ENVIRONMENTAL ASSESSMENT OF INFRASTRUCTURE ASSET - 2002 REVIEW AND UPDATE

PETROLEUM DEVELOPMENT OMAN

SULTANATE OF OMAN

Authorized for release by:

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EXECUTIVE SUMMARY

Introduction

This report updates the environmental assessment of Infrastructure asset, which is one of the eight service assets within PDO's concession area in the Sultanate of Oman. The first environmental assessment for Infrastructure asset was carried out in September 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.

Infrastructure asset is one of the service providers in PDO. The areas of operation of the asset cover the entire interior concession area in south and central Oman as well as Mina Al Fahal (MAF) on the coast.

The main responsibility of the infrastructure asset is to ensure optimum transport, storage and delivery of crude oil produced in PDO's concession area. Another major responsibility of the asset is the generation of most of the power required in the production assets as well as its distribution throughout the concession area. In addition, the asset is also entrusted with the responsibility of operating and maintaining the south Oman gas line (SOGL) to transport dry sweet gas from Saih Nihayda to Hubara to Marmul.

The infrastructure asset consists of three separate departments *viz.*, the terminal & Offshore operations department (TTT), Power Systems department (TTE) and pipeline department (TTP).

Description of Environment

The topographical features from the southernmost part of the concession area (Marmul) to the northern coast (MAF) show three distinct zones as below:

- Desert plains with very low population within most of the concession area
- Low to medium altitude hills over the southernmost and northernmost parts
- A small coastal plain surrounded with urban population

The natural vegetation is composed of desert plants and grasses, and is restricted to the wadi plains only. Among all the assets, Nimr and Marmul assets have relatively denser vegetation.

Most of the concession area falls under central and south-central Oman and is characterised by flat gravel desert plains with occasional rocky outcrops interspersed with a few wadi channels. The altitude in the plains is mostly in the range of 100-150m above the mean sea level. The desert plains are very thinly populated. Hills of low to medium altitude are encountered over the southernmost and northernmost parts of the concession area.

The MAF terminal area is located within the MAF industrial area on the shore of MAF bay and surrounded by hills, rising to 214 m altitude above the sea level on the eastern boundary. There are large urban settlements adjacent to MAF area to northwest.

The geology of most of the PDO's concession area comprises of mainly limestone with shale, dolomite and sandstone. The central plains mostly consist of flat limestones of oligocene and miocene ages to mid-tertiary. UeR aquifer is the main prolific aquifer in the area.

The mineral content in UeR water increases as it travels from south to north. Within the entire PDO concession area, only Marmul asset has groundwater that is potable without any pre-treatment. In all other assets the UeR water is very saline.

The mean monthly temperatures range from around 20°C in December/ January to about 35°C in July. The maximum absolute temperature will be as high as 50°C and the minimum absolute temperature will be as low as 5°C.

Rainfall in this region is scanty and is highly variable in time and space with an average of 36 mm per annum. Although the annual average rainfall is very low, flash floods are known to have occurred in the area. Wind speeds vary considerably from calm to strong gusts. The dominant wind direction is from the south with an average wind speed of 8 knots.

The natural flora in most of the concession area is composed of desert plants and grasses, and trees are rarely seen. Several fauna groups including mammals, birds and reptiles are seen. Large mammalian species known to inhabit the area include the Arabian Gazelle (*Gazelle gazelle*), the Rhim Gazelle (*Gazella subgutturosa marica*), the Nubian Ibex (*Capra nubiana*). These animals are currently listed on the IUCN World Red List and the Regional Red List threat categories. The Arabian Oryx is seen in Mukhaizna field in Bahja asset.

The beaches along the coastline are composed primarily of fine sand derived from the neighbouring land with shallow areas extending up to 2 km offshore. The seawater temperature at MAF ranges from 25°C in winter (February and March) up to 39°C in summer (June and July). The salinity ranges from 35 to 40 parts per thousand.

The human population density within PDO's concession area (interior areas) is extremely low and is to the order of 26 persons per 100 km^2. Within the total concession area of 114,000 km^2, the total current population is of the order of 30,000. The majority are the PDO and contractor staff living in the various accommodation camps located in the assets, and they number about 20,000 currently.

There are no forts, ruins or other archeological declared sites in PDO's concession area. However, abundant marine fossils are present in Jabal Fahud and Natih areas (Fahud asset).

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	• Power plant and booster plant stacks were not monitored to check compliance with emission standards. • Ambient air was not monitored to check compliance with air quality standards.	• All continuous air emission sources shall be monitored periodically, at least on quarterly basis. • Emissions from the crude oil tankers (hydrocarbon venting) to be monitored. • Ambient air quality shall be monitored in accommodation camps periodically, at least on quarterly basis.
SP-1006: Specification for Aqueous Effluents	• De-oiled produced water from MAF tank farm contains oil and grease content (50 mg/L) is well in excess of Omani marine discharge standards (5 mg/L)	• The effluent treatment plant in MAF tank farm shall be upgraded.
SP-1007: Specification for Accidental Releases to Land and Water	• It is very likely that quantities of oil spills are under-estimated and under reported.	• All oil spill / leak incidents shall be respond 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	• None	• None
SP-1009: Specification for Waste Management	• None	• None
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	• None	• None
SP-1170: Specification for Management of Naturally Occurring Radioactive Materials	• 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.

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ABBREVIATIONS

AP	atmospheric pressure (<0.5 kPa gauge pressure)
API	American Petroleum Institute
bar(g)	unit of gauge pressure (equal to 101.3 kPa gauge)
bbl	barrel (equal to about 159 liters)
bpd	barrels per day
Bq	Bequerel, unit for measurement of radioactivity (One nuclear disintegration/second)
^{o}C	degree centigrade
^{o}K	degree Kelvin
$CaCO_3$	calcium carbonate
CFC	chloro-fluoro-carbon
d	day
DGEA	Directorate General of Environmental Affairs
DLN	dry low NO_x
DWD	deep water disposal
ESP	electrical submersible pump
E&P	exploration & production
EPC	engineering, procurement and construction
EU	European Union
h	hour
ha	hectare
HCFC	hydro-chloro-fluoro-carbon
HFC	hydro-fluoro-carbon
HEMP	hazards and effects management process
HMR Consultants	HMR Environmental Engineering Consultants
HP	high pressure (>150 kPa gauge pressure)
kg	kilogram
km	kilometer
km^2	square kilometer
kPa	kilo Pascal, unit of pressure (1 atm = 101.13 kPa)
LP	low pressure (0.5 – 150 kPa gauge pressure)
m^3	cubic meter
mg	milligram
ml	milliliter
MLPS	main line pumping station
MOL	main oil line
MPN	most probable number
mPa.s	milli-Pascal-second (a unit of viscosity equivalent to 1 centipoise or cp)
MD	ministerial decision
MJ	mega-Joule
NOCS plant	North Oman crude stabilization plant
MW	megawatt
MWh	megawatt-hour
MRME&WR	Ministry of Regional Municipalities, Environment and Water Resources
MSDS	material safety data sheet
NAAQ	national ambient air quality
Nm^3	normal cubic meter (at 1atm and $0^{o}C$)
NO	nitric dioxide
NO_2	nitrogen dioxide
NO_x	oxides of nitrogen
NORM	naturally occurring radioactive materials
PDO	Petroleum Development Oman LLC
ppm	parts per million
ppmv	parts per million, volume based

PM_{10}	particulate matter of <10 µm size
$PM_{2.5}$	particulate matter of <2.5 µm size
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)
SOGL	south Oman gas line
STOIIP	stock tank of oil initially in place
t	metric tonne (equal to 1000 kg)
TDS	total dissolved solids
tpa	tonnes per annum (year)
tpd	tonnes per day
tph	tonnes per hour
TSP	total suspended particulates
UeR	Umm er Radhuma
UNEP	United Nations Environmental Program
UNESCO	United Nations Scientific and Cultural Organisation
USEPA	United States Environmental Protection Agency
WHO	World Health Organisation
µg	micro-gram
µm	micro-meter (also known as micron)
µS/cm	micro-Siemens per centimeter (unit of electrical conductivity)

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 administrative assets 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.

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).

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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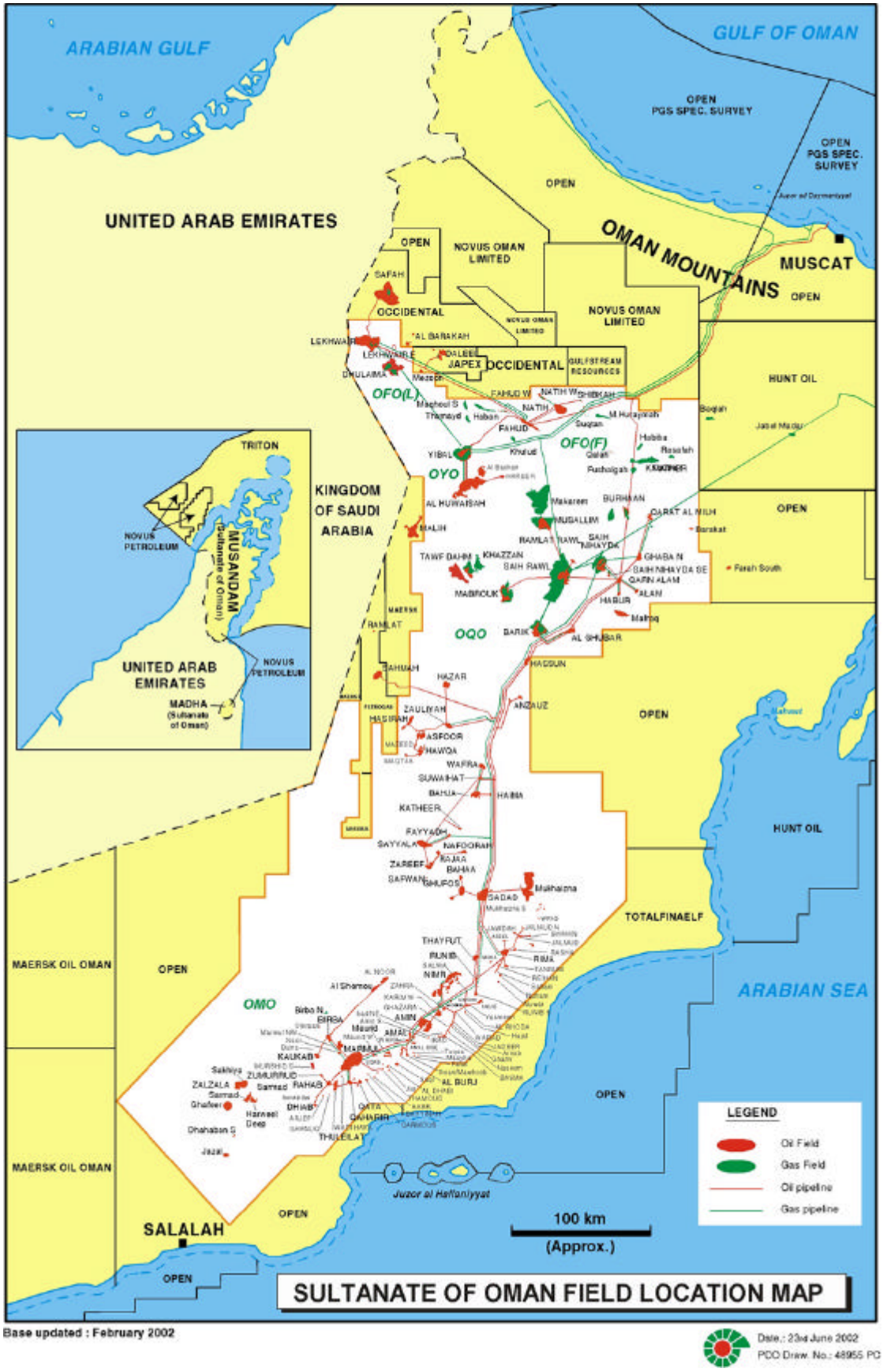

Figure 1.1: Geographical Map of PDO's Concession Area

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In addition to the seven production assets, there are eight service assets in PDO, which provide technical, analytical, engineering, supply and transportation support to the production assets. A brief description of the services assets is presented below in Table 1.2.

Table 1.2: Description of Service Assets in PDO

Service Asset	Main Activities and Areas of Operation
Exploration Asset	- Plan and execute 2D and 3D seismic surveys throughout PDO's concession area for identifying potential locations for drilling new oil wells
Well Engineering Asset	- Prepare and update preliminary and detailed designs for new oil wells throughout PDO's concession area - Prepare new oil well construction and completion programmes throughout PDO's concession area - Construct new oil wells and modifying any existing wells as required throughout PDO's concession area - Close out non-producing wells and restore abandoned well sites throughout PDO's concession area
Engineering Asset	- Plan, manage and execute preventive and remedial maintenance work for all production facilities throughout PDO's concession area - Manage and execute all well maintenance services throughout PDO's concession area - Manage and execute civil engineering construction work throughout PDO's concession area - Provide technical specialist service in detailed engineering design, field execution, material selection, process control and automation for all new projects throughout PDO's concession area
Infrastructure Asset	TERMINAL OPERATIONS DEPARTMENT - Operate and maintain the Mina Al Fahal Tank Farm consisting of 10 crude oil storage tanks with a total storage capacity of 5 million barrels - Operate and maintain the offshore oil export facilities in Mina Al Fahal consisting of three single point moorings and two coastal buoy moorings - Operate and maintain the oil export metering systems and offshore oil pollution combating equipment in Mina Al Fahal POWER SYSTEMS DEPARTMENT - Operate and maintain ten power stations consisting of 22 gas turbines throughout PDO's concession area - Operate and maintain twenty-two 132 kV substations throughout PDO's concession area - Operate and maintain 1276 km long 132 kV overhead electrical transmission lines throughout PDO's concession area PIPELINE DEPARTMENT - Operate and maintain 1510 km long main oil line for transportation of liquid hydrocarbons from all production assets to the export terminal in Mina Al Fahal - Operate and maintain 670 km long south Oman gas line for transportation of dry sweet gas hydrocarbons from Saih Nihayda (Qarn Alam Asset) to Marmul asset - Operate and maintain the main oil line booster stations in Hubara (Nimr Asset), Sahma (Bahja Asset) and Nahada (Fahud Asset)
Gas Asset	- Operate and maintain, on behalf of the government, gas treatment facilities (government gas plant, government butane plant and butane storage and loading facility) in Yibal - Operate and maintain, on behalf of the government, liquefied natural gas upstream facilities in Saih Rawl, Barik and Saih Nihayda

Service Asset	Main Activities and Areas of Operation
	- Operate and maintain, on behalf of the government, natural gas pipeline system from Yibal to Murayat (296 km long), from Murayat to Al Ghubra (29 km long) and from Murayat to Sohar (225 km long) as well as spur lines - Operate and maintain, on behalf of the government, pressure reducing terminals for natural gas customers throughout Oman
Supply & Logistics Asset	- Procure, store and distribute raw materials and process chemicals for consumption throughout PDO's concession area - Provide land and air passenger transport service (through sub-contracting) for all PDO and contractor staff throughout PDO's concession area - Supply and move land based drilling rigs throughout PDO's concession area
Estate Services Asset	- Provide and maintain accommodation facilities for PDO staff in Mina Al Fahal - Maintain air-conditioning and refrigeration system within PDO area in Mina Al Fahal - Provide catering and laundry services for PDO staff in Mina Al Fahal - Supply potable water and maintain electrical power distribution systems within PDO area in Mina Al Fahal - Manage sewage treatment plants, treated sewage re-use and solid waste disposal for waste generated within PDO area in Mina Al Fahal - Manage the incinerator located in mina Al Fahal for thermal destruction of clinical wastes generated throughout PDO's concession area
Production Chemistry Asset	- Provide drilling chemistry support including analysis of drilling fluids and cements, technical specifications for drilling fluids and cements, evaluation of new drilling fluid and cement products and technologies for all assets in PDO - Provide process and treatment support including expert advice on all chemical and physical processes related to production, treatment and transportation of gas and oil for all assets in PDO - Provide laboratory support for physico-chemical analysis of well fluids, crude oil, gas, produced water, groundwater, treated water, sewage, raw materials and process chemicals for all assets in PDO

The current organisation structure in PDO is shown in Figure 1.2.

