zone. The reserve covers an area of 24,785.4 km^2 in Al Wusta Region in Central Oman The United Nations Scientific and Cultural Organisation (UNESCO) declared the Reserve a World Heritage Site. The map of the Arabian Oryx Nature Reserve is shown in Figure 5.7.

At the heart of the Reserve is the Jiddah (central plateau), a foggy desert supporting diverse plant and animal communities. The Reserve is sanctuary for many wildlife species including the Arabian Oryx, which was reintroduced to the wild in 1982. The other mammals seen in the Reserve include Arabian Gazelle (*Gazelle gazelle*), Rhim Gazelle (*Gazella Subgutturosa marica*), Nubian Ibex (*Capra nubiana*), Arabian Wolf (*Canis lupus arabica*), Caracal (*Caracal caracal schmitzi*), Honey Badger (*Mellivora capensis*), Red Fox (*Vulpes vulpes arabica*), Ruepell's Sand Fox (*Vulpes ruepelli*), Cape Hare (*Lepus capensis*) and Ethiopian Hedgehog (*Parachimus aetheopica*). Among birds, 180 species have been recorded in the Reserve, with majority being migratory and only 26 breeding resident species. The resident species include Golden Eagle (*Aquila chrysaetos*) and Houbara Bustard (*Chlamoyodotis undulata*). Among reptiles, 24 species have been recorded including Monitor Lizard, *Malpolon moilensis, Cerastes cerastes* and *Uromastyx thomasi.*

Over 140 species of plants have been recorded in the Reserve, with 12 endemic species. While some are short-living (rain supported), others are long-living (fog supported). Simr (*Acacia tortilis*) is scattered all over the Reserve, while Ghaf (*Prosopis cineraria*) and Salem (*Acacia ehrenbergiana*) grow mostly in shallow sand depressions called haylat.

The Reserve is presently divided into five administrative zones to facilitate management, as described below:

Zone 1- Special protection Zone: This is the core zone of the Reserve that provides a safe haven for the Arabian Oryx and thus ensures their long-term survival in the wild of Oman. Zone 1 includes Yalooni, the Field headquarters of the White Oryx Project, and a representative section of the Huqf escarpment. The objective is to manage this zone to keep human disturbance and competition from domestic stock to a minimum.

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Zone 2 - Controlled Use Zone: This zone includes areas regularly used by the Oryx and tracts of land containing other important biological resources, wilderness, scenery of exceptional beauty and sites of archaeological interest. The management objective is to allow controlled access but keep development to a minimum.

Zone 3 - Buffer Zone: This encompasses further sites of interest, but with control of activities in order to help protect the inner zones.

Zone 4 - Utility Zone: This area is demarcated for locating the essential infrastructure facilities of the Reserve.

Zone 5 - Special Use Zone: The areas of land where a land use agreement has been reached with the government (military authorities) and private parties have been demarcated as Zone 5.

5.10 Human Settlements

Shalim is the major human settlement in the Nimr area. It is about 68 km from Nimr main camp. The total population is 492 and number of permanent houses is 120. There are several permanent and semi-permanent settlements in Rima area, the majority living in Wadis Mukhayzanah, Ghubbarah and Rawnab. The main village is Al Ghubbarh Ash Shamaliyah with a total population of 224. The details of the settlements located within Nimr asset area, population break-up and occupations are summarised in Table 5.3.

