ENVIRONMENTAL ASSESSMENT OF GEOSOLUTIONS 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 Geosolutions asset, which is one of the service assets within PDO's concession area in the Sultanate of Oman. The first environmental assessment for Geosolutions 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.

Geosolutions asset is a part of the Exploration Directorate and works under the overall direction of the Exploration Director. At the asset level, it is managed by the GeoSolution Manager (XGM). The asset provides geo-services to frontier exploration and production assets for the identification and development of hydrocarbon reserves within PDO's concession area. The areas of technical service provided by geosolutions asset include the following:

- Seismic data acquisition and processing
- Geological support and laboratory services
- Geomatics support
- Sub-surface information management and technology support
- Reservoir characterisation

The seismic data acquisition team, which takes care of most of the environmental impacts of the geosolutions asset is headed by the Chief Geophysicist (XGP).

The areas of operation of geosolutions asset (particularly the seismic survey team) stretch from Marmul in south Oman to Lekhwair north Oman, covering a vast land area of 113,550 km^2.

Description of Environment

The topographical features of the PDO's concession area show two distinct zones as below:

- Desert plains with very low populations within most of the concession area
- Low to medium altitude hills over the southernmost and northernmost parts

The geology of most of the PDO's concession area comprises of mainly limestone with shale, dolomite and sandstone. The tertiary aquifers are the potentially exploitable groundwater resources in PDO's concession area.

PDO's concession area as whole has an arid climate, with very low rainfall. The climate is typically hot with significant fluctuations between 12°C in December/ January to about 45°C

in July. Rainfall in this region is scanty and is highly variable in time and space with an average of 36 mm per annum.

The natural flora in most of the concession area is composed of desert plants and grasses, while trees are rarely seen. 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.

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. 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.

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	• Stack emissions from DGs used for power generation in seismic survey camps are suspected to exceed the permissible concentration limits prescribed in SP-1005 for stationary combustion sources. • Stack emissions from DGs may not disperse well in the atmospheric due to short stack heights. • No monitoring data are available demonstrating compliance with ambient air quality standards in seismic survey camps.	• SP-1005 may require an amendment since standard designs of DGs are unlikely to meet these emissions standards. • Ambient air quality shall be monitored in seismic survey camps to check for compliance. • If ambient air standards are not met, mitigation measures such as increasing the stack height, retrofitting the DGs with air pollution control devices, using better fuels etc. may need to be implemented.
SP-1006: Specification for Aqueous Effluents	• Grey water (wastewater from kitchen, bathrooms and laundries), which is discharged on land without any treatment will contain high concentration of detergents and hence will not comply with the land discharge standards.	• The causes for operational deficiency of the STPs shall be identified and corrected immediately. • Grey water shall not be discharged without any treatment.
SP-1007: Specification for Accidental Releases to Land and Water	• None	• None
SP-1008: Specification for Use of Energy, Materials and Resources	• Efficient use of fuel and water in the field activities of the asset is not demonstrated.	• Fuel conservation measures shall be promoted. • Water conservations measures shall be promoted.
SP-1009: Specification for Waste Management	• None	• None

Specification	Areas of Non-compliance or Concern	Recommended Additional Mitigation Measures
SP-1010: Specification for Environmental Noise and Vibration	• DGs used for power generation in seismic survey camp generate high level noise. • No monitoring data are available demonstrating compliance with ambient noise standards in seismic survey camps.	• Work place and ambient noise levels shall be monitored in seismic survey camps to check for compliance with the standards. • If warranted, noise attenuation measures shall be taken.
SP-1011: Specification for Flora and Fauna	• Earthmoving operations involving bulldozers prior to seismic survey may cause damage to vegetation on sites.	• Earthmoving operations shall be minimised to the extent possible. • Care shall be taken to avoid areas with dense vegetation.
SP-1012: Specification for Land Management	• Bulldozing operations prior to seismic survey may generate dust clouds. • The tracks and tyre marks left behind in virgin areas by the movement of heavy duty vehicles used by the seismic survey teams may last for a long time.	• Areas of visual significance shall be avoided to the extent possible. • Efforts shall be made to restore the worked-over areas to near natural state after completion of survey.
SP-1170: Specification for Management of Naturally Occurring Radioactive	• None	• None

Conclusion

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

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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)
^oC	degree centigrade
^oK	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)
YPS	Yibal Production Station
LRVC	liquid ring vacuum compressors
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^oC)
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 directorates viz., North Oman and South Oman. The production assets within North Oman include Fahud, Lekhwair, Yibal and Qarn Alam, and those within South Oman include Bahja, Nimr (including Rima) and Marmul. The crude oil export facilities and the administrative head quarters are located on the coast in Mina Al Fahal.