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. The previous environmental assessment study for infrastructure asset was completed in November 1999 (*Reference 1*). It is an internal requirement in PDO to review and update of the EIA once in every three years, in order to periodically reassess 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 infrastructure asset.

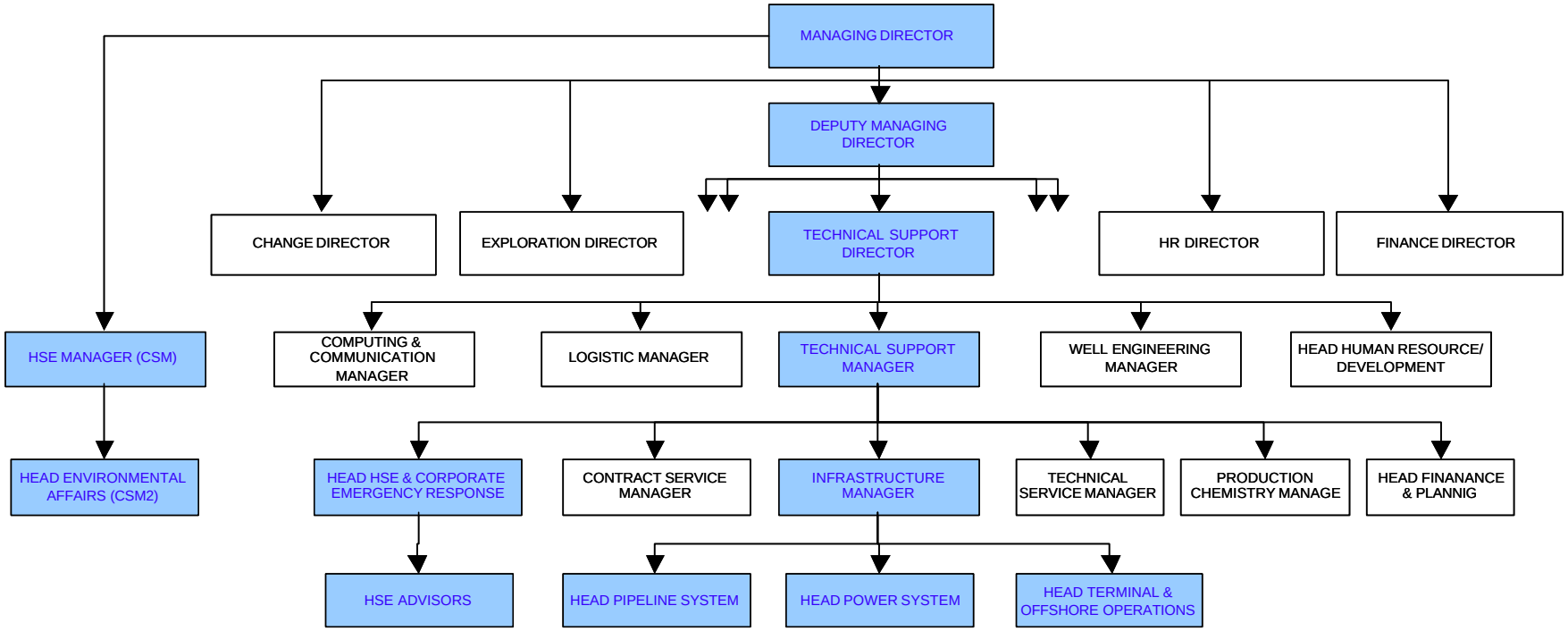


Figure 1.2: Organisation Structure in PDO

1.3 Objectives and Scope of Study

The objectives of the present 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 November 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 reassessing the environmental impacts, in view of the above.
- Revising the environmental mitigation and monitoring plan, wherever required.

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

1.4 Method of Study

The present study was carried out in three stages. In the first stage, the previous EIA reports (*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, 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 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 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 activities performed by infrastructure 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 by Infrastructure 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 of the areas within which the infrastructure asset operates.

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
Regulations for the handling of toxic substances	MD 248/97

Title	Reference Number
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 ^{o}C 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.

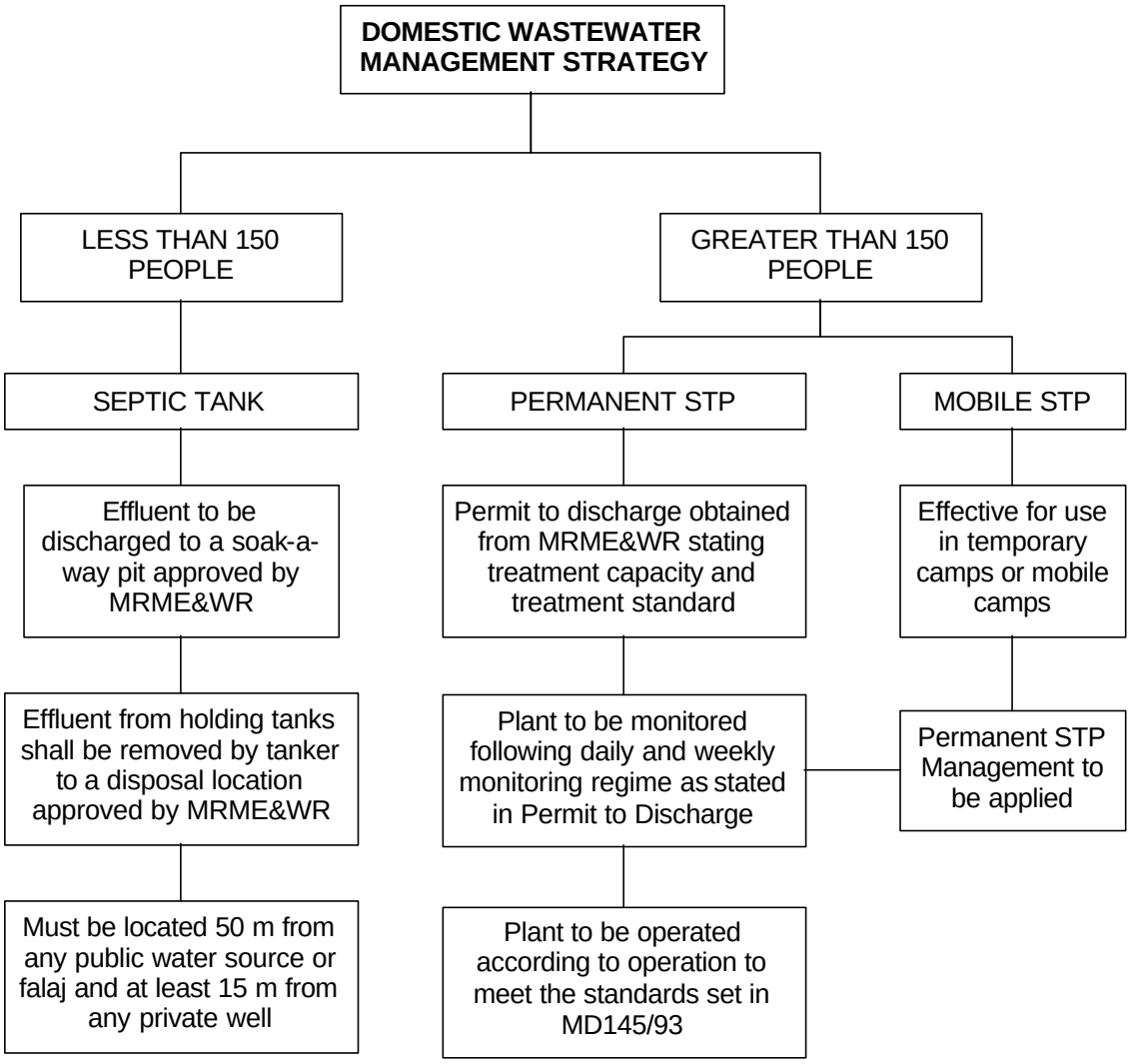
(e) Dispose surplus waters to formations, which have salinity greater than 35,000 mg/L, in conjunction with case-specific monitoring programs.

- **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 Introduction

Infrastructure asset is one of the technical service providers in PDO, whose area of operation covers the entire interior concession area in south and central Oman as well as Mina Al Fahal on the coast The main responsibility of the infrastructure asset is to ensure optimum transport, storage and delivery of crude oil produced in PDO's concession area. Another major responsibility of the asset is the generation of most of the power required in the production assets as well as its distribution throughout the concession area. In addition, the asset is also entrusted with the responsibility of operating and maintaining the south Oman gas line (SOGL) to transport dry sweet gas from Saih Nihayda to Hubara to Marmul. The infrastructure asset consists of three separate departments *viz.*, the terminal & Offshore operations department (TTT), Power Systems department (TTE) and pipeline department (TTP).

The infrastructure asset, like all other service assets works under the overall direction of the Technical Support Director and is managed by the Technical Support Manager. At the asset level, it is managed by the Infrastructure Manager followed by three departmental heads. The asset management structure including the health, safety and environment (HSE) management structure is shown in Figure 3.1.

The individual responsibilities of each department are summarized below:

- **Terminal & Offshore Operations Department (TTT)**

- Operate and maintain the Mina Al Fahal (MAF)Tank Farm consisting of 10 crude oil storage tanks with a total storage capacity of 5 million barrels
- Operate and maintain the offshore oil export facilities in MAF consisting of three single point moorings and two coastal buoy moorings
- Operate and maintain the oil export metering systems and offshore oil pollution combating equipment in MAF

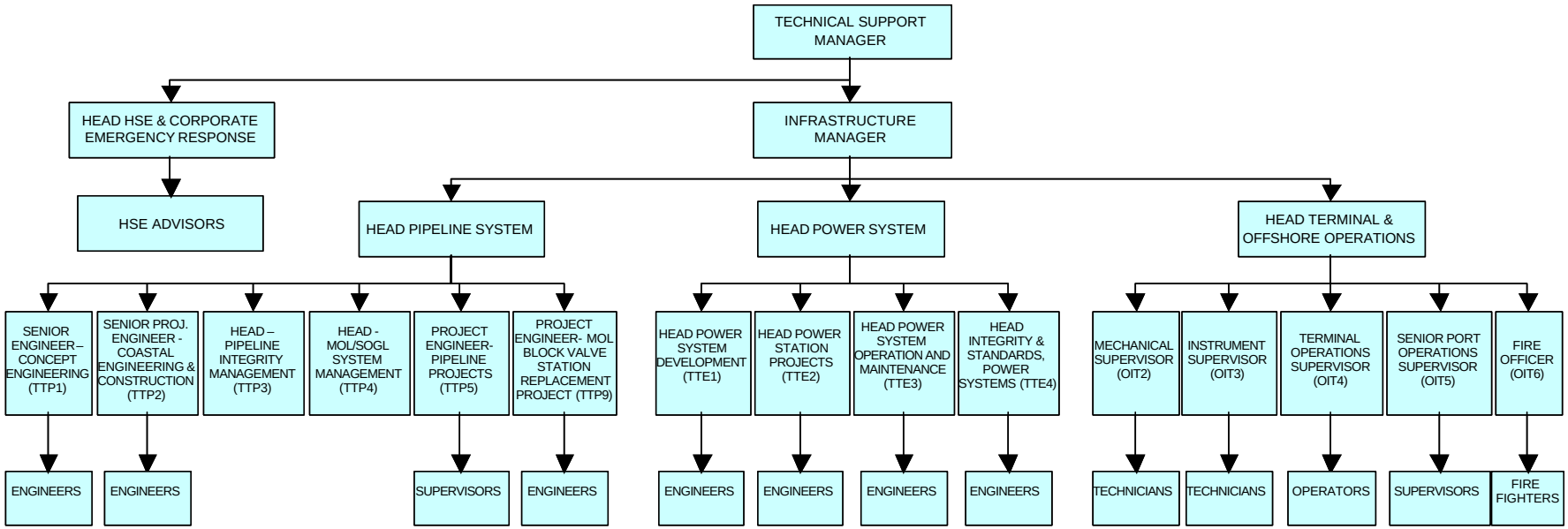


Figure 3.1: Asset Management Structure for Infrastructure Asset

- **Power System Department (TTE)**

- Operate and maintain ten power stations consisting of 22 gas turbines throughout PDO's concession area
- Operate and maintain twenty-two 132kV substations throughout PDO's concession area
- Operate and maintain 1,276 km long 132kV overhead electrical transmission lines throughout PDO's concession area

- **Pipeline System Department (TTP)**

- Operate and maintain 1,510 km long main oil line (MOL) for transportation of liquid hydrocarbons from all production assets to the export terminal in MAF
- Operate and maintain 670 km long SOGL for transportation of dry sweet gas hydrocarbons from Saih Nihayda (Qarn Alam asset) to Marmul asset
- Operate and maintain the MOL booster stations in Hubara (Nimr asset), Sahma (Bahja asset) and Nahada (Fahud asset)

3.2 Description of Facilities

The list of facilities currently managed by the infrastructure asset along with a brief description is presented in Table 3.1 below.