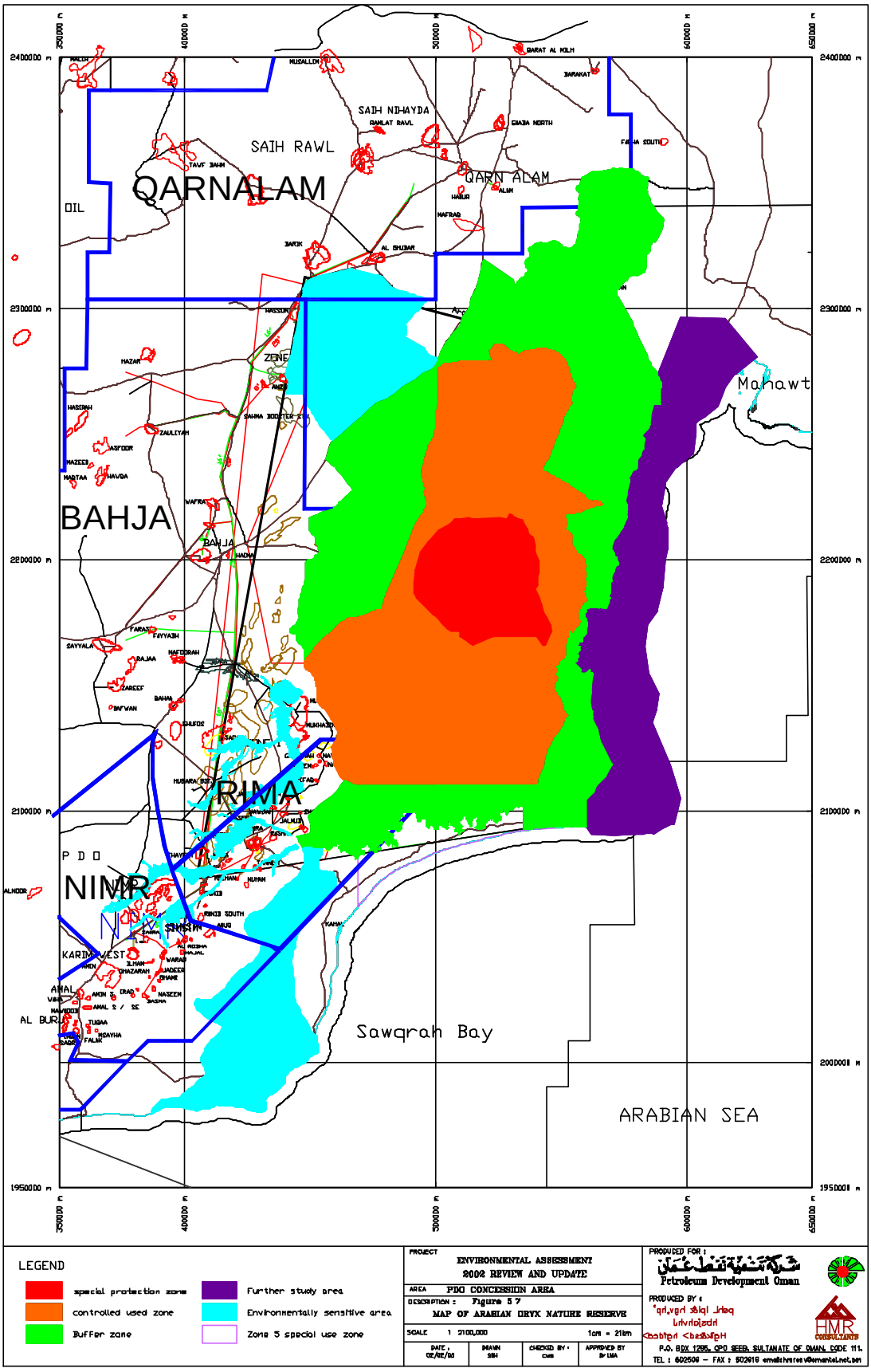

Figure 5.7: Map of Arabian Oryx Nature Reserve

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Table 5.3: Human Settlements in Nimr Asset

Village / Camp	Location	Current Total Population	Total Number of Housing Units	Main Occupations
PDO camp at Nimr	Within Nimr main camp	200	176	PDO employees
Contractor camp at Nimr	Outside Nimr main camp	1,362	600	PDO employees
Shalim	68 km toward southwest of Nimr main camp	492	120	Dates farming, trading, PDO Employees
Amal	60 km toward southwest of Nimr main camp	12	6	Dates farming, trading
Bathat	65 km toward southwest of Nimr main camp	10	1	Dates farming, trading
Al Masab	70 km toward southwest of Nimr main camp	26	1	Dates farming, trading
Saqar	50 km toward south of Nimr main camp	171	30	Dates farming, trading
Wadi Shiboot	6 km toward south of Nimr main camp	42	17	Dates farming, trading
Al Ghubbrah Al Janubiyah	5 km toward northeast of Nimr main camp	69	19	Dates farming, trading
Wadi Tayfot	45 km toward northeast of Nimr main camp	8	1	Dates farming, trading
Al Ghubbrah Ash Shamaliyah	50 km toward northeast of Nimr main camp	224	52	Dates farming, trading
Bedouin populations		Not available	Not available	Not available

5.11 Land Use

The land use in this region had undergone significant change due to PDO's exploration and production activities and facilities. Large areas of barren desert land are converted into industrial areas. The land take details by PDO for its production and associated facilities are summarised below in Table 5.4.

Table 5.4: Land Use in Nimr Asset

Facility	Total Area
Total asset area	16,160 km^2
Nimr Production Station	22,365 m^2
Amal Gathering Stations	73,887 m^2
Nimr Power Station	18,500m^2
Rima Production Station	258,370 m^2

Livestock, camels and goats, browse and graze in all wadis. There are no traditional grazing areas in the Nimr Asset. These are flat areas often surrounded by trees where

water collects after rains and gives good annual vegetation preferred for grazing. Agricultural activity in the asset area is limited to date plantations and subsistence farming. A small date farm is present at Ghubbarah Shamaliyah. All wadis (Tharwt, Ghubbarah, Runib, Lisq, Thayfut, Half, Batha, Qafaws, Mukhayzana) are used as rangelands for domestic livestock (camels and goats), gazelles and other wildlife. Wadi Rawnab is home to ibex, caracal lynx, fox and wolf and breeding site for some species of birds. Nomadic and semi-nomadic settlements occupy the main wadis. Two crushers are in operation in Wadi Ghubbarah in the Salwa area and one crusher is in operation in Wadi Maha. Wadi material is removed from an area of over 3 km^2 crushed and graded, for use in major construction activities, road maintenance etc.

5.12 Social Infrastructure and Public Services

The asset area is a thinly populated area and therefore has limited social infrastructure. Some public infrastructure facilities including hospital, school, petrol stations, restaurants and several shops are available in the main towns Shalim and Al Ghubbrah Ash Shamaliyah. Other towns and villages have very limited infrastructure. The recent developments associated with the oil industry have assisted to provide access to the necessary civic services.

- **Water and Electricity**

Groundwater is the only water resource in the region. Most of the potable water requirement for the population in Nimr asset, including the PDO and contractor camps is met with demineralised water from PDO's RO plants.

Most of the power requirement at Nimr stations and camp is met by production at power plant at Nimr, which has an installed generating capacity of 60 MW.

- **Roads and Communications**

The blacktopped two-lane national highway connecting Muscat and Salalah passes through Nimr asset. In addition, PDO maintains an extensive network of graded roads, which are open to local population. PDO also maintain two airstrips at Nimr, with regular flights. However, these flights are restricted only to PDO staff and its contractors. PDO maintains a network of telephone lines and radio transmitters in the concession area. The region is also covered by GSM telephone service.

- **Education**

There is a primary school at Shalim. PDO provides material assistance to the local schools.

- **Health Services**

There is a government health centre in Shalim in Nimr asset. Private health-care facilities (clinic and ambulance services) are available within PDO's residential camps. These facilities are generally made available to the surrounding communities.

5.13 Archaeological, Cultural and Recreational Resources

Wadis Ghubbarah and Shaybun are extensively vegetated sites, especially the woodland in Wadi Ghubbarah. The dramatically sculptured shapes of the limestone hills south of Shalim and the variety in Nimr Asset Area the coloured stratifications of these hills, are unmatched elsewhere in the Nimr Asset and qualify as a major visual amenity.

There is a cemetery on the south-eastern end of the Prosopis woodland in Wadi Ghubbarah and a grave site adjacent to the main tarmac road, 5 km from the boundary of the Rima Asset. The cemetery is in use and recent graves are present but the graves adjacent to the main Nimr-Rima road appear older. No other sites that might qualify as being of cultural heritage significance are present in the Nimr Asset Area. However, the area of Al Zakhier in the south of the Asset is unexplored and may contain historical artefacts and other features of cultural importance.

The details of environmentally significant areas located within Nimr asset are summarized in Table 5.5.