Currently PDO (including gas asset) operates from about a hundred fields and has 2,454 oil producing wells and 72 non-associated gas producing wells. The total production of oil (black oil and condensate) currently is about 843,490 barrels per day and that of gas (associated and non-associated) is about 44 million Sm^3 per day as reported for the year 2002. 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**

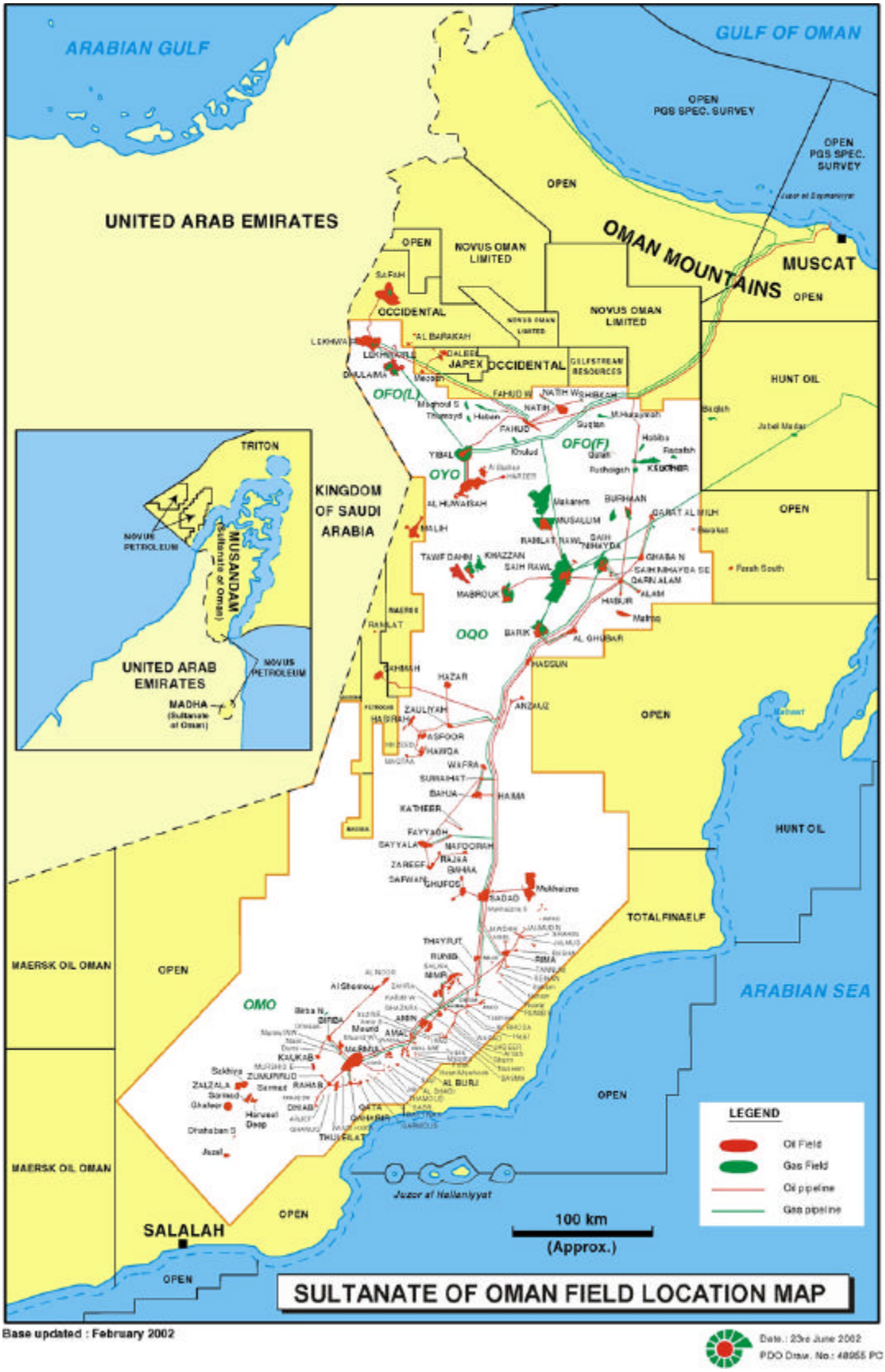


Figure 1.1: Geographical Map of PDO's Concession Area

In addition to the seven production assets, there are different 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
GeoSolutions Asset	- Provide geo-services to frontier exploration and production assets for the identification and development of hydrocarbon reserves within PDO's concession area - The areas of technical service include seismic data acquisition & processing; geological support & laboratory services; geomatics support; sub-surface information management & technology support; services; and reservoir characterisation.