Table 3.1: List of Facilities Managed by Infrastructure Asset

Name of Facility	Description	Managed By
Main Oil Line (MOL)	- MOL is a 1510 km long pipeline of 6-48 inch (varying) diameter transporting liquid hydrocarbons from all production stations to the export terminal in MAF at a maximum rate of 1 million barrels per day. - There are 40 pigging units available for periodic internal cleaning of the pipeline. - There are 31 intermediate block valve stations along the pipeline route for isolation of pipeline sections.	TTP
Main Oil Booster Stations	- There are three booster stations located in Hubara (Bahja asset), Sahma (Bahja asset) and Nahada-2 (Fahud asset) for intermediate pressurisation of the pipeline flow. - The mechanical drive for the booster stations is provided by gas fired gas turbines and electric motors, which form a part of the booster stations.	TTP
South Oman as Line (SOGL)	- SOGL is a 670 km long pipeline of 10-16 inch (varying) diameter of dry sweet gas hydrocarbons from Saih Nihayda (Qarn Alam asset) to Hubara (Nimr asset) to Marmul asset - There are 22 pigging units along the pipeline route for periodic cleaning of the pipeline. - There are 13 intermediate block valve stations along the pipeline route for isolation of pipeline sections.	TTP

MAF Tank Farm	- It consists of 10 crude oil storage tanks of combined storage capacity of 5.465 million barrels - It also includes a pressure reducing station at the inlet - There is an effluent treatment plant of 30m^3/h design capacity to de-oil the residual water settled in the storage tanks.	TTT
Metering Facilities	- Two banks of four crude oil meters for offshore export - One bank of two crude oil meters for supply to Oman Refinery.	TTT
MAF Terminal Inter-connector Lines	- There are three offshore lines, three onshore lines and others of 12-40 inch (varying) diameter connecting the crude storage tanks with the offshore facilities and Oman Refinery.	TTT
Offshore Facilities	- There is a purpose built harbour. - There are three single buoy moorings (SBM) for offshore export of crude oil. - There are two coastal buoy moorings (CBM) operated on behalf of Shall Oman Marketing Company for export/import of refined petroleum products. - There are three tugs and a maintenance barge, which are contracted.	TTT
Power Plants	- There are ten power stations with a combined generating capacity of 494 MW, which are operated by the infrastructure asset. - The power plant locations are Marmul, Nimr, Rima, Hubara, Suwaihat, Siah Rawl, Saih Nihayda, Yibal, Fahud and Lekhwair. - All power plants are gas turbines based plants operating on open cycle using associated gas as the fuel. - There are a total of 22 gas turbines including 3 Avon engines each 7.75 MW capacity each, 5 Frame-5 engines of 15.2 MW capacity each, 14 Frame-6 engines of 28.2 MW capacity each - A new 6FA engine of 55 MW capacity is currently under commissioning in Marmul. There are plans to install three more 6FA engines of 55 MW capacity each in Nimr, Qarn Alam and Fahud by year 2005.	TTE
Electrical Substations	- There are twenty-three 132 kV, two 66 kV, eighteen 33 kV and two 11 kV electrical substations throughout PDO's concession area operated and maintained by the infrastructure asset. - There are seventy-seven power 132 kV transformers, 26 high voltage switchboards and two main control centres.	TTE
Overhead Electrical Transmission Lines	- Total length of overhead transmission line for 132 kV is 1276 km throughout PDO's concession area.	TTE

3.3 Activity Description

3.3.1 Overview

A broad description of the activities of the infrastructure asset is given in Section 3.2 and a broad description of the facilities managed by the asset is presented in Section 3.3. In the following sections, the detailed description of the systems and activities performed by the infrastructure asset is presented.

3.3.2 Liquid Hydrocarbon Transportation

The liquid hydrocarbons from all production stations are transported to the export terminal in MAF by the MOL. The liquids include the stabilised crude from PDO's production stations, third party crude oils (including Occidental, Japex and Petrogas) and condensates from government gas plant. MOL is a 1510 km long pipeline with diameter varying from 6 to 48 inch. It runs from Marmul in the south and Lekhwair in the north to MAF terminal on the coast, after passing through a high point (670 m altitude above mean sea level) near Izki (~100 km from MAF). The internal pressure is normally in the range of 2-68 bar and the maximum flow rate is 1 million barrels per day (~156,000 m^3/d).

The pipeline is buried throughout to a depth of ¾- 3 m below surface. Access roads are available all along the pipeline route for inspection, maintenance and repair. The pipeline is provided with cathodic protection and sacrificial anodes for external corrosion control. Solar cell stations are provided along the pipeline route to provide power for the cathodic protection regime. Sacrificial anodes normally require replacement every 20 years.

Integral to the MOL system are the booster stations, intermediate block valve stations and operation control centres. Booster stations ensure that adequate fluid pressure is maintained in the pipeline so that the crude will reach the MAF terminal via high point. Intermediate block valve stations along the pipeline route ensure that any section of the pipeline can be isolated for maintenance, repair or emergency control.

Currently, there are two booster stations in the south and four in the north. The booster stations located in the south are in Hubara and Sahma (both in Bahja asset). The booster stations located in the north are in Fahud, Nahada-1 & Nahada-2 (all in Fahud asset) and Qarn Alam. Fahud and Qarn Alam booster stations are operated by respective production assets and therefore they are not a part of the infrastructure asset. There are 31 intermediate block valve stations along the pipeline route. The operation control centres for MOL are located in Marmul, Qarn Alam, Fahud and MAF.

MOL system is operated with each production asset giving the first line operational support from the main control room for the particular section passing through the asset. The TTT department (terminal operations) provides the first line operational support for the section of the pipeline passing from the high point to MAF from the main control room in MAF. Thus the principal activity of the infrastructure asset with respect to the operation and maintenance of the MOL system is the pipeline integrity

management. The routine operation of the MOL and the booster stations does not require significant man-power.

Pipeline integrity management consists of routine and periodic inspection and assessment of pipeline integrity. The facilities provided along the pipeline for integrity management include the following:

- Cathodic protection check points at every 2 km
- Magnetic pits at every 2 km
- Corrosion monitoring points at strategic locations
- Forty pigging units for internal cleaning of the pipelines
- Intelligent pigs for internal inspection of the pipelines

The pipeline inspection regime includes the following:

- Daily aerial visual inspection of pipeline corridor
- Weekly on-ground inspection for external corrosion
- Quarterly to yearly inspection for internal corrosion

Corrosion monitoring pits provide access to the pipeline by trapdoors for inspection of internal corrosion. The metal strips inserted into the oil flow are retrieved here for analysis. These pits also allow ultrasound scan and magnetic flux measurements.

The schematic diagram of MOL system is shown in Figure 3.2.

3.3.3 Dry Sweet Gas Transportation

The excess associated gas and non-associated gas produced in Qarn Alam asset, after drying and sweetening, is transported to the south by SOGL. The gas is used partly as fuel gas in the production stations and power plants and partly for injection into the reservoir, purging and blanketing. SOGL is a 670 km long pipeline consisting of two sections. One section of 293 km length with 16-inch diameter runs from Saih Nihayda (Qarn Alam asset) to Hubara (Bahja asset) and another section of 293 km length with 16-inch diameter runs Hubara (Bahja asset) to Marmul asset. There are five gas supply points to SOGL from Saih Nihayda, Barik, Zauliya and Anzauz production stations and the Government Gas Plant in Qarn Alam. There are twelve off take points along the gas line. There are 22 pigging units along the pipeline route for periodic cleaning of the pipeline and 13 intermediate block valve stations along the pipeline route for isolation of pipeline sections.

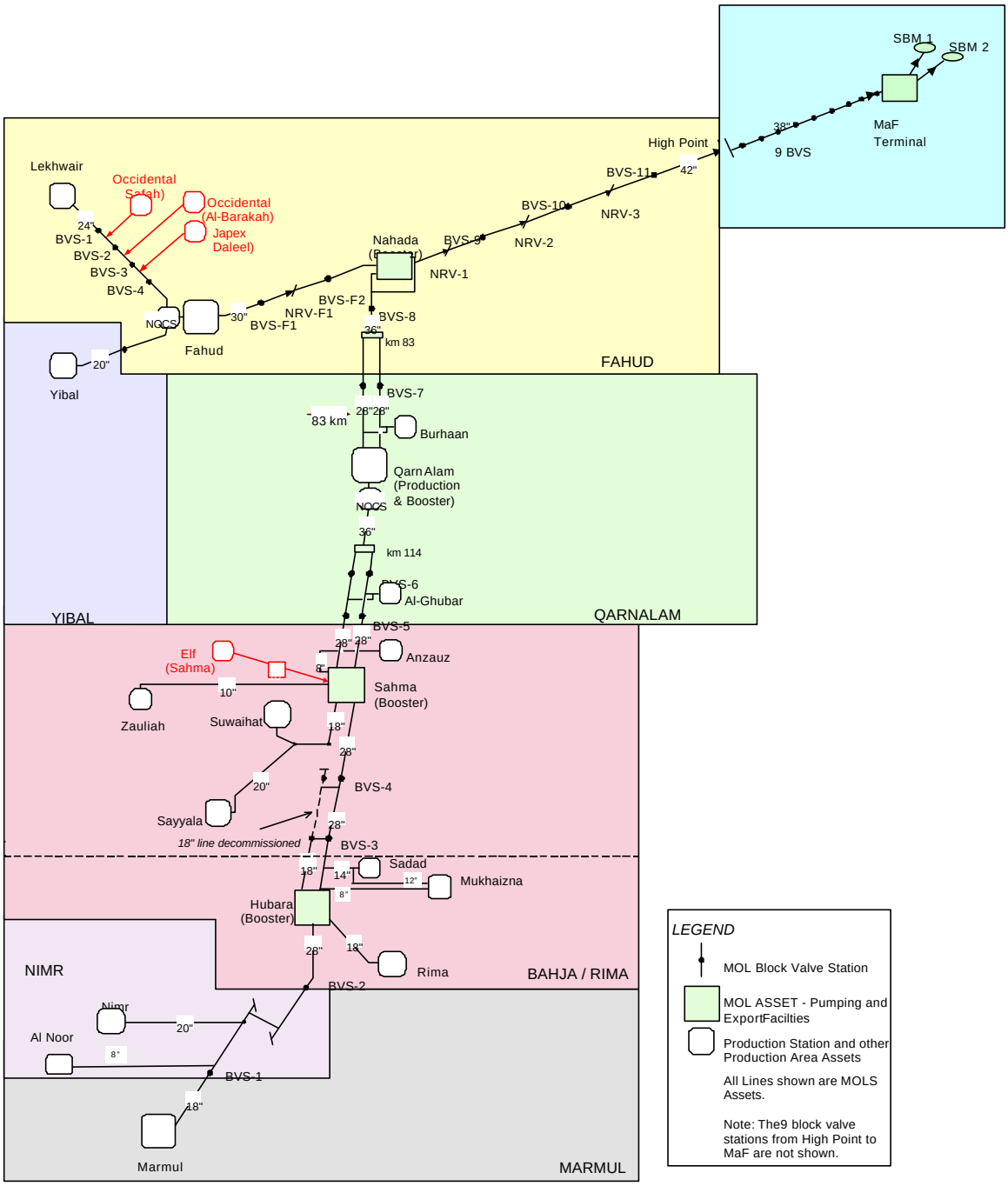


Figure 3.2: Schematic Diagram of Main Oil Pipeline System

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There is a 5 km long 10-inch diameter inter-connector pipeline that links SOGL to the 48-inch natural gas pipeline to Sur. This allows export of excess gas from SOGL system to natural gas line and vice versa. The inter-connector is pressure controlled such that flow is initiated by low pressure in the system.

SOGL system is operated with each production asset giving the first line operational support from the main control room for the particular section passing through the asset.

Thus the principal activity of the infrastructure asset with respect to the operation and maintenance of the SOGL system is the pipeline integrity management. Pipeline integrity management consists of routine and periodic inspection and assessment of pipeline integrity. The pipeline inspection regime includes the following:

- Daily aerial visual inspection of pipeline corridor
- Weekly on ground inspection for external corrosion
- Quarterly to yearly inspection for internal corrosion

The schematic diagram of SOGL system is shown in Figure 3.3.

3.3.4 Crude Oil Storage and Export at MAF

The dehydrated and stabilised crude oil from all the production stations in the interior along with third party crude oil (from Occidental, Japex and Petrogas) and condensates from the government gas plants is transported to the MAF Terminal on the coast for storage and export by sea. The MAF terminal consists of the following facilities:

- A pressure reducing station for the incoming fluid
- A tank farm consisting of ten crude oil storage tanks
- An effluent treatment plant to de-oil the residual water settled in the storage tanks
- Crude oil meters for offshore export and for supply to Oman Refinery
- Inter-connector pipelines from crude storage tanks to offshore facilities and Oman Refinery
- Offshore facilities including a purpose built harbour, 3 SBMs, 2 CBMs, 3 tugs and a maintenance barge
- Full suite of oil spill response (OSR) equipment designed to cope with spills of tier 1 magnitude.

- Pressure Reduction

The pressure reducing station (PRS) is provided in the MAF Terminal to reduce the pressure of the incoming fluid to near atmospheric pressure. The PRS consists of six parallel restriction pipes of 6-10 inch diameter and total length of 15 km, connected to trim control valves.

The PRS is designed to handle a maximum of 960, 000 bpd (152,600 m^3/d) flow rate. A pig receiver is provided to retrieve the pigs inserted into the MOL and a filter is provided for filtering any solid particles present in the MOL.

- Crude Oil Storage

The liquid hydrocarbon received via the PRS is stored prior to export in ten floating roof bulk storage tanks of combined storage capacity of 5,465,000 barrels, equivalent to about 6 days of total PDO production rate. The tank farm is divided into two area viz., upper tank farm (UTF) and lower tank farm (LTF). Two tanks are located in UTF and eight tanks are located in LTF. In addition, LTF contains two other tanks for the storage of un-cut long residue from Oman Refinery.

In the storage tanks, the incoming crude is allowed to stand so that any residual water settles to the bottom of the tank. The crude for export, which is checked every 4 hours must have less than 0.05% Bottoms, Sediments and Water (BS&W). The settled water is continuously drawn out from the tank bottom and treated in an effluent treatment plant for de-oiling.

- Effluent Treatment

In the effluent treatment plant, the residual water settled in the storage tanks is de-oiled to about 15 mg/L oil-in-water for discharge into the sea. The oil removal is achieved by using corrugated plate interceptor separators. The design capacity of the effluent treatment plant is 30m^3/h. The plant consists of two raw effluent holding tanks of 400 m^3 capacity each for oily water, one separation tank of 400 m^3 capacity, three CPI separators of 100 m^3 capacity each, and three treated effluent holding basins of 480 m^3 capacity each. The treated effluent is released into the sea through a marine outfall and the separated oil is collected in a sump.

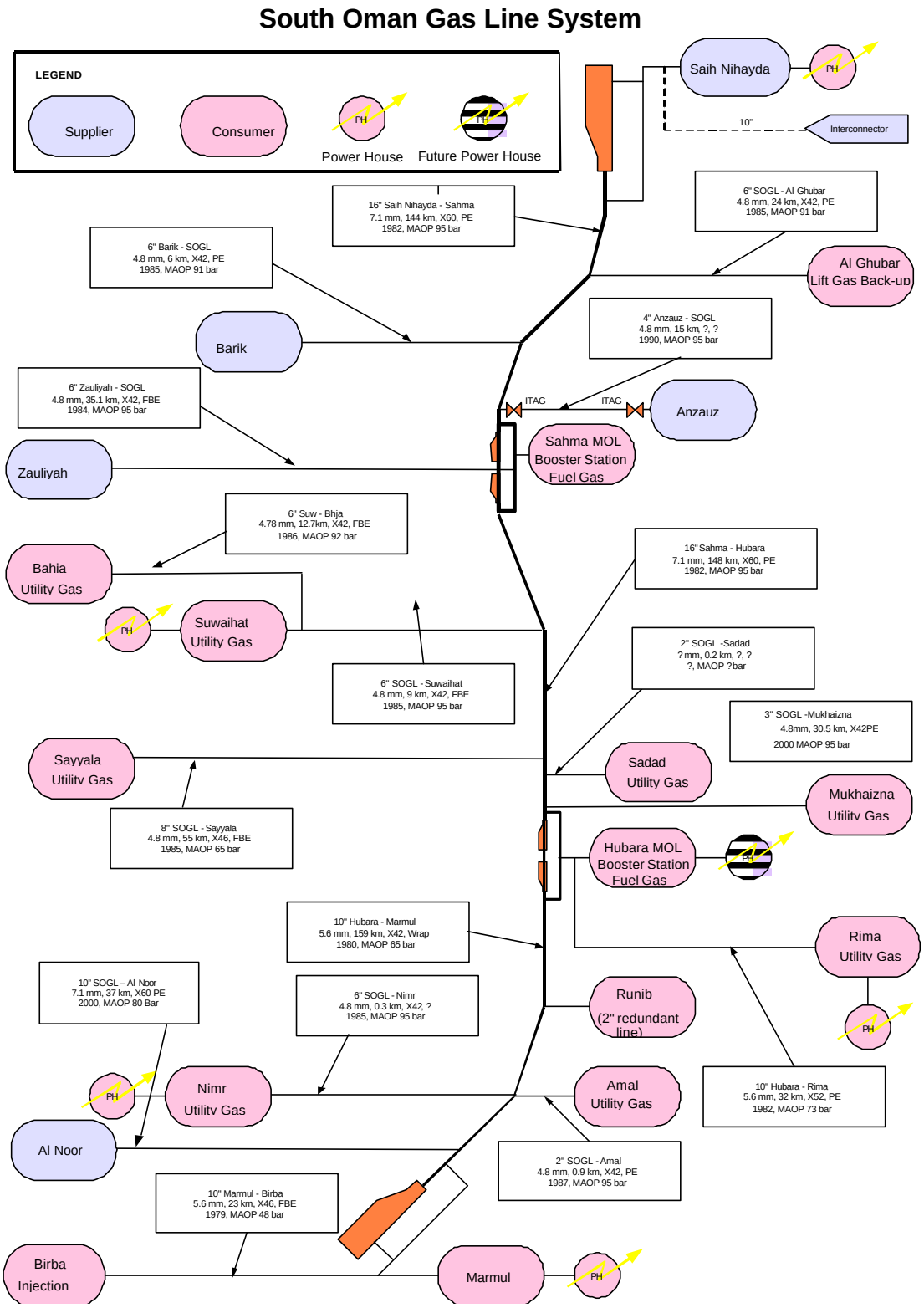

Figure 3.3: Schematic Diagram of South Oman Gas Line System

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- Crude Oil Metering and Inter-connection

From the storage tanks, crude oil delivered to tankers for export and to Oman Refinery for refining. Two banks of four turbine meters are provided for crude oil metering to tankers and one bank of two turbine meters are provided for Oman Refinery. In addition four separate meters are provided for the long residue. Slope drainage headers are provided in the metering area to collect the low pressure drainage into a sump pit from where it is pumped to a slop tank and then to the crude export line. There are three offshore lines, three onshore lines and others of 12-40 inch (varying) diameter connecting the crude storage tanks with the offshore facilities and Oman Refinery.