Table 5.5: Environmentally Significant Areas in Nimr Asset

Area	Significance
Arabian Oryx Nature Reserve	An area of 24785.4 km^2 bordering the Rima field is designated as a nature reserve for Arabian Oryx. The United Nations Scientific and Cultural Organisation (UNESCO) subsequently declared the Reserve a World Heritage Site.
Archaeological Sites	No areas are designated as archaeological sites.
Cultural Sites	The area of Al Zakhier in the south of the Asset is unexplored and may contain historical artifacts and other features of cultural importance.
Areas of Exceptional Natural Beauty	- Core zone of Arabian Oryx Nature Reserve - The dramatically sculptured shapes of the limestone hills south of Shalim and the variety of the coloured stratifications of these hills, are unmatched elsewhere in the Nimr Asset and qualify as a major visual amenity.
Vegetated Areas	- Woodland in Wadi Ghubbarah is extensively vegetated. - The new and old city of Adam and the village of Aweifi have agricultural farms.
Water Protection Zones	Wadi Rawnib is in the yellow zone

6 ENVIRONMENTAL IMPACTS

6.1 Methodology

In this chapter, the significant environmental hazards and effects present in the asset are identified and assessed based on the methodology outlined in PDO's document GU-195 "Environmental Assessment Guideline" (*Reference 2*). In PDO's terminology, the term "environmental hazard" is used for the sources (causes) of potential environmental effects, and term “effect” is used for the impact.

The environmental effects may include all those that are beneficial or adverse, short or long term (acute or chronic), temporary or permanent, direct or indirect, and local or strategic. The adverse effects may include all those leading to, harm to living resources, damage to human health, hindrance to other activities, impairment of quality for use, reduction of amenities, damage to cultural and heritage resources, and damage to physical structures.

For each identified potential environmental effect, the associated environmental risk is assessed based on its likelihood and significance. The likelihood (frequency) of occurrence of an effect, the significance of its consequence and the potential risk level are evaluated qualitatively as described below:

- Rating of likelihood (frequency) of occurrence of an effect:

  A (very low), B (low), C (medium), D (high), E (very high)

- Rating of significance of its consequence:

  slight, minor, localized, major and massive

- Rating of potential environmental risk level:

  l*ow, medium, high and extreme*

The criteria used for rating the environmental risk are discussed in detail in *Appendix 4.*

6.2 Potential Environmental Hazards and Effects

The potential environmental hazards and effects associated with the various activities performed in the asset are presented in *Appendix 5*. These are presented in the form of matrices. In the following sections, the impacts identified are qualitatively assessed according to the methodology presented in Section 6.1.

6.3 Beneficial Impacts

Several beneficial environmental impacts accrue from the asset activities. They include socio-economic, socio-cultural and ecological benefits. These beneficial impacts outweigh the adverse impacts, which are discussed in the subsequent sections. The beneficial impacts from the asset are on the economy, employment, local amenities and ecology. These impacts are discussed below. They are however not rated or ranked as per the methodology discussed in Section 6.1 since PDO's rating criteria apply for adverse impacts only. Therefore, only descriptive treatment is given for the magnitude and significance of the beneficial impacts.

- Economy

In Oman, the national economy is significantly dependent on crude oil production, with petroleum sector contributing about 40% to the gross domestic product. More significantly however, nearly 75% of the government revenue is from oil exports. Thus, there is ever-increasing need for more production of crude oil to sustain the current economic (gross domestic product) growth rate of 10.8%. The total crude oil production in Oman is presently about 330 million barrels annually, out of which about 90% exported. While PDO accounts for over 90% of the total crude oil produced in Oman, Nimr asset accounts for about 27.5% of the total PDO production. Thus the economic benefits from the asset are quite significant.

- Employment

The total number of permanent staff directly employed by PDO for Nimr asset is about 400. The number of permanent staff employed by PDO's contractors in Nimr asset is about 1500. In addition, a large number of persons, including local population are also provided indirect employment to provide a number of supporting services. Providing service to PDO is the only alternative employment for the local communities, whose main occupation is farming and animal husbandry. Therefore, the beneficial impact on employment is also significant.

- Amenities

The asset provides and shares several amenities developed by PDO with the local population. They include the access roads, power supply, potable water supply, clinical facilities and telecommunication facilities. In addition, the assets provide financial and other material assistance to local schools, local bodies and cultural events.

- Ecology

While some adverse impacts on ecology may be expected from the asset activities, a few direct beneficial impacts on the ecology also exist. The most significant is the greening of the desert by re-using treated sewage effluents. The land within the PDO main camp and the contractor camps is significantly vegetated with trees, shrubs and lawns. The significant vegetal cover developed in the asset has provided a habitat for the native fauna, most importantly birds and terrestrial invertebrates.

6.4 Impacts on Natural Resources

The potential environmental effects on the natural resources and the associated environmental hazards are listed below:

Environmental Hazards
- Consumption of mineral resources
- Consumption of groundwater
- Consumption of construction and road building materials
- Land take

Potential Environmental Effects
- Depletion of natural mineral resources
- Depletion of groundwater resources
- Claim of local assets

- **Depletion of Mineral Resources**

Large quantities of crude oil (35,669 m^3/d) and some associated gas (780,000 Sm^3/d) continuously extracted will result in the depletion of petroleum reserves in the asset. However, the environmental impact and risk resulting from this activity is not discussed here since this forms the core activity of the asset.

Almost all of the construction materials are imported and not sourced from any local natural resources. For road building, stone aggregates and soil are used. Soil is sourced locally from borrow pits. Considering that their requirement is very low compared to their availability, this is not expected to have any significant adverse impact.

Based on the above discussion, the overall impact on natural mineral resources is rated as below:

Impact Rating	Depletion of Mineral Resources
Nature of impact (beneficial / adverse)	Adverse
Duration of impact (short term / long term)	Long term
Likelihood of occurrence (very low / low / medium / high / very high)	Low
Significance of impact (slight / minor / localized / major / massive)	Slight
Potential risk level (low, medium, high and extreme)	Low

- **Depletion of Groundwater Resources**

Currently, 2,988 m^3/d of groundwater on average is abstracted continuously from the UeR aquifer for process and domestic use in this asset. Some additional groundwater is also used in drilling. Though the total quantity of groundwater abstracted in this asset is not very significant, it has the potential to cause adverse impact on future groundwater availability considering that this aquifer is not the prolific aquifer in this region. The magnitude of the impact depends on the groundwater balance. Currently, sufficient information is not available on the groundwater recharge rate and on long term fluctuations in the water well yields and water levels. Nevertheless, based on the information available from the other assets, it may be considered that likelihood of adverse impact is low to medium.