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
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 - 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

Logistics Asset	Provide dedicated logistics support to all other assets in PDO through sub-contracting for the following services: - Cargo handling and haulage including rig moves - Passenger commuting by land and air - Fleet management - Warehousing including central chemical storage
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 asset 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 studies for geosolutions asset were 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 retained HMR Environmental Engineering Consultants (HMR Consultants) to carry out the first review and update of the EIA for all its assets.

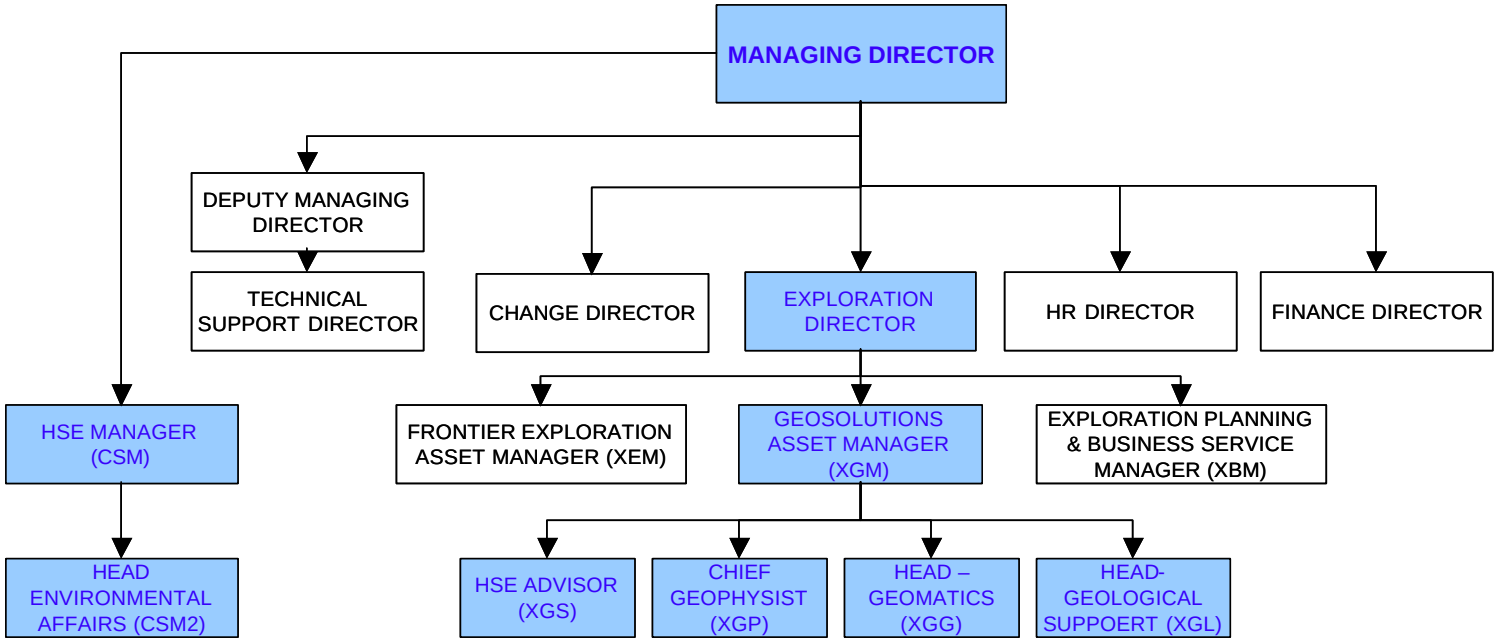


Figure 1.2: Asset Organisation Structure in PDO

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 contractor staff 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.