- Crude Oil Export

Crude oil is exported by sea in tankers. The offshore oil loading and unloading facilities include three SBMs and two CBMs. The SBM-1 and SBM-2 are used for loading PDO's crude or Oman Refinery's long residue into the ships. SBM-3 and the two CBMs are used for the import/export of refined products for Shell Oman Marketing Company. There are also three tugs boats and a maintenance barge.

The export to ships is planned in advance. Each ship stops on shore for about 3 days to receive crude. Crude loading rate starts at a low flow rate initially for about 15 minutes and thereafter increased to normal flow rate.

Offshore oil spill response and fire fighting equipment are also available at the terminal. They include the following:

- 8.5 m rigid inflatable fast response craft fitted with 240 hp diesel engine
- 4.5 m rigid inflatable pollution boom craft fitted with 38 hp diesel engine

The schematic diagram of the crude oil storage and export facilities in MAF is shown in Figure 3.4.

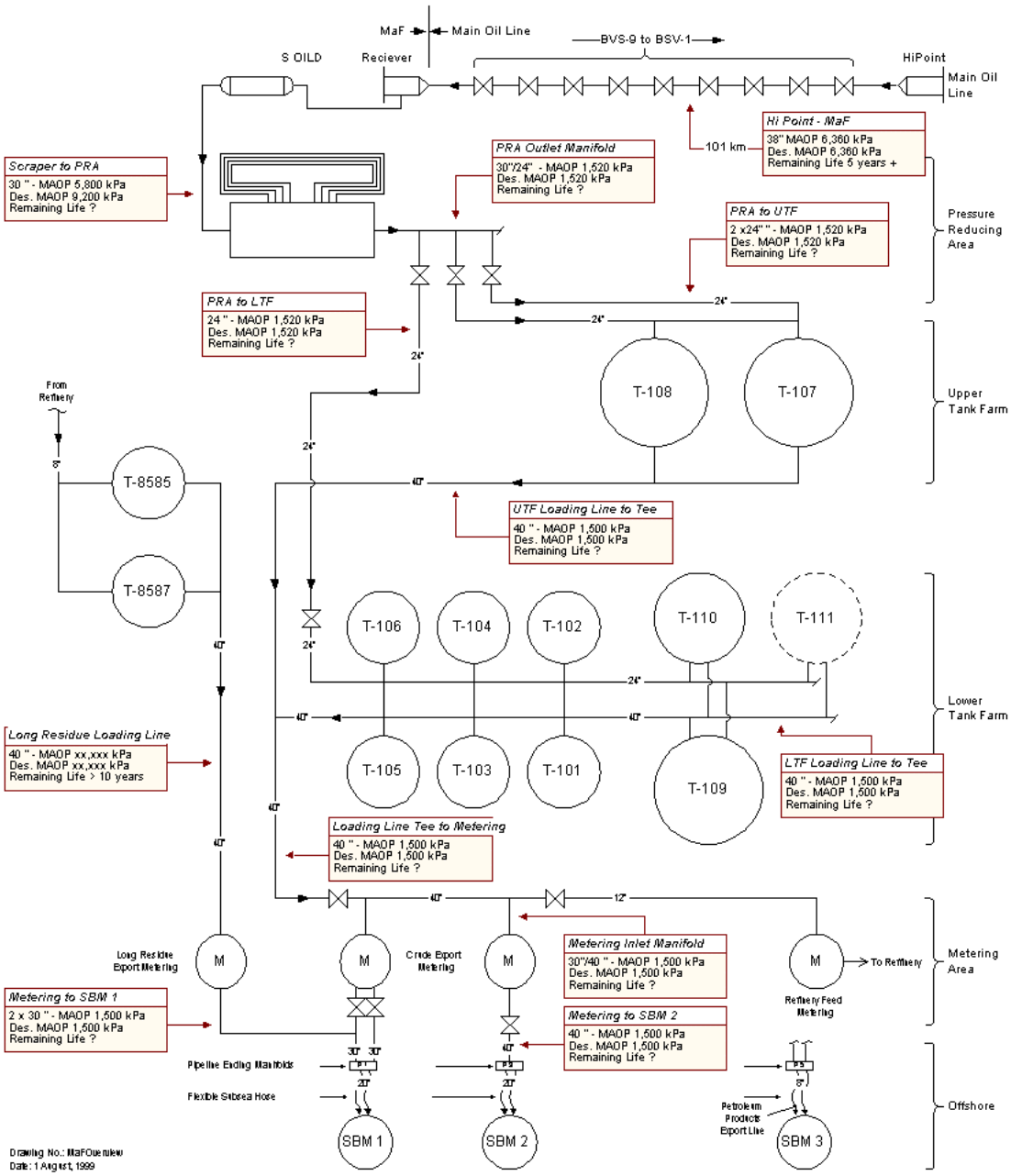

Figure 3.4: Schematic Diagram of Crude Storage and Export Facilities in MAF

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3.3.5 Power Generation and Distribution

The TTE department of the infrastructure asset operates ten power stations with a combined generating capacity of 494 MW. The power plants are located at Marmul, Nimr, Rima, Hubara, Suwaihat, Siah Rawl, Saih Nihayda, Yibal, Fahud and Lekhwair. All power plants are gas turbines based and they operate on an open cycle system with no waste heat recovery except the power plant at Saih Rawl. They use dry sweet associated gas as the fuel, which is supplied from the SOGL, and they can run on diesel oil in the event of non-availability of gas. Currently, they are 22 gas turbine units in the power plants operated by TTE and they include 3 Avon engines of 7.75 MW capacity each, 5 Frame-5 engines of 15.2 MW capacity each, and 14 Frame-6 engines of 28.2 MW capacity each. A new 6FA engine of 55 MW capacity is currently under commissioning in Marmul. There are also plans to install three more 6FA engines of 55 MW capacity each in Nimr, Qarn Alam and Fahud by year 2005.

Except for the new 6FA engines, none of the existing gas turbines is equipped with any low NO_x control system. The new 6FA engines are provided with dry low NO_x (DLN) combustion systems, which ensure that the NO_x emissions will be below 25 ppmv. Each gas turbine is provided with a stack of 15 m height for the release of flue gases into the atmosphere.

The generated power is fed into PDO grid for use by the production assets. The electrical power distribution system managed by TTE consists of twenty-three 132 kV outdoor substations, two 66 kV outdoor substations, eighteen 33 kV indoor substations and two 11 kV indoor substations throughout PDO's concession area. The power distribution system also includes seventy-seven 132 kV transformers and twenty-six high voltage switchboards. The total length of overhead transmission lines for 132 kV managed by TTE is 1276 km.

The operation of the entire electrical system is controlled from the two main control centres located in Yibal and Marmul, with the production assets providing the first line operation support. Thus, the principal activity of the infrastructure asset with respect to power generation and distribution system is to ensure the reliability of power supply to the production assets. This includes providing guidance at corporate level on future demand forecasts, providing electrical engineering inputs for all new power projects and distribution systems, executing new power projects and maintaining the power systems in a safe, reliable and efficient manner. The last function consists of a high quality integrity management system.

The electrical system integrity management consists of routine and periodic inspection and assessment of the power plant equipment, substations, transformers, switchgear and overhead lines.

The schematic diagram of the power generation and distribution system managed by TTE department is shown in Figure 3.5

3.4 Materials and Utilities

The infrastructure asset is not a major consumer of materials and utilities, except for the fuel gas consumed in the power plant. Some minor materials and chemicals are consumed for the inspection and maintenance activities performed by the asset team. The list of fuels, water, materials and process chemicals used in the infrastructure asset is given in Table 3.2 below together with their description (nature and purpose) and quantities consumed currently.

Table 3.2: Consumption of Materials, Process Chemicals and Utilities by Infrastructure Asset

Item	Description (Nature and Purpose)	Quantity Consumed (2002)		
		TTP	TTT	TTE
Fuel gas	Power plant, booster station	$55x10^6 m^3$	Nil	$1220 x10^6 m^3$
Diesel oil	Emergency DG sets, Fire water pumps	-	$950 m^3$	-
Lubricating oils	Pumps, compressors, motors	Data not available		
Transformer oils		-	-	Data not available
Power	For internal generation	1.7 MWh		
Corrosion inhibitors	Pipe line	Data not available	-	-
Biocides	During pigging of pipeline	Data not available	-	-

"-" means Not relevant

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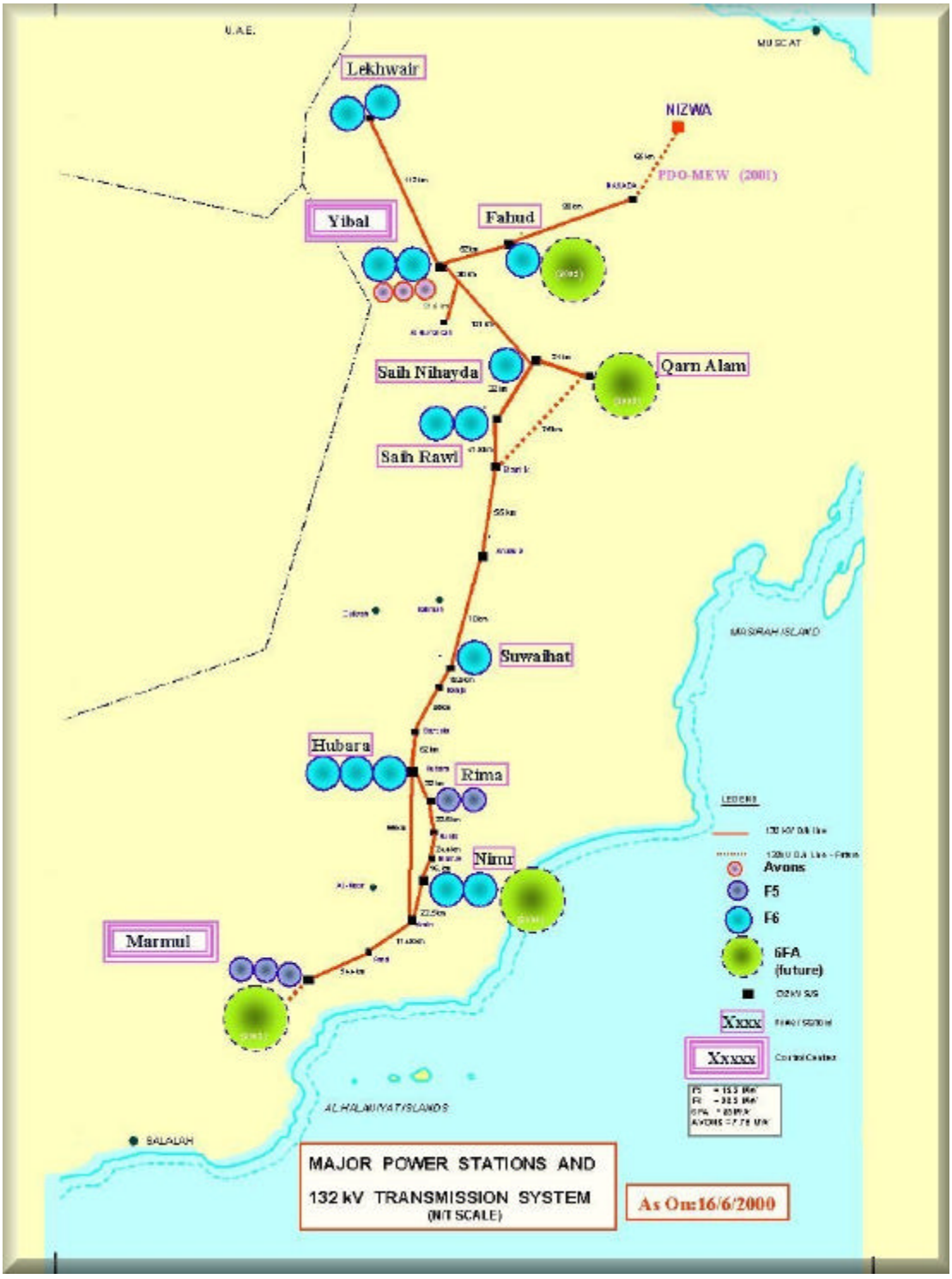

Figure 3.5: Schematic Diagram of Power Generation and Distribution System Managed by Infrastructure Asset

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 by the infrastructure asset are discussed. The contribution from those activities that are directly handled by the production assets on behalf of infrastructure asset are not included here, since thy are included in their EIA reports. However, the contributions from all those activities that are performed by contractors under direct contract with the infrastructure asset are included here.

The activities performed by the infrastructure asset may be classified under the following headings:

- Transport of liquid hydrocarbons in MOL
- Transport of dry sweet gas in SOGL
- Storage of liquid hydrocarbons in MAF terminal
- Offshore loading / unloading of crude oil, long residue and refined products
- Generation of power in OIE power plants
- Transmission of generated power to consumers
- Inspection and maintenance of MOL
- Inspection and maintenance of SOGL
- Inspection and maintenance of MAF terminal systems
- Inspection and maintenance of power systems

In addition, the following construction and decommissioning activities may also generate some waste streams:

- Major replacement of any existing gas or oil pipeline sections or fittings
- Laying of new electrical transmission lines or substations
- Replacement of any existing onshore storage facilities in MAF

Construction activities involving laying of any new gas or oil pipelines, new power plants and offshore facilities in MAF are not considered here. These environmental impacts from these activities will be site-specific and therefore shall have to addressed under a separate EIA study.