Based on the above discussion, the overall impact on groundwater resources is rated as below:

Impact Rating	Depletion of Ground Water Resources
Nature of impact (beneficial / adverse)	Adverse
Duration of impact (short term / long term)	Long term
Likelihood of occurrence (very low / low / medium / high / very high)	Low to medium
Significance of impact (slight / minor / localized / major / massive)	Localized
Potential risk level (low, medium, high and extreme)	Medium

- **Claim on Local Assets**

The local population within the asset are very few and their demands or claim on local assets is low. Except for groundwater, there are no local claimants or competing users of natural resources. However, PDO supplies or makes available potable water for local communities from its facilities.

Land may be considered to have competing users. However, the entire area of land on which PDO operates has no alternate use, due to the poor soil quality, lack significant vegetation and harsh environmental conditions. Moreover, majority of the asset area (excluding the production facilities, accommodation facilities and pipeline corridors) are freely accessible to local population. The roads built by PDO are also freely accessible to local population.

Based on the above discussion, the overall impact on claim on local assets is rated as below:

Impact Rating	Claim on Local Assets
Nature of impact (beneficial / adverse)	Adverse
Duration of impact (short term / long term)	Long term
Likelihood of occurrence (very low / low / medium / high / very high)	Very low
Significance of impact (slight / minor / localized / major / massive)	Minor
Potential risk level (low, medium, high and extreme)	Low

6.5 Impacts on Air Environment

The potential environmental effects on the air environment and the associated environmental hazards are listed below:

Environmental Hazards
- Release of dust from construction activities and road traffic
- Release of gaseous emissions from stationary sources
- Release of gaseous emissions from mobile sources
- Generation of noise from stationary sources
- Generation of noise from mobile sources

Potential Environmental Effects
- Global warming
- Air pollution
- Noise pollution

- **Global Warming**

CO_2 and methane emissions from the asset have a potential to contribute to global warming. Since there is virtually no venting in the asset, methane emissions are negligible. CO_2 emissions from stacks, flares and vehicles are of the order of 1,500 tpd. This quantity is not large enough to contribute significantly to global warming, when compared to the land area covered by the asset. Based on the above discussion, the overall impact on global warming is rated as below:

Impact Rating	Global Warming
Nature of impact (beneficial / adverse)	Adverse
Duration of impact (short term / long term)	Short term
Likelihood of occurrence (very low / low / medium / high / very high)	Very low
Significance of impact (slight / minor / localized / major / massive)	Slight
Potential risk level (low, medium, high and extreme)	Low

- **Air Pollution**

Dust emissions from construction activities and road traffic, and gaseous emissions from stationary and mobile sources can have potential adverse impacts on ambient air quality.

Significant dust emissions may be expected due to the site being dry gravel plain with little vegetation. However, dust emissions are not continuous and highly localized. Further, only the respirable particulates (PM_{10}), which are expected to be 35-50% by mass in the dust have significant health hazard.

High concentration of H_2S in associated gas from Al Noor is of concern. The maximum H_2S concentration in the associated gas is in the order of 12.5%. The associated gas from this field is treated in an amine absorber for removing H_2S and mercaptans. The off gases from the amine stripper have about 45% H_2S content. The off-gases instead of being injected into the reservoir are currently flared. Malfunction of the flare could result in serious public health concerns.

There are several stationary (point and non-point) and mobile sources of air emissions in the asset. However, point sources (stacks and vents) account for most of the emission loads in the asset. These emissions release pollutants such as NO_x, SO_2, CO and unburnt hydrocarbons into air. The total emission loads in the asset are estimated to be <10 tpd for CO and NO_x and <1 tpd for hydrocarbons. SO_2 emission load is about 43 tpd most of which comes from the flare in Al Noor field.

Considering that the emission loads are not high and there is no population close to the emission sources, it is reasonable to assume that the impact on overall ambient air quality in the asset is not very significant. However, in Al Noor field the potential for adverse impact on air quality due to extremely high concentration of H_2S in off-gases shall be assumed to be high. Moreover, in the absence of sufficient data on ambient air quality and atmospheric dispersion modeling, the likelihood of degradation of ambient air quality at locations close to the major emission sources in the asset shall be considered as significant. Based on the above discussion, the overall impact on ambient air quality is rated as below:

Impact Rating	**Air Pollution**
Nature of impact (beneficial / adverse)	Adverse
Duration of impact (short term / long term)	Long term
Likelihood of occurrence (very low / low / medium / high / very high)	High
Significance of impact (slight / minor / localized / major / massive)	Localized
Potential risk level (low, medium, high and extreme)	High

- **Noise Pollution**

Both stationary and mobile noise generating sources can adversely affect the ambient noise levels. Since the noise from mobile sources is intermittent as well as transient, most of the potential impacts are due to the continuous and stationary sources such as gas turbines, heaters, air compressors, flares, pumps, motors and other rotating equipment. While sufficient data on source noise levels are not available, it is reasonable to expect that their impacts will be highly localized and limited to less than

1 km distance. There are no human settlements in the asset areas except for PDO and contractors' camps. It is however likely that some areas in these camps may be subjected to elevated noise levels. No data are currently available to check whether there is any breach of regulatory standards.

Based on the above discussion, the impact on ambient noise is assessed as below:

Impact Rating	**Increase in Ambient Noise Levels**
Nature of impact (beneficial / adverse)	Adverse
Duration of impact (short term / long term)	Long term
Likelihood of occurrence (very low / low / medium / high / very high)	Low
Significance of impact (slight / minor / localized / major / massive)	Minor
Potential risk level (low, medium, high and extreme)	Medium

6.6 Impacts on Water Environment

The potential environmental effects on the water environment and the associated environmental hazards are listed below:

Environmental Hazards
- Disposal of produced water
- Disposal of RO plant rejects + backwash
- Land discharge of treated sewage effluent
- Accidental spillage of hazardous liquids
- Release of leachates from landfill sites

Potential Environmental Effects
- Groundwater contamination

The disposal of highly saline produced water and RO plant rejects + backwash into the aquifer system can result in degradation of groundwater quality if injected into an exploitable aquifer, particularly the shallow aquifer. Currently, in the asset, only about 60% of the produced water is disposed into deep aquifer (Haima formation). However, the remaining produced water is disposed into the shallow aquifers (UeR formations). This practice is in existence for a long time, though it is planned to be discontinued by year 2004. It is not known how shallow disposal of produced water has affected groundwater quality and whether it will continue to affect the groundwater elsewhere in future due to groundwater hydrology.