Following this introductory, the regulatory framework from environmental assessment is presented in Section 2. The detailed description of activities performed by geosolutions asset is presented in Section 3. In Section 4, the wastes generated as a result of these activities are discussed and their treatment and disposal practices are analysed.

A brief description of the current environment status of the areas within which the geosolutions asset operates is presented in Section 5. In Section 6, the significant environmental hazards associated with the asset activities are identified and the environmental effects are reassessed. The summary of significant effects and mitigation plan for adverse impacts is presented in Section 7. The list of references is presented at the end of the report under Section 8.

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

2 REGULATORY FRAMEWORK

2.1 Omani Regulations

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

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

Table 2.1: Environmental Laws and Regulations in Oman

(Presented in Chronological Order)

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

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

2.2 Shell Group Environmental Guidelines

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

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

Table 2.2: Shell Group Environmental Specifications

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

2.3 PDO Corporate Environmental Specifications

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

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

Table 2.3: PDO's Environmental Specifications

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

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

2.4 Environmental Standards

2.4.1 Emissions to Atmosphere

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

Table 2.4: Air Emission Standards

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

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

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

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

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

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

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

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

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

2.4.2 Ambient Air Quality

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

Table 2.5: Ambient Air Quality Standards

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

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

2.4.3 Aqueous Effluents

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

- **Production Water:**

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

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

(b) Maximise reuse of such produced waters.

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

(d) Return production water to the producing reservoir.

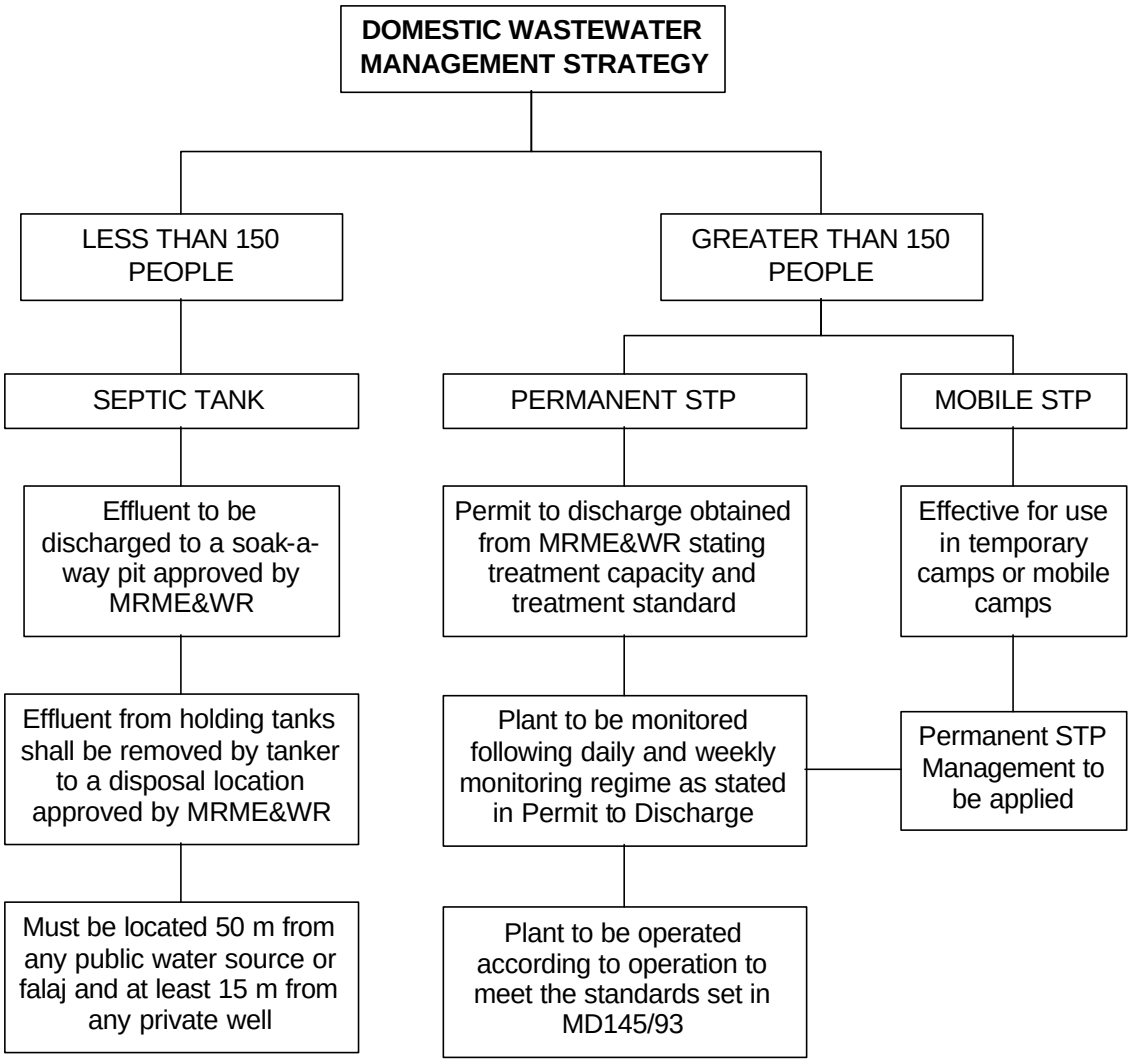
(e) Dispose surplus waters to formations, which have salinity greater than 35,000 mg/L, in conjunction with case-specific monitoring programs.