The wastes released into the environment from all the activities discussed above may 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
- Vent and fugitive emissions
- Mobile source emissions

The discussion on the emission sources, quantities, characteristics and emission controls is presented in the following sections.

4.2.2 Stack Emissions

Stack emissions are the most dominant air emissions for infrastructure asset by virtue of their number and the quantity of emissions. The sources of stack emissions are the gas turbines, which are used in the power stations and the booster stations. In addition, there are some 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 that fall under infrastructure asset is presented below in Table 4.1.

Table 4.1: Inventory of Stacks Under Infrastructure Asset

Location	Number of Stacks			
	TTP	TTI	TTE	Asset Total
Marmul power station (Three F5 GTs)	0	0	3	3
Nimr power station (Two F6 GTs)	0	0	2	2
Rima power station (Two F5 GTs)	0	0	2	2
Hubara power station (Three F6 GTs)	0	0	3	3
Suwaihat power station (one F6 GT)	0	0	1	1
Saih Rawl power station (Two F6 GTs)	0	0	2	2
Saih Nihayda power station (One F6 GT)	0	0	1	1
Fahud power station (One F6 GT)	0	0	1	1
Yibal power station (Two F6 + three Avon GTs)	0	0	5	5
Lekhwair power station (Two F6 GTs)	0	0	2	2
Hubara booster station (Seven turbine compressors)	7	0	0	7
Sahma booster station (Eight turbine compressors)	8	0	0	8
Nahada booster station (Six turbine compressors)	6	0	0	6
All locations	21	0	22	43

Notes:

1. *A new6FA GT of 70 MW capacity is currently under commissioning in Marmul.*
2. *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 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.

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 not currently available. The stack emissions are not regularly monitored. Instead, the emissions rates are estimated based on empirical emission factors, as given below for gas turbines:

CO_2	: 2750 kg per tonne of gas burned
CO	: 2.7 kg per tonne of gas burned
NO_x as NO_2	: 6.7 kg per tonne of gas burned
SO_2	: 20 x S kg per tonne of gas burned
HC	: 0.47 kg per tonne of gas burned

The emission inventories for all the assets are summarized in Table 4.2 below.

Table 4.2: Emission Loads from Stacks Under Infrastructure 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)
Marmul power station (Three F5 GTs)	400.80	NA	947.9	0.0	2.3	0.9	0.2
Nimr power station (Two F6 GTs)	349.20	NA	825.9	0.00	2.0	0.8	0.1
Rima power station (Two F5 GTs)	246.62	NA	583.3	0.00	1.4	0.6	0.1
Hubara power station (Three F6 GTs)	558.00	NA	1319.7	Negligible	3.2	1.3	0.2
Suwaihat power station (one F6 GT)	154.00	NA	364.2	Negligible	0.9	0.4	0.1
Saih Rawl power station (Two F6 GTs)	470.0	Not reported	1111.6	0.0	2.7	1.1	0.2
Saih Nihayda power station (One F6 GT)	178.0	NA	421.0	0.0	1.0	0.4	0.1
Fahud power station (One F6 GT)	191.00	NA	499.0	0.5	1.2	0.1	0.1
Yibal power station (Two F6 + three Avon GTs)	438.67	NA	1290.8	0.4	3.1	1.3	0.2
Lekhwair power station (Two F6 GTs)	357.46	NA	1494.2	0.00	3.6	1.5	0.3
Hubara booster station (Seven turbine compressors)	38.00	NA	89.9	Negligible	0.2	0.1	0.0
Sahma booster station (Eight turbine compressors)	12.00	NA	28.4	Negligible	0.1	0.0	0.0
Nahada booster station (Six turbine compressors)	100.00	NA	261.3	0.3	0.6	0.0	0.0
All locations	3493.75	0	9237.2	1.2	22.3	8.5	1.6

Note: For the cells marked NA, data are not available and not reported. Details are given in Appendix 2.

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 are dependent 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.

SO_2 emissions are dependent on the sulphur content (or H_2S concentration) in the fuel gas. The gas used in the power plants and booster stations is the dry sweet gas with H_2S concentration is negligible. Hence SO_2 emissions will not be significant. It may be noted that 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 existing combustion systems. The new 6FA gas turbine currently under commissioning in the Marmul power plant is however provided with dry low NO_x combustion system, which limits the NO_x emissions to <25 ppmv.

4.2.3 Vent and Fugitive Emissions

The only sources venting emissions into air are the offshore tankers berthing at the MAF terminal into which the hydrocarbon liquids are loaded. During the loading process, the hydrocarbon vapours remaining in the storage space are displaced by the incoming liquid. The tankers are provided with vents to release these vapours into the atmosphere. Venting from tankers is almost continuous. The crude oil and long residue storage tanks in the MAF terminal are of floating roof design. The SOGL system is provided with emergency vents at some locations. No emissions are expected from these vents under normal conditions.

There are several sources of fugitive air emissions in the MOL and SOGL systems. The most significant are the crude oil and long residue storage tanks located in MAF tank farm, all of which are of floating roof design. Compared to fixed roof tanks, fugitive emissions from floating roof tanks are less. The other sources of fugitive emissions are the numerous valves, pipe connections and rotating shafts. The fugitive emissions from all sources are basically hydrocarbon vapours.

The vent and fugitive hydrocarbon vapour emissions are estimated based on Tier 3 emission factors given in the Shell group specification EP 95-0377 on "Quantifying Atmospheric Emissions" (*Reference 3*):

Loading tankers	: 118 grams per tonne of throughput
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
Pipe components – light crude	: 1.41 kg per year per component
Pipe components – heavy crude	: 0.303 kg per year per component
Pipe components – gas	: 3.86 kg per year per component

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. Based on the above, the vent and fugitive hydrocarbon emissions from these sources of infrastructure asset are estimated as given in Table 4.3 below.

Table 4.3: Vent and Fugitive Emissions of Hydrocarbon Vapours from Infrastructure Asset Sources

Sources and Location	Quantity (Tonnes per Year)
Vent emissions from offshore tankers in MAF bay	4737.7
Fugitive emissions from storage tanks in MAF tank farm	9.4
Fugitive emissions from MOL system	1.4
Fugitive emissions from SOGL system	3.9
Asset total	4752.4

Notes:

1. Vent and fugitive emissions from offshore tankers and storage tanks are estimated based on 110,000 tpd throughput
2. Fugitive emissions from MOL and SOGL systems are estimated assuming conservatively that there are 1000 pipe connector components for each system.
3. About 85% of these hydrocarbons are assumed to be methane and the rest non-metahnes.

4.2.4 Mobile Source Emissions

Road vehicles used by the asset personnel for the transportation of materials and men within their areas of operation and ships used for the export of crude oil from the MAF terminal constitute the mobile air emission sources. The types of road 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. The crude cargo ships use diesel or light / heavy gas oil fired engines.

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 3).* 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, and common emission factors for all categories of marine vessels as shown below:

	Road Vehicles	**Marine Vessels**
CO_2	3200 kg per tonne of fuel	3200 kg per tonne of fuel
CO	27 kg per tonne of fuel	8 kg per tonne of fuel
NO_x as NO_2	38 kg per tonne of fuel	59 kg per tonne of fuel
SO_2	8 kg per tonne of fuel	8 kg per tonne of fuel
HC	5.6 kg per tonne of fuel	2.7kg per tonne of fuel

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 data for total emissions from mobile sources in the asset are not available.

4.3 Liquid Effluents

4.3.1 Overview

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

- Residual produced water from MAF tank farm (continuous)
- Ballast water from crude export ships (intermittent)
- Hydrotest water from new pipelines (intermittent)
- Vessel and floor washings in power stations and MAF tank farm (intermittent)
- Leaks and spills of oils and chemicals (accidental)

The only continuous liquid effluent stream is the de-oiled produced water separated from the crude in the storage tanks in the MAF tank farm. Another major liquid effluent, though intermittent is the ballast water discharged by the crude export ships at the time of loading.

With respect to the other intermittent effluents, hydrotest water refers to the wastewater that is finally disposed after the hydrotesting of new pipelines. Since laying of any new pipelines for MOL or SOGL systems is considered as a major

project for which a separate EIA study will be considered, this effluent is not considered here. With respect to vessel and floor washings in power stations and MAF tank farm, they occur very rarely.

The oil and chemical leaks and spills occur only accidentally due to pipeline failure, storage tank failure and accidents involving offshore facilities. The leaks and spills usually result in the contamination of soil or marine waters. There 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 4.4 below, along with a brief description of their nature.

Table 4.4: Liquid Effluents Generated by Infrastructure Asset Activities

Liquid Effluent	Source of Generation	Quantity Generated	Typical Nature and Characteristics of Raw Effluent
Residual produced water (Continuous)	MAF tank farm	460 m^3/d	High dissolved inorganic salts, traces of oil and virtually free of organic matter
Ballast water (Intermittent)	Crude export ships	378,720 m^3 /d (average)	May contain traces of hydrocarbons, normally <15 mg/L
Hydrotest water (Intermittent)	New MOL or SOGL pipeline sections under testing	Very infrequent	May contain traces of hydrocarbons
Floor and vessel washings (Intermittent)	Process tanks and vessels	Very infrequent	Occasional washings with traces of oil and detergents,

4.3.3 Effluent Treatment and Disposal

The crude oil received at the MAF tank farm contains some residual produced water. This is settled in the storage tanks in MAF tank farm. The settled water from the tank bottom is pumped to an effluent treatment plant for de-oiling and then for disposal into the sea through a marine outfall. In the effluent treatment plant, the oil removal is achieved by using corrugated plate interceptor separators. The design capacity of the effluent treatment plant is 30m^3/h. The plant consists of two raw effluent holding tanks of 400 m^3 capacity each for oily water, one separation tank of 400 m^3 capacity, three CPI separators of 100 m^3 capacity each, and three treated effluent holding basins of 480 m^3 capacity each. The effluent after de-oiling will contain about 50 mg/L or less of oil-in-water. From the treated effluent holding tanks, the de-oiled production

water is released into the sea through a marine outfall. The oil separated in the effluent treatment plant is collected in a sump for recovery.

The Omani marine disposal standards (MD7/84) require that the oil and grease content in the effluent shall be <5 mg/L. It is understood that PDO has an exemption from MRME&WR to discharge effluents with up to 15 mg/L oil and grease content.

Hydrotesting is performed for only the new pipelines. The standard practice in PDO for the disposal of hydrotest water is as following. If the hydrotest water quality meets the discharge standards (refer Table 2.7), it will be drained into the desert. If the volume is higher, then it will be sent to the production station for disposal along with the produced water.

With respect to vessel and floor washings in the power plants and tank farm, they occur very rarely. In the case of tank farm, the washings will be routed to the effluent treatment plant for treatment and disposal. In the case of power plant sites, if there is any suspicion of oil or chemical contamination, the washings will be taken to the nearest production station for treatment. Otherwise, they will be discharged on land without any treatment.

4.4 Solid Wastes

In PDO, the solid wastes are classified into broad categories as non-hazardous and hazardous. The sub-groups in each category are as below:

Non-hazardous wastes: domestic and office waste; water based drilling mud and cuttings; non-hazardous industrial waste

Hazardous wastes: oil based mud and cuttings; sewage sludge; waste lubricants; oily sludges; 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)

From the activities performed by the infrastructure asset, only a few types of wastes are generated. Their sources of generation, quantities and methods of disposal are shown in Table 4.5.

Table 4.5: Solid Wastes Generated by Infrastructure Asset Activities

Waste Type	Source of Generation	Quantity Generated per Year	Method of Disposal
Oil sludge	MAF tank farm	~ 20-40 m^3	Temporarily stored in the sludge pit and then sent to Fahud land farm for bio-remediation.
Pigging waste	MOL and SOGL pipeline cleaning	Unknown	Sent to the nearest PDO Waste Management Centre in PDO for landfilling
Waste lubricant oils	Power stations, substations, booster stations and block valve stations	Unknown	Sent to the nearest PDO Production Station or Waste Management Centre for storage in the oil saver pit for recycling
Oily sands	Leaks and spills along MOL	Unknown	Sent to the nearest PDO land farm for bio-remediation.
Waste transformer cooling fluids	Substations	Very rare	If PCB free (<50ppm), drained and sent to the nearest oil saver pit for recycle; otherwise, sent to the nearest PDO Waste Management Centre for final disposal by a specialist

4.5 Noise

The major noise generating sources are present mainly in the power stations, booster stations, substations and offshore facilities. 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.

The mobile sources include the road transportation vehicles such as cars, vans, buses and trucks used by the infrastructure asset staff, and the marine engines used for offshore loading and unloading operations.

Due to the presence of a large number of noise generating sources in process areas (such as power stations and booster stations), it is not possible to measure the noise level at the source point for each 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. No information is available on noise levels for mobile sources.

All the major noise generating equipment such as pumps, motors, compressors, burners etc. are provided with standard noise control systems such as 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

While water leaks and spills do not lead to any environmental consequences, they are reported as a matter of water conservation issue.

For the current year (2002), the leaks and spills are reported by the infrastructure asset are summarized in Table 4.6.

Table 4.6: Accidental Leaks and Spills Reported by Infrastructure Asset

Description	Incidents Reported in 2002 (Jan-Sep)		
	Oil Leaks and Spills	Chemical Leaks and Spills	Water Leaks and Spills
Total number of incidents	7	0	0
Number of spills into wadis (Interior areas)	0	0	0
Number of spills into the sea (MAF bay)	0	0	0
Total volume leaked / spilled (m^3)	25.5	0	0
Total land area impacted (m^2)	375	0	0
Total quantity of soil contaminated (t)	Data not available	0	Not applicable

5 ENVIRONMENTAL SETTING

5.1 Introduction

The infrastructure asset is one of the eight technical service providers in PDO. The infrastructure consists of three departments *viz.*, pipelines department (TTP), power systems department (TTE) and terminal operations department (TTT). The TTP department operates and maintains the MOL system, which exports the stabilised crude and the condensates produced from the interior locations (southern and central Oman) to the north coast. It also operates and maintains the SOGL system, which delivers dry sweet gas from central Oman to south Oman. The TTE department operates and maintains ten power stations in all production assets and distributes the power throughout its concession area. The TTT department operates and maintains crude oil storage and offshore export facilities at Mina Al Fahal (MAF) on the northern coast. The schematic maps showing the MOL and SOGL pipelines routes, booster station locations, power plant locations, substation locations, electrical transmission line routes and MAF terminal location are presented in Chapter 3.

As seen from these maps, the areas of operation of the infrastructure asset stretch from Marmul in southern Oman to Fahud in central Oman to MAF on the northern coast. From an environmental viewpoint, terrestrial environment is of interest in the interior areas and marine environment is of interest in MAF.

The detailed description of environment throughout the PDO's concession area is given in the individual environmental impacts assessment reports prepared for all the production assets *(Reference 4)*. In this chapter, a brief description of the environment in the interior and coastal areas of operation of infrastructure asset is presented.

5.2 Topography

The topographical features from the southernmost part of the concession area (Marmul) to the northern coast (MAF) show three distinct zones as below:

- Desert plains with very low population within most of the concession area
- Low to medium altitude hills over the southernmost and northernmost parts
- A small coastal plain surrounded by urban population

Most of the concession area falls under central and south-central Oman and is characterised by flat gravel desert plains with occasional rocky outcrops interspersed

with a few wadi channels. The altitude in the plains is mostly in the range of 100-150m above the mean sea level. The desert plains are very thinly populated.