The surface discharge treated sewage effluents, accidental spillages of oils and chemicals and the release of leachates from the landfill sites can affect the groundwater quality provided they percolate into the groundwater table. Since groundwater table is 110 m below the ground level and arid weather conditions prevail in the asset, there is no possibility for such occurrence.

Based on the above discussion, the impact on the groundwater quality is assessed as below:

Impact Rating	Groundwater Pollution
Nature of impact (beneficial / adverse)	Adverse
Duration of impact (short term / long term)	Long term
Likelihood of occurrence (very low / low / medium / high / very high)	High
Significance of impact (slight / minor / localized / major / massive)	Localized
Potential risk level (low, medium, high and extreme)	High

6.7 Impacts on Land Environment

The potential environmental effects on the land environment and the associated environmental hazards are listed below:

Environmental Hazards
- Land take
- Land discharge of treated sewage effluent
- Accidental spillage of hazardous liquids
- Landfilling of solid wastes

Potential Environmental Effects
- Alteration of land use
- Loss of vegetation
- Land contamination

- **Alteration of Land Use**

Land take for the installation of project facilities; construction of accommodation camps; drilling of oil wells; laying of pipelines, power lines and access roads; and constructing storage and disposal sites for construction materials and waste materials can have adverse impacts on land use. The land taken for these purposes is barren and has no utility. The extent of permanent land take is marginal compared to the total available land in the asset. Majority of the land take is temporary, for the purpose of drilling of oil wells and laying of pipelines, power lines and access roads. This land is restored nearly to its natural condition after completion of the construction activities.

Based on the above discussion, the impact on land use is rated as below:

Impact Rating	Alteration of Land Use
Nature of impact (beneficial / adverse)	Adverse
Duration of impact (short term / long term)	Short term (mostly)
Likelihood of occurrence (very low / low / medium / high / very high)	Low
Significance of impact (slight / minor / localized / major / massive)	Minor
Potential risk level (low, medium, high and extreme)	Low

- **Loss of Vegetation**

Loss of vegetation is directly related to land take, and therefore the impacts are similar. In addition, the land irrigation of treated sewage effluents compensates any loss of vegetation elsewhere. The increase is vegetal cover in PDO and contractor camps is significant.

Based on the above discussion, the impact on vegetation is rated as below:

Impact Rating	**Loss of Vegetation**
Nature of impact (beneficial / adverse)	Adverse
Duration of impact (short term / long term)	Short term (mostly)
Likelihood of occurrence (very low / low / medium / high / very high)	Low
Significance of impact (slight / minor / localized / major / massive)	Minor
Potential risk level (low, medium, high and extreme)	Low

- **Land Contamination**

The discharge of treated sewage effluents on land, accidental spillage of hazardous liquids and landfilling of solid wastes can potentially degrade the soil quality. There is no hazardous waste landfill is the asset. The current data on the treated sewage effluent quality in the asset indicate that the regulatory standards are occasionally exceeded. Chemicals are stored inside the Nimr production station in an open ground without any spillage containment facility. Hence, there is a potential risk of soil contamination due to accidental spillage of chemicals inside the production station.

The accident spillage of crude oil, mainly due to pipeline and flowline leaks leads to soil contamination. In the current year so far 22 incidents of oil spills were reported in the asset. The total volume of the oil spill was reported as 116 m^3 and the total land area contaminated was reported as 3,504 m^2. Though the frequency of occurrence of oil spill occurrence in the asset is not high, volume of soil contaminated is the highest in the asset among all PDO assets. Further, there is a possibility of under-reporting of the oils spills as in any PDO asset.

Based on the above discussion, the impact on soil quality is assessed as below:

Impact Rating	**Land Contamination**
Nature of impact (beneficial / adverse)	Adverse
Duration of impact (short term / long term)	Long term
Likelihood of occurrence (very low / low / medium / high / very high)	High
Significance of impact (slight / minor / localized / major / massive)	Localised
Potential risk level (low, medium, high and extreme)	High

6.8 Impact on Ecology and Wildlife

The potential environmental effects on the ecology and wildlife and the associated environmental hazards are listed below:

Environmental Hazards
- Land take
- Road transport of hazardous substances
- Road travel

Potential Environmental Effects
- Loss of endangered flora
- Loss of endangered fauna
- Threat to wildlife habitats

There are no endangered flora and wildlife habitats in the asset. The population of fauna in the asset are very limited. The environmentally significant core zone of the Arabian Oryx Nature Reserve is 40 km away from the Nimr Production station and is a part of the Rima area. The road traffic for transportation of materials and people is not high but significant. Few road accidents with casualties of common fauna (mostly camels) were ever reported.

Overall, the impact on ecology is considered negligible.

6.9 Impact on Social Environment

Under social environment, employment, agriculture, animal husbandry, native lifestyle, cultural heritage, public health and safety, landscape and aesthetics are considered. Most of the impacts on social environment are beneficial, which are discussed in Section 6.2. There are also a few adverse impacts on the social environment.

The asset area is very thinly populated and there are no human settlements except for PDO and contractor camps. Therefore, the significance and magnitude of adverse impacts on social environment are very limited. The only direct adverse impact on social environment that may need to be considered is the public safety and health of the transient population across the asset.

The hazards associated with potential impact on public safety and health are listed below:

Environmental Hazards
- Bulk storage of hazardous substances
- Road transport of hazardous substances
- Accidental release of toxic gases and vapours
- Deployment of large number of migrant workers

Potential Environmental Effects

- Public safety and health

Storage and transportation of hazardous substances, such as combustible liquids, combustible gases and chemicals have the potential to cause damage to public health and safety in the event of significant release into the environment following structural failure and loss of containment. This may lead to fire, explosion, reactivity or toxicity hazard. Bulk storage facilities are located within the production areas and therefore general public are not exposed to any consequences from storage facilities.