- **Other Process Effluents:**

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

- **Sewage Effluent:**

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



- **Storm Water Runoff:**

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

- **On Land Discharge:**

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

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

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

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

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

Table 2.7: Standards for Treated Wastewater Discharged on Land

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

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

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

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

Table 2.8: Maximum Permissible Metal Concentrations in Sludge

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

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

- **Marine Disposal:**

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

Table 2.9: Standards for Treated Wastewater Discharged into Marine Environment

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

2.4.4 Accidental Releases to Land and Water

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

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

2.4.5 Use of Energy, Materials and Resources

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

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

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

2.4.6 Waste Management

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

Table 2.11: Classifications of Hazardous and Non-Hazardous Wastes

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

PDO's waste management hierarchy is as below:

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

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

2.4.7 Environmental Noise and Vibration

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

Table 2.12: Ambient Noise Standards

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

2.4.8 Flora and Fauna

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

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

Table 2.13: Classification of Environmentally Sensitive Areas

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

2.4.9 Land Management

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

Table 2.14: Land Management Requirements

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

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

2.4.10 NORM Waste Disposal

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

3 ASSET DESCRIPTION

3.1 Introduction

Geosolutions asset is one of the eight technical service providers in PDO, whose areas of operation cover the entire interior concession area of PDO. The asset is provides geo-services to frontier exploration and production assets for the identification and development of hydrocarbon reserves within PDO's concession area. The areas of technical service provided by geosolutions asset include the following:

- Seismic data acquisition
- Geological support and laboratory services
- Geomatics support
- Sub-surface information management and technology support
- Reservoir characterisation

Among these, the geophysical services *viz.*, seismic data acquisition almost account for most of the environmental impacts of the asset.

Geosolutions asset is a part of the Exploration Directorate and works under the overall direction of the Exploration Director. At the asset level, it is managed by the GeoSolution Manager (XGM).

The seismic data acquisition team, which takes care of most of the environmental field activities of the geosolutions asset, is headed by the Chief Geophysicist (XGP). The asset management structure including the health, safety and environment (HSE) management structure is shown in Figure 3.1.