Sand dunes occur over the western parts of central Oman forming a part of Rub Al Khali (the empty quarter). A large area constituting the southern part of Yibal asset and northwest part of Qarn Alam asset fall under Umm as Samim, the largest sabka (natural salt pan) of the Arabian Peninsula.

The natural vegetation is composed of desert plants and grasses, and is restricted to the wadi plains only. Among all the assets, Nimr and Marmul assets have relatively denser vegetation. Wadi Raunib in Rima is one of the most significant naturally vegetated areas. Rahab Farms in Marmul asset are the most significant cultivated vegetated areas within the concession area.

Hills of low to medium altitude are encountered over the southernmost and northernmost parts of the concession area. In the south, from Thuleilat (Marmul asset) onward, the altitude rises steeply up to 600m above the men sea level into Dhofar mountains. Similarly, in the north from Fahud onward, several hills up from 300-600m altitude are encountered. At the high point of MOL near Izki, the altitude is about 670 m above the mean sea level.

The MAF terminal area located within the MAF industrial area on the shore of MAF bay and surrounded by hills, rising to 214 m altitude above the sea level on the eastern boundary. There are large urban settlements adjacent to MAF area to the northwest.

5.3 Geology and Soil

The geology of most of the PDO's concession area comprises of mainly limestone with shale, dolomite and sandstone. The central plains mostly consist of flat limestones of oligocene and miocene ages to mid-tertiary. The limestone plains are covered sparsely with alluvial gravel or aeolian sand. The hills from Fahud to MAF along the pipeline routes are formed from sedimentary carbonate strata comprising limestones, sandstones and dolomites dating from the Permian to the late Cretaceous. Toward the north, the low hills are comprised of tertiary sedimentary sandstones, limestones and conglomerates overlying igneous and metamorphic rocks formed under ocean sediments in the Mezozoic period. The rock types include gabbros, Hartsburgites, basalts and locally pillow larva.

The simplified stratigraphy map of Oman is shown in Figure 5.1.

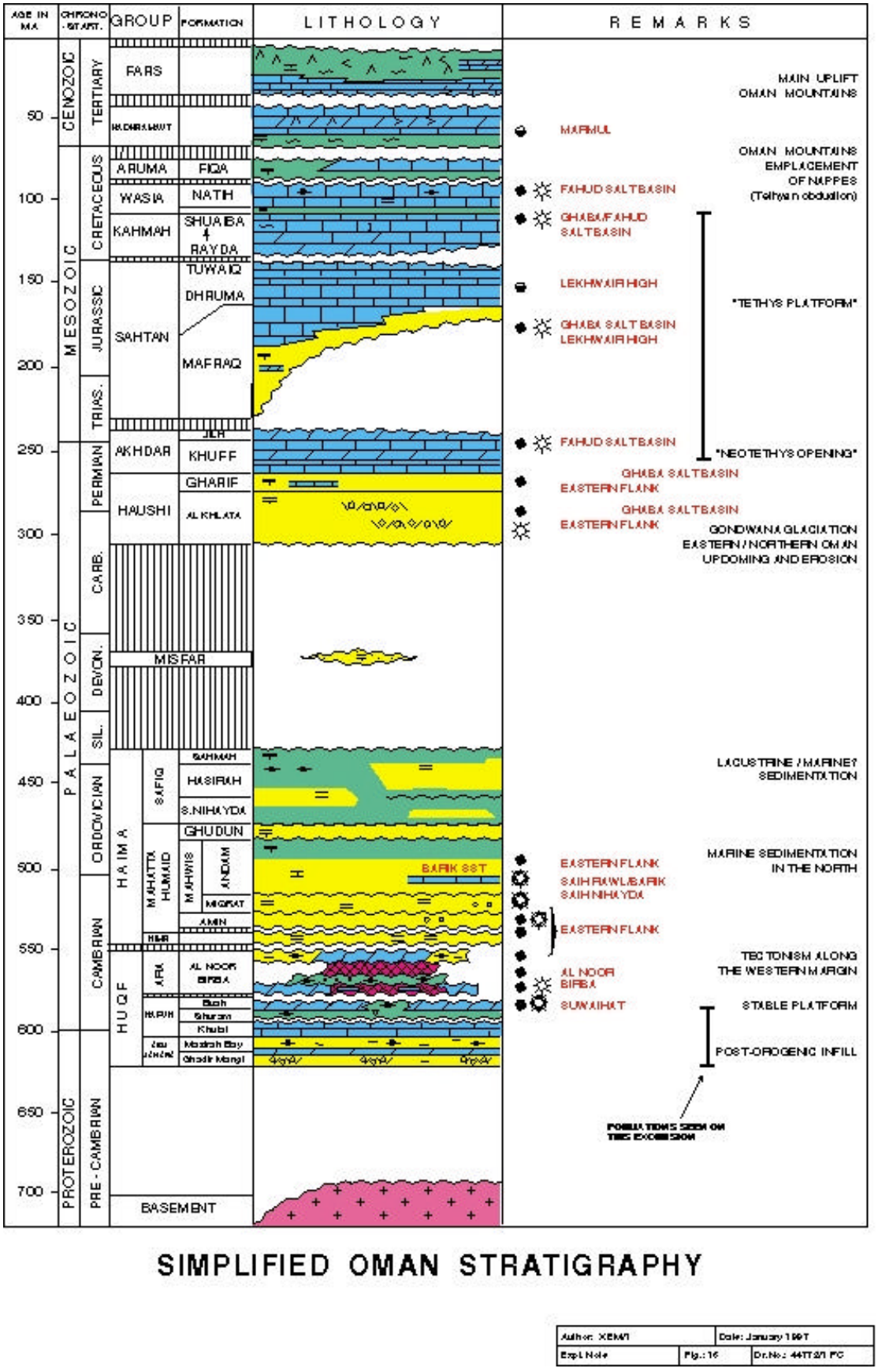

Figure 5.1: Simplified Stratigraphy Map of Oman

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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 5.2.

5.4 Hydrogeology and Groundwater Quality

The tertiary aquifers are the potentially exploitable groundwater resources in PDO's concession area. Tertiary aquifer systems in Oman are recharged from the flow from the Oman mountains to the north and Dhofar mountains to the south. Surface hydrology in this area is of no significance due to very scanty rainfall. The shallow aquifer systems consists of the Fars formations (0-150 m depth), Dammam formations (150-200 m depth), Rus formations (200-300 m depth) and Um er Raduma (UeR) formations (300-600 m depth).

Fars formations are basically formed by sedimentary carbonates. Groundwater availability in these formations is not significant in most of the assets. Dammam formations are primarily limestone beds and have very limited groundwater potential due to their reduced thickness. Rus formations are formed by gypsum anhydrite beds. They have significant groundwater potential in some assets. This aquifer appears to be confined at some places and connected with the UeR aquifer at other places.

UeR aquifer is the main prolific aquifer in the area. UeR formations are sub-divided into lower, middle and upper layers. The upper and middle layers are composed of limestone and dolomite, while the lower layers are composed of thin impermeable shale and marl. UeR aquifer is recharged in Dhofar mountains in the south during monsoon from July to September. The groundwater is estimated to travel at a velocity of 10 m per year.

The mineral content in UeR water increases as it travels from south to north. Within the entire PDO concession area, only Marmul asset has groundwater that is potable without any pre-treatment. In all other assets the UeR water is very saline. The total dissolved solids content ranges from 1000 mg/L to 150,000 mg/L. The groundwater salinity map of the region is shown in Figure 5.3.

The historical well yield and water quality data collected from various water supply wells in the concession area have not shown any significant change over most parts of the concession area.

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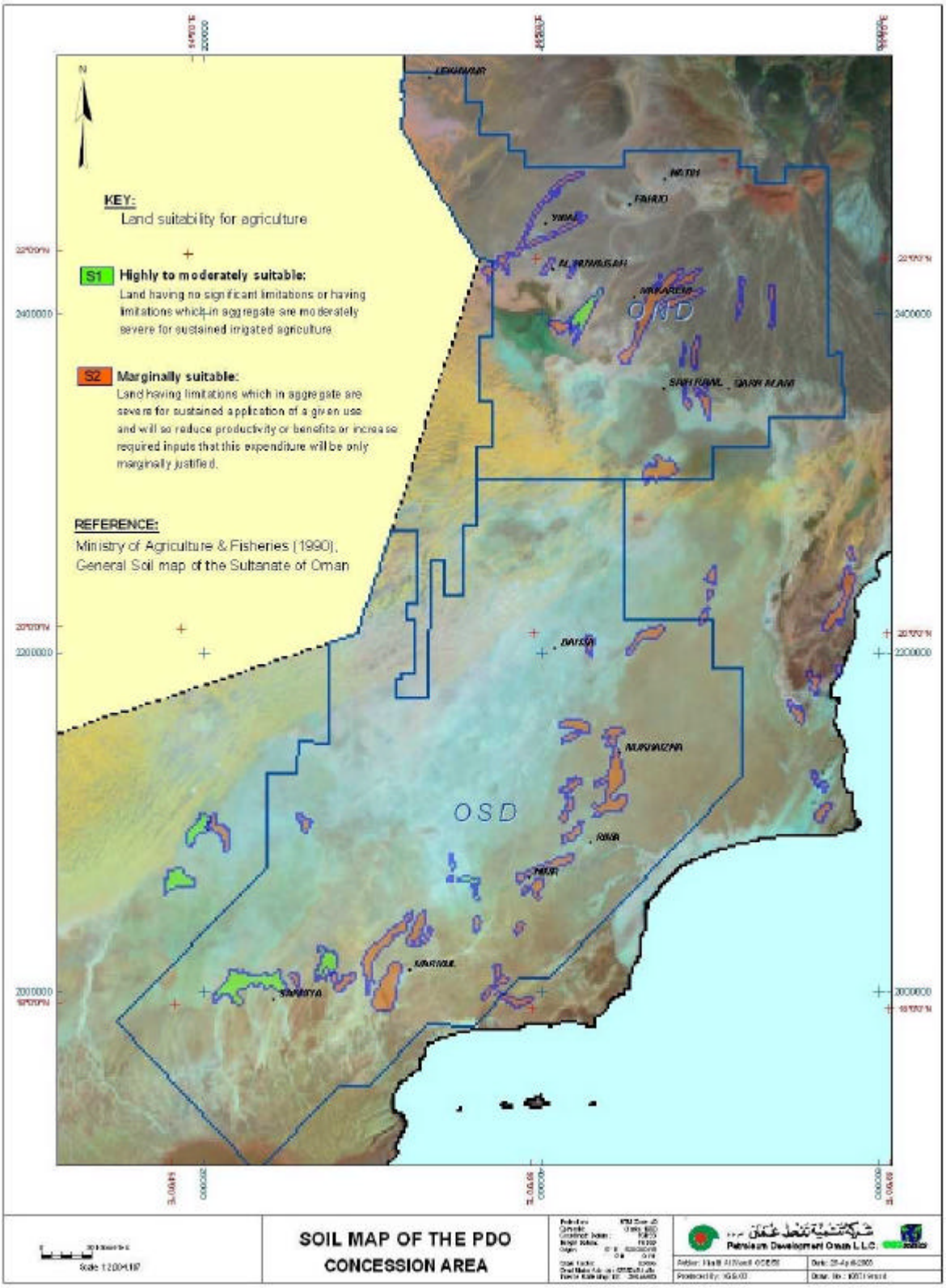

Figure 5.2: Soil Map of PDO's Concession Area

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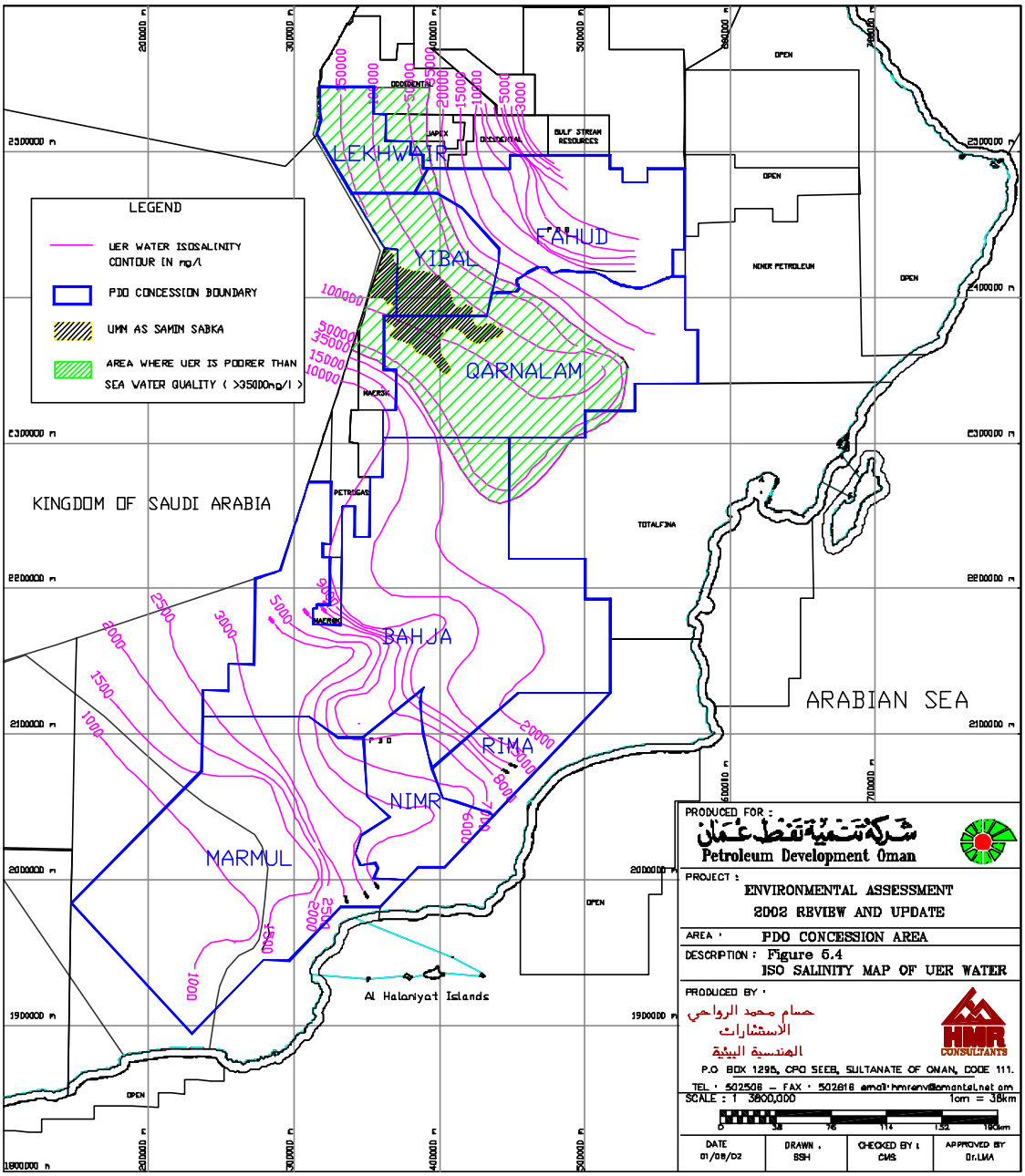

Figure 5.3: Iso-salinity Map of UeR Aquifer in Oman

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5.5 Climate

PDO's concession area as whole has an arid climate, with very low rainfall. The climate is typically hot with significant fluctuations between maximum and minimum temperatures. The hottest temperatures occur throughout summer months (May – August) and cooler temperatures occur during the winter months (November-February). The mean monthly temperatures range from around 20°C in December/ January (with mean minimum of about 12°C and mean maximum of about 28°C) to about 35°C in July (with mean minimum of about 24°C and mean maximum of about 45°C). The maximum absolute temperature will be as high as 50°C and the minimum absolute temperature will be as low as 5°C.