However, general public are exposed to road accidents involving hazardous substances. Fortunately, the major substances, crude oil and gas are transported by pipelines and not by road. With respect to accidental leaks of toxic gases and vapours, there are no such substances handled in bulk in the asset.

The deployment of large number of migrant workers can pose a threat to public health, if they carry communicable diseases or if they are carriers of parasitic diseases. Large scale deployment of migrant workers is not expected in the asset, since no major developmental activity is envisaged. Further, there are no major habitations near the project site.

Based on the above discussion, the impacts on public health and safety are assessed as below:

Impact Rating	**Public Health and Safety**
Nature of impact (beneficial / adverse)	Adverse
Duration of impact (short term / long term)	Short term
Likelihood of occurrence (very low / low / medium / high / very high)	Low
Significance of impact (slight / minor / localized / major / massive)	Minor
Potential risk level (low, medium, high and extreme)	Low

7 SUMMARY OF SIGNIFICANT ENVIRONMENTAL EFFECTS AND MITIGATION MEASURES

The identification and assessment of environmental hazards and effects in the asset are discussed in Chapter 6. All adverse environmental effects with medium to extreme risk are considered as significant environmental effects. In this chapter, the additional mitigation measures required for minimizing the environmental consequences from these effects are developed. It may be noted that PDO has a comprehensive environmental management plan as a part of the HSE management system (refer Chapter 2), which is implemented in the asset. No change in the existing environmental management system is required. However, certain additional mitigation measures will reduce the potential environmental risk and improve the overall environmental performance.

The significant environmental effects are listed below along with explanatory notes.

Environmental Effect	Impact Rating	Potential Risk Level	Comments
Groundwater contamination	• Adverse • Long term • High occurrence • Localized significance	• High risk	• The asset has a long legacy of shallow disposal of produced water. • Shallow disposal of some produced water and RO rejects is still in practice in the asset. • The produced water quantity generated in this asset is very high and it accounts for over 90% of the reservoir fluid.
Land contamination	• Adverse • Long term • Medium occurrence • Localised significance	• High risk	• Large quantity of chemicals is stored inside the production station without any hardstand or spillage containment • The quantity of oil spills and the land area contaminated are the highest for the asset. • Some potential risk may also exist due to occasional exceedence of discharge standards for treated sewage.

Air pollution	• Adverse • Long term • High occurrence • Localised significance	• High risk	• High concentration of H_2S in associated gas from Al Noor is of concern. The off gases from the amine stripper with about 45% H_2S content, instead of being injected into the reservoir are currently flared. Malfunction of the flare could result in serious public health concerns. • The currently available information on air quality and air emissions is insufficient to conclude that there is no breach of ambient air quality standards, particularly in the accommodation camps. Hence, the potential risk shall be considered to exist.
Groundwater depletion	• Adverse • Long term • Low occurrence • Localized significance	• Medium risk	• In the absence of comprehensive long-term data on groundwater balance and water well monitoring in the asset, the potential risk on the depletion of groundwater shall be considered to exist.
Noise pollution	• Adverse • Long term • Low occurrence • Minor significance	• Medium risk	• The currently available information is insufficient to conclude that there is no breach of ambient noise standards, particularly in the accommodation camps. Hence, the potential risk shall be considered to exist

The recommended additional mitigation measures for reducing the environmental risk levels and improving the environmental performance are listed below against each of the environmental specifications of PDO, *viz.*, SP-1005 to SP-1012 and SP-1170.

Specification	**Areas of Non-compliance or Concern**	**Recommended Additional Mitigation Measures**
SP-1005: Specification for Emissions to Atmosphere	• Stationary sources of air emissions are not monitored to check compliance with emission standards. • Positive assurance of unlit flares is not available. In case of unlit flare, very high concentration of toxic H2S gas is vented to atmosphere leading to very high concentration of H2S at ground level • Ambient air is not monitored to check compliance with air quality standards.	• H_2S laden off gases from the stripper in Al Noor shall be injected into the reservoir, instead of flaring. • All continuous air emission sources shall be monitored periodically, at least on quarterly basis. • Ambient air quality shall be monitored in accommodation camps periodically, at least on quarterly basis.

SP-1006: Specification for Aqueous Effluents	• Disposal of produced water into shallow aquifer is in practice. • The operation of some STPs is not satisfactory. The treated effluent quality often exceeds the standards. • The application of Standard A-2 for treated sewage quality is questionable since the irrigated areas are accessible to public. Application Standard A-1 will lead to repeated non-compliance. • Current STP monitoring frequency and schedule are inadequate. Once a day or once a week monitoring cannot detect if standards are breached during peak load times. • Technical proficiency of STP operators and supervisors is below par.	• Shallow water disposal shall be discontinued. • The issue relating to the application of Standard A-2 needs to be resolved, in consultation with MRME&WR. • STP monitoring frequency and schedule need to be revised to ensure compliance at all times. Monitoring frequency may be increased to 4 times per day for on-site measurements and composite samples may be taken for laboratory analysis. • All STP operators and supervisors shall be provided continuing education and training on STP operation and monitoring.
SP-1007: Specification for Accidental Releases to Land and Water	• Appropriate storage area for chemicals is not provided inside the Nimr production station. • No improvement in oil spill incidents has been achieved over the years. • It is likely that quantities of oil spills are under-estimated.	• Spillage containment and proper storage area shall be prepared for the chemical store inside the Nimr production station. • The oil spills / leaks shall be minimized through better pipeline and flow line integrity check. • All oil spill / leak incidents shall be responded to promptly to minimize quantities of release as well as quantity of soil contaminated. • More accurate methods for estimating the volumes of oil spills and the quantities of contaminated soil shall be evolved.
SP-1008: Specification for Use of Energy, Materials and Resources	• Optimal use of energy and water is not demonstrated as required in the specification.	• Avenues for minimization of water consumption shall be explored. • Monitoring of water wells shall be continued to ensure that there is no depletion of groundwater reserves.
SP-1009: Specification for Waste Management	• Waste consignments are not properly weighed or estimated. • Some wastes, such as rig site wastes are not segregated at source as required. • Waste compaction equipment is inadequate and some are non-functional. • Waste recycling is not significant. • There is no evidence of regular wetting of land farms.	• Compliance with waste handling procedures shall be enforced. • Waste operators shall be closely supervised. • Waste recycling avenues shall be explored at corporate level.

SP-1010: Specification for Environmental Noise and Vibration	• Ambient noise levels are not monitored to check compliance with the standards.	• Ambient noise levels shall be monitored in accommodation camps periodically, at least on quarterly basis
SP-1011: Specification for Flora and Fauna	• None	• None
SP-1012: Specification for Land Management	• There are several abandoned well sites, which require restoration.	• Site restoration shall be accelerated.
SP-1170: Specification for Management of Naturally Occurring Radioactive	• None	• None

8 REFERENCES

1. WS/Atkins, *Nimr asset area Environmental Assessment Report*, Petroleum Development Oman L.L.C., July 1999

2. PDO, *HEALTH, SAFETY AND ENVIRONMENT GUIDELINE - Environmental Assessment* GU 195, July 2002

3. SIEP, EP 95-0377, *Quantifying Atmospheric Emissions*, September 1995

4. HMR, *Environmental Audit Report of Sewage Treatment Plant,* April 2003

5. HMR, *Environmental Audit Report of Waste Management Centres in PDO,* April 2003

APPENDIX 1: ORGANIZATION RESPONSIBLE FOR PREPARATION AND REVIEW OF THE REPORT

HMR Environmental Engineering Consultants, Oman are responsible for the preparation of this report on environmental assessment for Nimr asset of PDO's concession area. HMR is the leading environmental engineering consultancy in Oman. HMR specializes in the fields of environmental management, water resources management, environmental assessment, environmental auditing, environmental monitoring, pollution control and environmental training.

HMR has a large pool of environmental engineers and scientists, who have work experience throughout the world and the Arabian Gulf. HMR also has technical collaborations and associations with a number of international engineering consulting companies. HMR is registered with the World Bank as well as with the Ministry of Regional Municipalities and Environment, Sultanate of Oman.

The following HMR Staff are responsible for the technical component of this report.

Name of EIA Team Member	Position in HMR	Position in EIA Team	Role in Project Execution
Dr. Laks M. Akella	Senior Consultant	Team Leader and Project Manager	Project management, data analysis and editorial review
C. S. Shaji	Consultant	EIA Expert	Data collection, site audit and report preparation
Robert Spence	Senior Consultant	EIA Expert	Data collection and site audit
C. M. Sushanth	Consultant	EIA Expert	Data collection and site audit
Babu Krishanan	Consultant	EIA Expert	Data collection and site audit
Krishnasamy	Consultant	EIA Expert	Data collection and site audit
Vinod Gopinath	Environmental Technician	EIA Expert	Data collection and site audit
Shubha Srinivas	IT Consultant	Cartographer	Cartography
Nabeela Ismaily	IT Consultant	Cartographer	Cartography
Randa Mounir	Consultant	Team member	Editing

On behalf of the client, Petroleum Development Oman, the following individuals are responsible for the review of the EIA report at all stages of the study.

Position in PDO	Name of Reviewer	Role in Project Development
CSM/22	Dr. Muralee R. Thumarukudy	Senior Corporate Environmental Advisor
CSM/25	Ahmed Al Sabahi	Environmental Advisor
OSS	Mr. Salim Al Alawi	HSE Team Leader – South
OSO/1N		Area Coordinator – Nimr

APPENDIX 2: FUEL GAS ANALYSIS

Parameter	Flare gas at Nimr Production Station	Flare gas at Rima Production Station	Fuel gas at Nimr Power plant	Fuel gas at Rima Power plant	LP Flare gas at Al Noor Production Station	HP Flare gas at Al Noor Production Station	Acid Gas flare gas at Al Noor Production Station
Methane, in % v/v	82.91	33.18	85.01	85.01	39.72	44.26	1.71
Ethane, in % v/v	1.75	9.08	6.54	6.54	17.62	19.63	0.57
Propane, in % v/v	2.23	25.90	2.68	2.68	15.40	17.16	0.77
i-Butane, in % v/v	0.55	3.24	0.66	0.66	1.34	1.50	0.10
n-Butane, in % v/v	1.67	11.70	0.61	0.61	5.34	5.95	0.79
i-Pentane, in % v/v	0.37	1.33	0.20	0.20	0.89	1.00	0.06
n-Pentane, in % v/v	0.75	1.82	0.19	0.19	1.58	1.76	0.08
Hexane +, in % v/v	0.53	0.72	0.26	0.26	0.62	0.69	0.27
Nitrogen, in % v/v	12.45	9.89	3.01	3.01	2.11	2.35	0.21
Carbon Dioxide in % v/v	0.93	2.80	0.85	0.85	2.75	3.06	50.37
Hydrogen Sulphide in ppm	0	3400	0	0	125000	25000	450700

APPENDIX 3: DETAILS OF STACKS

Source Description	Number of identical stacks	Stack Height (above ground level)	Stack Internal Diameter (at exit)	Stack Gas Temp (at exit)	Fuel Gas Mass Flow Rate	CO2 Mass Emission Rate	SO2 Mass Emission Rate	NOx Mass Emission Rate	CO Mass Emission Rate	HC Mass Emission Rate
		(m)	(m)	(C)	(kg/h)	(kg/h)	(kg/h)	(kg/h)	(kg/h)	(kg/h)
Nimr Production Station: Heater Stacks	4	10	0.6	-	2,552	-	-	6,730.0	0.0	7.5
Al Noor Production Station: Heater Stacks	2	10	0.6	-	1,319	-	-	3,811.7	154.6	4.2
Nimr Power Station: Gas Turbine	2	15	4.3	-	12,513	-	-	34,100.0	154.6	81.3
Rima Power Station: Gas Turbine	2	15	4.3	-	16,133	-	-	2,408.3	154.6	57.5
Total					32,517			47,050	464	150

APPENDIX 4: PDO'S ENVIRONMENTAL RISK EVALUATION CRITERIA

Rating of Consequence of Effect on Environment	**Rating of Frequency of Occurrence**				
	A. Very low: Not heard of but could occur	**B. Low:** Has occurred in other industry	**C. Medium** Has occurred in oil and gas industry	**D. High:** Occurs several times a year in oil and gas industry	**E. Very high:** Occurs several times a year in PDO
Slight effect: Local environmental damage. Within the fence and within systems. Negligible financial consequences	**LOW RISK**				
Minor effect: Contamination. Damage sufficiently large to attack the environment. Single exceedence of statutory or prescribed criterion. Single complaint. No permanent effect on the environment.		**MEDIUM RISK**			
Localized effect: Limited loss of discharges of known toxicity. Repeated exceedence of statutory or prescribed limit. Affecting neighborhood.					
Major effect: Severe environmental damage. The company is required to take extensive measures to restore the contaminated environment to its original state. Extended exceedence of statutory limits		**HIGH RISK**			
Massive effect: Persistent severe environmental damage or severe nuisance or nature conservancy extending over a large area. In terms of commercial or recreational use, a major economic loss for the company. Constant, high exceedence of statutory or prescribed limits				**EXTREME RISK**	