Rainfall in this region is scanty and is highly variable in time and space. Historical data give an average of 36 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.

Wind speeds vary considerably from calm to strong gusts. The dominant wind direction is from the south with an average wind speed of 8 knots.

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. These 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 emissions 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 sometimes. 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 stations, 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 Terrestrial Ecology

5.8.1 Flora

The natural flora in most of the concession area are composed of desert plants and grasses, and trees are rarely seen. The distribution pattern of vegetation is dependent on the water drainage pattern and the presence of adequate sand or fissures in the bedrock for plant establishment. With rainfall being very scanty and erratic, the fog moisture largely influences the vegetation in this region. The species diversity and density somewhat improves in the highlands in the southern and northern parts of the concession area. Coastal communities are encountered only in MAF.

The flora found in the central and southern plains in the concession area are typical to central Oman. Larger species such as *Prosopis cineraria* are present in low-lying sumps with deeper sand and *Acacia ehrenbergiana* is abundant. This region supports no trees or bushes, but characteristic forbs such as *Fagonia ovalifolia*, and species of *Cornulacea* and *Salsola* cover very large areas. The vegetation cover is relatively denser in the wadis with frequent grass tussocks of *Stipagrostic* sp., *Cymbogon schoenathus* and *Panicum turgidum* and includes scattered *Acacia ehrenbergiana* bushes. The wadis provide more forage for both wild and domesticated grazing animals due to plant height and coverage and the presence of grasses. Low-lying perennial shrubs cover the undeveloped areas within the concession area and serve as pastor grounds for local livestock, mostly camels and goats.

In the highlands, halophytes such as *Zygophyllum* decrease in abundance and the shrub communities become more diverse with additional species such as *Zyziphus spina-christi*, *Euphorbia larica*, *Fagonia sp.*, *Dyerophytum indicum*, *Peroploca aphylla*, *Calotropis procera*, *Tephrosia* sp. and *Solanum*. Grass species increase in

cover. With high spate flows, there is often little vegetation in the main wadi channels.

5.8.2 Fauna

Due to the sparse vegetal cover, fauna are not very abundant and diverse in this region. However several fauna groups including mammals, birds and reptiles are seen. Large mammalian species known to inhabit the area include the Arabian Gazelle (*Gazelle gazelle*), the Rhim Gazelle (*Gazella subgutturosa marica*), the Nubian Ibex (*Capra nubiana*). These animals are currently listed on the IUCN World Red List and the Regional Red List threat categories. The Arabian Oryx is seen in Mukhaizna field in Bahja asset. Mukhaizna field is located just outside the buffer zone of the Arabian Oryx Nature Reserve. Ruepell's Sand Fox and the Cape Hare are also thought to inhabit the some areas and burrow in earthen mounds associated with well development activities. A few smaller mammals, mostly gerbils, jirds and jerboas are also known be present in the vegetated areas.

Bird surveys revealed about 40 different species with a half of them breeding in this region. There are no regional Red Data Lists for birds and their threatened status in Oman is yet to be established. Distribution records for reptiles in the area indicate that 30 species inhabit the area. Both the monitor lizard (*Varanus griseus*) and the spiny tailed lizard (*Uromastyx thomasi*) are common throughout the region. All of the animal species recorded in the concession area are typical of the central plains.

5.8.3 Wildlife Sanctuaries

Two of the important wildlife sanctuaries in Oman namely the Arabian Oryx Nature Reserve and the Jebel Samhan Nature Reserve are in the proximity of in PDO concession areas. A small portion of the buffer zone of the Arabian Oryx Nature Reserve falls under Bahja and Nimr assets. The Jebel Samhan Nature Reserve in the Dhofar governorate is to the south of Marmul asset.

- **Arabian Oryx Nature Reserve**

An area of 24785.4 km^2 in Al Wusta Region was proclaimed in 1994 as the Arabian Oryx Nature Reserve and subsequently declared a World Heritage Site by the United Nations Scientific and Cultural Organisation. 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. The special protection zone is the core zone of the reserve that provides a safe haven for the Arabian Oryx and thus ensures their longterm survival in the wild of Oman. The objective is to manage this zone to keep human disturbance and competition from domestic stock to a minimum. The controlled use 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. The buffer zone encompasses further sites of interest, but with control of activities in order to help protect the inner zones. The utility zone is demarcated for locating the essential infrastructure facilities of the reserve. The special use zone constitutes the areas of land where a land use agreement has been reached with the government (military authorities) and private parties. The map of the Arabian Oryx Nature Reserve is shown in Figure 5.4.

- **Jebel Samhan Nature Reserve**

The Jebel Samhan reserve covering an area of 4500 km^2, contains a wilderness of limestone highlands rising steeply from coastal plain and sloping gently toward north. The deep cayopns with water pools and many plant species provide an ideal habitat for Arabian Leopard, Nubian Ibex, Arabian Gazelle, Striped Hyaenas, Wild Cats, Foxes and Wolves. The reserve has typical monsoon vegetation and is the only Arabian location of African tree Papea capensis. The reserve has a protected core zone where minimal human activity is permitted, surrounded by multiple use zone. PDO currently does not operate in any part of the reserve.

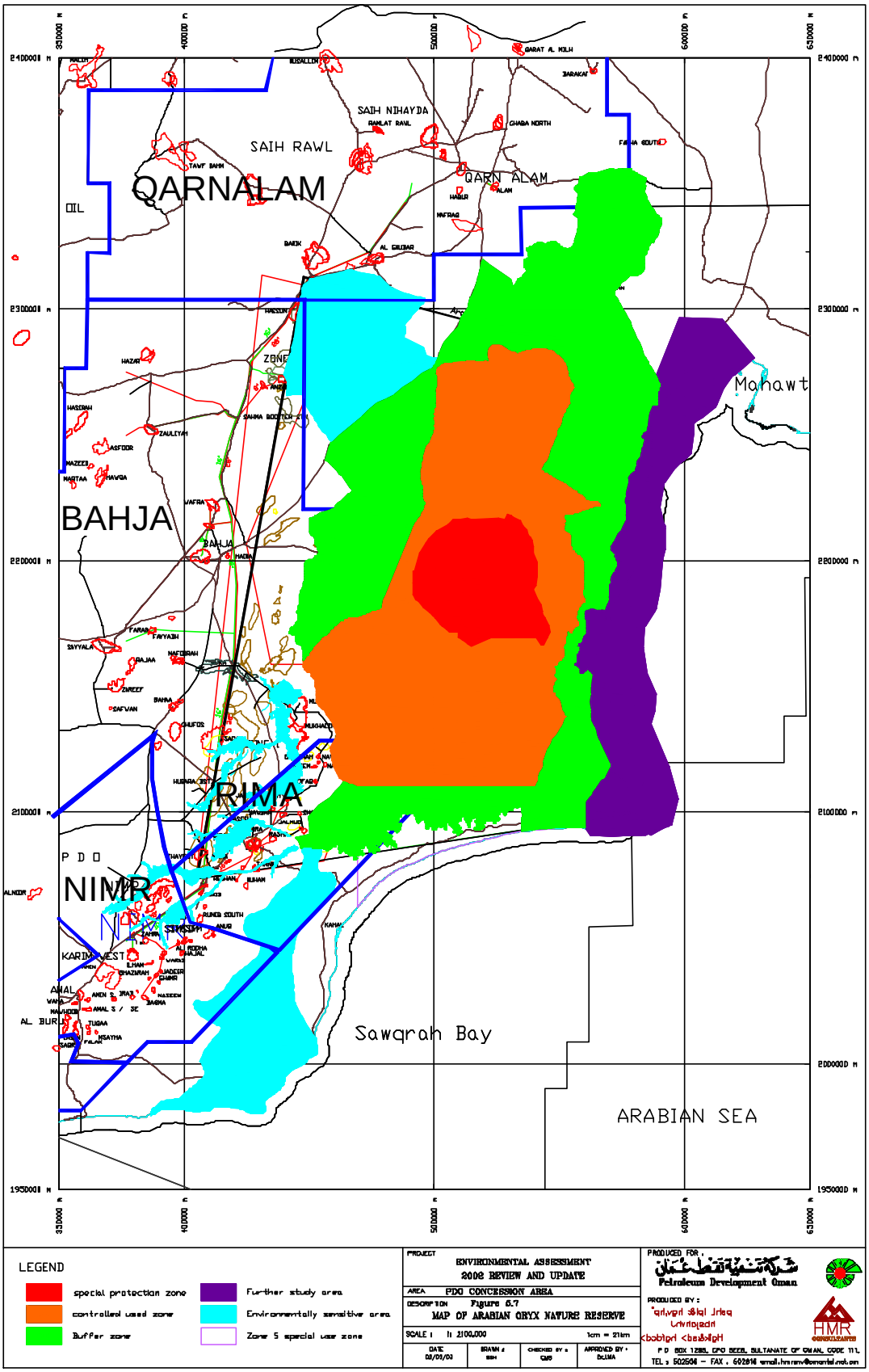

Figure 5.4: Map of Arabian Oryx Nature Reserve

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5.9 Marine Ecology

5.9.1 General

The beaches along the coastline are composed primarily of fine sand derived from the neighbouring land with shallow areas extending up to 2 km offshore. The shoreline along the east coast of Oman is known to be mobile with a generally north west drift of sediment along the coastline. Several inlets along the coastline provide important habitats for coastal flora, birds and juvenile fish populations. The Dimaniyat Island Nature Reserve is an archipelago of nine islands approximately 16km off the coastline. These islands provide a protected habitat for a diverse population of birds, marine, and terrestrial fauna.

5.9.2 Seawater Quality

The seawater temperature at MAF ranges from 25°C in winter (February and March) up to 39°C in summer (June and July). The salinity ranges from 35 to 40 parts per thousand. Recent studies did not indicate at gross contamination of the seawater in MAF bay. Earlier studies indicate high levels of phytoplankton chlorophyll in winter/spring dominated by diatom blooms (e.g. *Coscinodiscus, Skeletonema*). One characteristic of this region is the occurrence of red tides dominated by dinoflagellates (e.g. *Ceratium, Noctiluca*). During late summer and early autumn, nutrient enrichment produces blooms, which means that there is continuously high primary productivity and rich herbivorous zooplankton communities available (e.g. copepods). These in turn support large stocks of sardines, anchovies and larger pelagics.

5.9.3 Sediment Flora and Fauna

The coast has unstable sand substrates, which produce high turbidity leading to poor underwater light penetration. Such turbid conditions limit sea flora populations, such as sea grasses. The direct grazers on sea grasses include the green turtle *Chelonia mydas*, parrot fish and sea urchins. In Oman, there are four species of sea grass, the smaller *Halodule uninervis* and *Halophila ovalis* and the larger *Thalassodendron ciliatum* and *Syringodium isoetifolium* which form limited beds. In shallow water sediments along the coast, the typical infauna found include polychaetes, snails, olive shells, cowries, sand dollars and heart urchins. Very little is known about the deeper subtidal infauna of coastal areas of the Gulf of Oman. A variety of benthic macrofauna including polychaetes, molluscs, echinoderms can be expected to inhabit the deeper coastal zone.

Recent studies in MAF bay showed generally low levels of hydrocarbons and heavy metals in intertidal beach samples, with the exception of vanadium. The subtidal sediment samples in general indicated no contaminated. The sediment samples taken from single buoy mooring locations were found to contain high levels of copper and tributyl tin, possibly due to the use of antifouling paints.

5.9.4 Fish Communities

The predominant pelagic species include the most important commercial fish in Oman, viz., the kingfish (*Scomberomorus commerson*), tunas and mackerel (*Scombridae*), the scad (*Decapterus russelli, Sardinella longiceps* and *Selar crumenophthalamus*) and others in the 20 to 100 m depth range. Other commercially important demersal species here include croakers (*Sciaenidae*), snappers (*Lutjanidae*), jacks (*Carangidae*), barracudas (*Sphyraenidae*), and emperors (*Lethrinidae*).

5.9.5 Turtles

There are five kinds of marine turtles found off the coasts of Oman; the Green Turtle *Chelonia mydas*, the Hawksbill *Eretmochelys imbricata*, the Olive Ridley *Lepidochelys olivacea*, the Loggerhead *Caretta caretta* and the Leatherback Turtle *Dermochelys coriaca*. The Green Turtle and the Hawksbill are regarded as "endangered". Both endangered species use the Dimaniyat Islands as a nesting ground.

5.9.6 Cetaceans

The toothed cetaceans and the Baleen Cetaceans are both found in the waters of Oman. The toothed cetaceans (suborder Odontoceti) are a more varied group of cetaceans and include the sperm whale *Physeter* spp. and dolphins and porpoises. The species include sperm whale (*Physeter macrocephalus),* dwarf sperm whale (*Kogia simus),* Cuviers beaked whale (*Ziphius caviostris),* false killer whale (*Pseudorca crassidens),* killer whale (*Orcinus orca),* indo-pacific humpback dolphin (*Sousa chinensis),* Risso's dolphin (G*rampus griseus),* bottlenose dolphin (*Tursiops truncatus),* pantropical dolphin (S*tenella attenuata),* spotted dolphin, spinner dolphin (*Stenella longirostris) and* common dolphin (*Delphinus delphis).*

The baleen whales (suborder *Mysticeti*) filter feed on zooplankton using comb-like plates of baleen or "whalebone" with which they sieve their prey from large volumes of water. Oman's baleen cetaceans are all large whales and belong to one family, the Balaenopteridae. They include humpback whale (*Megaptera novaeangliae),* Bryde's

whale (*Balaenoptera edeni),* sei whale (*Balaenoptera borealis),* minke whale (*Balaenoptera acutorostrata),* blue whale (*balaenoptera musculus)* and fin whale (*Balaenoptera physalus).*

5.9.7 Coral Reefs

Most of the coast has unstable, sandy substrates with often high turbidity, making it largely unsuitable for coral growth. The rocky promontory of Ra's Sawadi and the Dimaniyat Islands located offshore are the only areas in the region with good coral development. The Dimaniyat Islands are situated 16 km offshore in clear, oligotrophic water and substantial patch and fringing reefs are found along leeward and protected shores of the nine islands in the chain. Abundant coral growth is found to 20 m depth. There are massive *Porites* colonies, *Acropora* colonies and large stands of *Pocillopora* on rubble substrates. The reefs here provide habitat and feeding ground for many fish. With the importance of these islands to nesting turtles (the hawksbill *Eretmochelys imbricata* and green turtle *Chelonia mydas*) and seabirds, the area was declared as the "Dimaniyat Islands Nature Reserve" in 1996 (RD 23/96).

With specific reference to MAF bay, the recent studies has indicated hard corals around the Fahal Island with about 45% cover. Soft corals are seen in the West Headland and East Headland sites with about 20% cover and with low cover (<5%) in Fahal Island. The common genera seen at all sites were *Sinularia* and *Sarcophyton* with occasional records of species of *Cladiella* and *Dedronephthya*. The overall conclusion from the coral reef survey is that coral communities in MAF have not significantly changed over the past five years.

5.10 Human Settlements

The human population density within PDO's concession area (interior areas) is extremely low and is to the order of 26 persons per 100 km^2. Within the total concession area of 114,000 km^2, the total current population is of the order of 30,000. The majority are the PDO and contractor staff living in the various accommodation camps located in the assets, and they number about 20,000 currently.

As for the civilian populations, the main populated areas are in the Wilayats of Haima (in Bahja asset) and Adam (in Fahud asset). Wilayat of Haima is in the Jiddat Al Harasiis plateau and has an estimated total civilian population of about 2500 persons. Wilayat of Adam has a total population of 8350 persons. In addition to the above, relatively small settlements can be found near to major wadis. These settlements are receiving various benefits from the PDO including water and power.

The Bedouin settlements are found to be mostly in the central and western parts of the PDO's concession area mostly around wadis. Particularly, Fahud, Nimr and Bahja assets are known to have more of Bedouin populations. The central plateau region, known as Jiddat al-Harassis is historically characterised by migratory populations due to the harsh climate and lack of freshwater sources. The principal inhabitants in Jiddat al-Harassis are the Harsoosis tribe. Historically, Harsoosis sustained on migratory pastoralism and adopted a nomadic lifestyle to cope with the harsh water-starved and desolate environmental conditions. Presently however, with year-round water supply provided by PDO and the government, Harsoosis have taken up permanent settlement and are no longer nomadic. A recent socio-economic survey indicates that there are an estimated 3,000 to 3,500 members of the Harsoosis residing within the central plateau.

In contrast, the human populations within MAF terminal area and the surrounding areas are typically urban populations. These areas form a major part of the Muscat Municipal areas. The main populated area near MAF terminal is the PDO's residential camp in Ras Al Hamra, housing about 4000 persons. The other major populated areas are Qurum Heights (about 1 km away) and Darsait (about 4 km away).

5.11 Archeological, Cultural and Recreation Resources

There are no forts, ruins or other archeological declared sites in PDO concession area. However, abundant marine fossils are present in Jabal Fahud and Natih areas (Fahud asset). The significant cultural site within PDO's concession area include the old city of Adam in the Wilayat of Adam (Fahud asset), which dates back to pre-Islamic times. Adam is also the birthplace of Imam Ahmad bin Said, the founder of the Al Busaid dynasty. Within the Bahja asset, there are several traditional weavers. There is an ancient cemetery within the Nimr asset on the southeastern end of the Prosopis woodland in Wadi Ghubbarah.

Sand dunes in the western and northern part of the Lekhwair asset qualify as areas of exceptional natural beauty. The landscape is peaceful and this area is used as recreational area during the winter months. Umm as Samim, the largest sabkha of the Arabian Peninsula, and one of the largest in the world is also an area of visual interest in Qarn Alam asset. The Prosopis woodland in Al Ghubbarah and the eroded limestone hills with small caves and rock overhangs in Wadi Rawnab in the Nimr asset are also considered areas of visual interest. The dramatically sculptured shapes of the limestone hills south of Shalim in the Marmul asset are also considered as a major visual amenity. On the coast, the MAF bay and the beaches are of significant recreational value particularly for the PDO staff.

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 3.*

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 4*. 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 socio-economic and socio-cultural impacts accrue from PDO's production activities. Infrastructure asset, as a key service provider to the production assets shall be credited with a proportional share of these beneficial impacts. These beneficial impacts outweigh the adverse impacts, which are discussed in the subsequent sections. The major 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. PDO accounts for over 90% of the total crude oil produced in Oman. Thus the economic benefits from PDO activities are quite significant.

- Employment

PDO currently employs over 4000 permanent staff and 16000 contractor staff. In addition, a large number of persons, including local populations in the interiors are also provided indirect employment to provide a number of supporting services. In the interior areas, 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

PDO provides and shares several amenities developed by PDO all over its concession area with the local populations. 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 camps and the contractor camps is significantly vegetated with trees, shrubs and lawns. In addition, PDO has developed a large farm in Rahab under "Desert Agriculture Project" over an area of over 100 ha. 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 (gas)
- Land take

Potential Environmental Effects
- Depletion of natural mineral resources (gas reserves)
- Claim of local assets

- **Depletion of Mineral Resources**

For power generation and booster plants, the infrastructure asset consumes annually about 1275 million Sm^3 of sweet gas. The continuous extraction of gas from the reservoir for this purpose will result in the depletion of gas reserves in Oman. However, the environmental impact and risk resulting from this activity is not discussed here since this forms the core activity of the asset.

- **Claim on Local Assets**

The local populations within the asset are very few and their demands or claim on local assets is low. 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 of significant vegetation and harsh environmental conditions. Moreover, majority of the areas through which gas / oil pipelines and electrical transmission lines pass corridors are freely accessible to local populations. The roads built by PDO are also freely accessible to local populations. The MAF terminal is located within designated industrial area.

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 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 contribute to global warming. For infrastructure asset, most of the CO_2 emissions are from the power plants and booster plants. The total CO_2 emissions from all the stacks in power plants and booster plants are of the order of 11500 tpd. Hydrocarbon emissions are mostly from the crude loading tankers and storage tanks in MAF tank farm. The average release of hydrocarbons is of the order of 13 tpd. The quantities of global warming gases release as a result of the asset activities is significant, it 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**

Air emissions are mostly from crude oil tankers, power plants and booster plants. They contain pollutants such as NO_x, SO_2, CO and unburnt hydrocarbons. The total emission loads for the asset are estimated to be about 28 tpd for NO_x, 11 tpd for CO, 15 tpd for hydrocarbons and negligible for SO_2. Emissions from the power plants and booster stations are released over a large area, they are not expected to lead to any

significant degradation of air quality. Further, most of the asset areas are uninhabited. Hydrocarbon release from the crude oil storage tanks is significant and may have an impact on the main building and the residential areas in the MAF depend on the wind direction.

For these reasons, it is reasonable to assume that the impact on ambient air quality in the asset will be medium. Additionally, 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 have to be considered medium. 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)	Medium
Significance of impact (slight / minor / localized / major / massive)	Localised
Potential risk level (low, medium, high and extreme)	High

- **Noise Pollution**

Continuous and stationary sources such as gas turbines, heaters, air compressors, flares, pumps, motors and other rotating equipment may be expected to have an adverse impact on noise levels in the environment. 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 Marine Environment

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

Environmental Hazards
- Discharge of treated effluent from MAF tank farm into the sea
- Discharge of ballast water from crude loading ships into the sea
- Accidental spillage or leakage of crude oil into the sea

Potential Environmental Effects
- Marine water pollution
- Damage to marine ecology

Only the MAF tank farm and the offshore facilities in the MAF bay will have an interface with the marine environment. A quantity of 460 m^3/d of de-oiled residual produced water is released into the sea from the tank farm area through an outfall. This effluent will have an oil-in-water content of about 15 mg/L. Further; on average 378720 m^3/d of ballast water is released into the sea from the crude export tankers. The ballast water will have an oil-in-water content of less than 15 mg/L.

Accidental oil spills and leaks from tank farm and offshore facilities into the MAF marine environment are possible. However, currently no such incidents are reported.

The Omani standards require the marine discharges to have <5 mg/L oil and grease content, while the effluents from the tank farm have currently up to 15 mg/L oil and grease content. PDO is currently permitted by MRME&WR to discharge at higher concentration, as a special case.

The marine ecology in the MAF bay area is considered to be of significant importance. The details are presented in Chapter 5. There are two beaches in this area, one exclusively used PDO staff in MAF and another used by general public in Qurum. The bay has also good eco-tourism interest. Therefore, the marine environment in MAF bay is considered to be of great environmental significance. However, recent marine ecological studies (refer Chapter 5) have not indicated any ecological damage.

Based on the above discussion, the impact on the marine ecology is assessed as below:

Impact Rating	**Marine Ecology**
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
- Accidental leakage of hydrocarbon liquids

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

- **Alteration of Land Use**

Land take for the installation of power plants, substations, booster station; laying of pipelines, power lines and access roads; and for installation of crude storage and export facilities can have adverse impacts on land use. The land taken for these purposes in the interior areas 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 laying of pipelines, power lines and access roads. This land is restored nearly to its natural condition after completion of the construction activities. The land taken for MAF tank farm falls within designated industrial area.

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 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**

Leakage of crude oil from MOL passing through the interior areas can result in land contamination. In the current so far (Jan-Sep 2002), 7 incidents of oil leaks / spills are reported by infrastructure asset. The total volume of the oil spill is reported as 25.5 m^3 and the total land area contaminated is reported as 375 m^2. The oil spill occurrence frequency is low and the extent of soil contamination is negligible compared to the total land area of the asset. However, there is a possibility of under-estimation of the oils spills and area contaminated, as in any PDO asset. Further, any major damage to the pipeline can result in substantial volume of oil leak and contaminated area.

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)	Medium
Significance of impact (slight / minor / localized / major / massive)	Localised
Potential risk level (low, medium, high and extreme)	High

6.8 Impact on Terrestrial Ecology and Wildlife

The power stations, substations and booster stations are not located in or near areas considered to be ecologically significant. Similarly, MOL and SOGL pipelines and high voltage transmissions lines do not pass through any ecologically sensitive areas. Therefore, the impact on terrestrial ecology and wildlife 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.

PDO's concession area is very thinly populated and there are no human settlements except for PDO and contractor camps. Only the MAF tank farm area and offshore facilities are located close to human populations. 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 populations across the asset.

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

Environmental Hazards
- Pipeline transport of liquid and gaseous hydrocarbons
- Bulk storage of liquid hydrocarbons in MAF tank farm
- Venting of hydrocarbon vapours from crude transport tankers

Potential Environmental Effects
- Public safety and health

Storage and pipeline transport of highly combustible liquid and gaseous hydrocarbons 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 or toxicity hazard. Specifically, the bulk storage of liquid hydrocarbons in MAF tank farm poses a greater threat to public safety and health due to the presence of large population in the MAF area.

In addition, venting of hydrocarbon vapours during loading of crude oil export tankers also poses a threat to public health and safety in the MAF area. 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)	Medium
Significance of impact (slight / minor / localized / major / massive)	Localised
Potential risk level (low, medium, high and extreme)	High

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
Air pollution	• Adverse • Long term • Medium occurrence • Localised significance	• High risk	• Emissions from the crude oil tankers, especially the hydrocarbon venting, may have an impact on the nearby residential area. • 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.
Marine water pollution	• Adverse • Long term • High occurrence • Localized significance	• High risk	• De-oiled residual produced water discharged into the sea from MAF tank farm exceeds Omani marine discharge standards. • MAF bay has significant eco-tourism significance.
Land contamination	• Adverse • Long term • Medium occurrence • Localised significance	• High risk	• Potential for large volumes of leakage of crude oil from MOL system due to pipeline failure shall be treated as significant.

Environmental Effect	Impact Rating	Potential Risk Level	Comments
Public Health and Safety	• Adverse • Short term • Medium occurrence • Localised significance	• High risk	• Storage and transport of highly combustible liquid and gaseous hydrocarbons have the potential to cause damage to public health and safety in the event of significant release.
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	• Power plant and booster plant stacks were not monitored to check compliance with emission standards. • Ambient air was not monitored to check compliance with air quality standards.	• All continuous air emission sources shall be monitored periodically, at least on quarterly basis. • Emissions from the crude oil tankers (hydrocarbon venting) to be monitored. • Ambient air quality shall be monitored in accommodation camps periodically, at least on quarterly basis.
SP-1006: Specification for Aqueous Effluents	• De-oiled produced water from MAF tank farm contains oil and grease content (50 mg/L) is well in excess of Omani marine discharge standards (5 mg/L)	• The effluent treatment plant in MAF tank farm shall be upgraded.
SP-1007: Specification for Accidental Releases to Land and Water	• It is very likely that quantities of oil spills are under-estimated and under reported.	• All oil spill / leak incidents shall be respond 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.

Specification	Areas of Non-compliance or Concern	Recommended Additional Mitigation Measures
SP-1008: Specification for Use of Energy, Materials and Resources	• None	• None
SP-1009: Specification for Waste Management	• None	• None
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	• None	• None
SP-1170: Specification for Management of Naturally Occurring Radioactive Materials	• None	• None

8 REFERENCES

1. WS/Atkins, *Infrastructure asset area Environmental Assessment Report*, PDO, September 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, EIA update and Review, PDO, April 2003

APPENDIX 1: ORGANIZATION RESPONSIBLE FOR PREPARATION OF THE REPORT

HMR Environmental Engineering Consultants, Oman are responsible for the preparation of this report on environmental assessment of infrastructure asset 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
Randa Mounir	Consultant	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
TTS	Frank Igbelina	Head, HSE & Corporate Emergency Response
TTT/5	Mark WMH Crowther	Senior Port Operations Supervisor

Appendix 2: DETAILS OF STACKS

Source Description	Number of identical stacks	Stack Height (above ground level) (m)	Stack Internal Diameter (at exit) (m)	Stack Gas Temp (at exit) (C)	Fuel Gas Mass Flow Rate (kg/h)	CO2 Mass Emission Rate (kg/h)	SO2 Mass Emission Rate (kg/h)	NOx Mass Emission Rate (kg/h)	CO Mass Emission Rate (kg/h)	HC Mass Emission Rate (kg/h)
Marmul Power Station: Gas Turbine	3	15	2.2	482	14,362	-	-	39,496	0.0	96.2
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
Hubara Power Station: Gas Turbine	3	15	2x2 m	-	19,995	54986	0	134	54	9
Suwaihat Power Station: Gas Turbine	1	15	4.3	-	5,518	15175	3	37	15	3
Sahma Booster Station: Gas Turbine	8	12	0.6	-	430	1183	0	3	1	0
Hubara Booster Station: Gas Turbine	7	10	0.2	-	1,362	3745	0	9	4	1
Saih Rawl Power Station: Gas Turbine	2	-	-	-	6,378	17,382.0	0.0	0.0	16.7	2.9
Saih Nihayda Power Station: Gas Turbine	1	-	-	-	16,842	45,896.0	0.0	0.0	44.2	7.5
Nahada Booster Station: Gas Turbine	6	-	-	-	3,958	11,363.3	1.3	26.3	10.8	1.7
Fahud Power Station: Gas Turbine	1	-	-	-	7,560	21,704.6	2.1	50.4	20.4	3.3
Yibal Power Plant: Gas Turbine	5	15	4.3	-	19,557	55,460.0	8.8	129.2	52.1	9.2
Lekhwair Power Station: Gas Turbine	2	15	4.3	480	12,809	46,639.0	0.0	108.3	43.8	6.7

APPENDIX 3: 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 4: ENVIRONMENTAL HAZARDS AND EFFECTS IDENTIFICATION MATRIX: INFRASTRUCTURE 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 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 storage of construction materials										X	***X***		X	***X***	***X***						
Utilization of Mineral Resources																					
For construction materials	X																				
For road building materials	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 Groundwater Resources																					
For construction water		X						X													
Utilization of Human Resources																					
Employment of migrant construction workers																				X	
Employment of permanent workers																					
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	

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 Energy into Atmosphere																					
Hot gases from flares and stacks																					
High level noise from stationary sources						X															
High level noise from mobile sources						X															
Discharges of Liquid Effluents																					
Marine discharge of treated effluent									X			X									
Accidental spillage of hazardous liquids								X				X									
Disposal of Solid Wastes																					
Handling and transport 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							
Marine travel																					

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