APPENDIX 5: ENVIRONMENTAL HAZARDS AND EFFECTS IDENTIFICATION MATRIX: NIMR ASSET

Environmental Hazards	**Environmental Sensitivities**																					
	Natural Resources			**Air Environment**			**Water Environment**			**Land Environment**			**Ecology and Wildlife**			**Social Environment**					
	Mineral Resources	Groundwater Resources	Claim on Local Assets	Climate (Global Warming)	Ambient Air Quality	Ambient Noise	Surface Hydrology & Water Quality	Hydrogeology & Ground Water Quality	Marine Water Quality	Land Use	Loss of Vegetation	Soil Quality	Flora	Fauna	Wildlife Habitats	Employment	Agriculture & Animal Husbandry	Native Lifestyle	Cultural Heritage	Public Health & Safety	Landscape & Aesthetics
Land take																					
For installation of project facilities										**X**	X										
For construction of accommodation facilities										**X**	X										
For drilling of oil wells										**X**	X		**X**	X	X						
For laying oil/gas pipelines			X							**X**	X		**X**	X	X						
For laying power lines			X							**X**	X		**X**	X	X						
For laying access roads			X							**X**	X		**X**	X	X						
For land irrigation of treated wastewater										**X**	X										
For storage of construction materials										**X**	X		**X**	X	X						
For storage and disposal of waste materials			**X**							**X**	X		**X**	X	X						

Environmental Hazards	Environmental Sensitivities																				
	Natural Resources			Air Environment			Water Environment			Land Environment			Ecology and Wildlife			Social Environment					
	Mineral Resources	Groundwater Resources	Claim on Local Assets	Climate (Global Warming)	Ambient Air Quality	Ambient Noise	Surface Hydrology & Water Quality	Hydrogeology & Ground Water Quality	Marine Water Quality	Land Use	Loss of Vegetation	Soil Quality	Flora	Fauna	Wildlife Habitats	Employment	Agriculture & Animal Husbandry	Native Lifestyle	Cultural Heritage	Public Health & Safety	Landscape & Aesthetics
Utilization of Mineral Resources																					
For production of oil and gas	**X**																				
For construction materials	**X**																				
For road building materials	**X**		**X**																		
Utilization of Groundwater Resources																					
For construction water		**X**						**X**													
For process water		**X**						**X**													
For potable water		**X**	**X**					**X**													
Utilization of Human Resources																					
Employment of migrant construction workers																				**X**	
Employment of permanent workers																					

Environmental Hazards	Environmental Sensitivities																				
	Natural Resources			**Air Environment**			**Water Environment**			**Land Environment**			**Ecology and Wildlife**			**Social Environment**					
	Mineral Resources	Groundwater Resources	Claim on Local Assets	Climate (Global Warming)	Ambient Air Quality	Ambient Noise	Surface Hydrology & Water Quality	Hydrogeology & Ground Water Quality	Marine Water Quality	Land Use	Loss of Vegetation	Soil Quality	Flora	Fauna	Wildlife Habitats	Employment	Agriculture & Animal Husbandry	Native Lifestyle	Cultural Heritage	Public Health & Safety	Landscape & Aesthetics
Release of Air Pollutants																					
Dust from construction activities and road traffic					**X**																
Gaseous emissions from stationary sources				**X**	**X**																
Gaseous emissions from mobile sources				**X**	**X**																
Accidental release of toxic gases and vapours																				**X**	
Release of Energy into Atmosphere																					
Hot gases from flares and stacks																					
High level noise from stationary sources						**X**															
High level noise from mobile sources						**X**															

Environmental Sensitivities	**Social Environment**	Landscape & Aesthetics									
		Public Health & Safety									
		Cultural Heritage									
		Native Lifestyle									
		Agriculture & Animal Husbandry									
		Employment									
	Ecology and Wildlife	Wildlife Habitats									
		Fauna									
		Flora									
	Land Environment	Soil Quality			X	X				X	X
		Loss of Vegetation									
		Land Use									
	Water Environment	Marine Water Quality									
		Hydrogeology & Ground Water Quality		X	X	X					
		Surface Hydrology & Water Quality									
	Air Environment	Ambient Noise									
		Ambient Air Quality									
		Climate (Global Warming)									
	Natural Resources	Claim on Local Assets									
		Groundwater Resources									
		Mineral Resources									
Environmental Hazards			**Discharges of Liquid Effluents**	Injection of production water and process effluents into aquifers	Land discharge of treated sewage effluent	Accidental spillage of hazardous liquids	Release of leachates from landfill sites	**Disposal of Solid Wastes**	Handling and transport of hazardous wastes	Landfilling of domestic and non-hazardous industrial wastes	Landfilling of hazardous wastes

Environmental Hazards	**Environmental Sensitivities**																			
	Natural Resources			**Air Environment**			**Water Environment**			**Land Environment**			**Ecology and Wildlife**			**Social Environment**					
	Mineral Resources	Groundwater Resources	Claim on Local Assets	Climate (Global Warming)	Ambient Air Quality	Ambient Noise	Surface Hydrology & Water Quality	Hydrogeology & Ground Water Quality	Marine Water Quality	Land Use	Loss of Vegetation	Soil Quality	Flora	Fauna	Wildlife Habitats	Employment	Agriculture & Animal Husbandry	Native Lifestyle	Cultural Heritage	Public Health & Safety	Landscape & Aesthetics
Functional Activities																					
Pipeline transport of oil and gas																					
Road transport of hazardous substances														**X**						**X**	
Bulk storage of hazardous substances																				**X**	
Road travel														**X**							
Air travel																					

Note: Filled-in cells indicate potential interaction and blank cells indicate no or negligible interaction.