3.2 Activity Description

3.2.1 Overview

As described earlier geosolutions asset consists of six teams *viz.*, seismic data acquisition ; geological support and laboratory services; geomatics support; sub-surface information management and technology support and reservoir characterisation. Except for seismic data acquisition, none of the activities of the asset involve field operations. A brief description of the activities of each team is presented below.

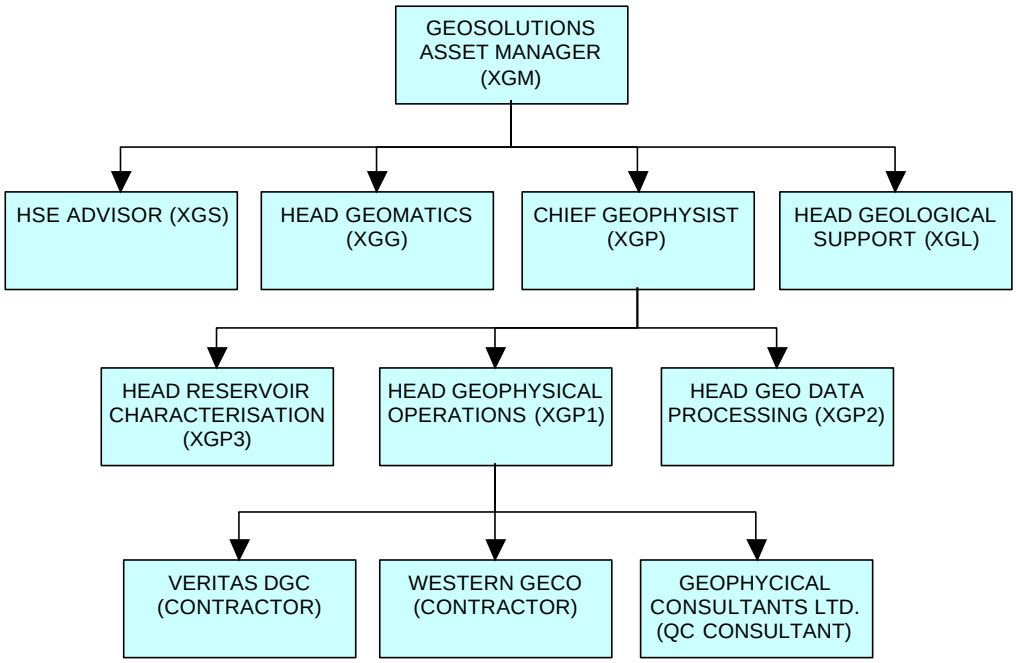


Figure 3.1: Asset Management Structure for GeoSolutions Asset

- **Seismic Data Acquisition Team (XGP)**

The fieldwork associated with the activities of geosolutions asset is almost entirely restricted to the seismic data acquisition . The majority of this work (60%) is performed for the frontier exploration asset and the balance is performed for the production assets and the government gas asset. The activities of this team have impact on the bookings of hydrocarbon reserves in the concession area. The seismic data acquisition is actually performed by approved contractors under operational management of the XGP/1 staff. The data processing is performed by both contractors and XGP/2 staff, with XGP/2 staff performing high-end work (pre-stack depth migration, etc) and contractor management.

- **Geological Support and Laboratory Services (XGL)**

The XGL team provides geological consultancy and laboratory services on matters related to subsurface geology with the objective to reduce subsurface uncertainty and to optimize field development, exploration and appraisal strategies. The exploration laboratory consists of analytical facilities such as microscopes, fluroscopes, photographic equipment, gamma ray equipment, miniperm and poroperm equipment, fluid analysis equipment etc. These XGL activities have impacts on both production levels and growth of reserves in PDO's concession area. XGL customers include the frontier exploration, deep oil, government gas and production assets. XGL also provide field trip management under contract with Shuram Oil & Gas for PDO and interested parties.

- **Geomatics Support (XGG)**

The XGG team provides graphical support services related to positioning; detail surveys for wells, pipelines and related infrastructure; the management of spatial information and geo-referenced data for all asset teams. This information is essential for general operations including HSE and the planning of new wells and surface infrastructure. In addition, XGG team provide support on remote sensing mapping and geographical information systems.

- **Sub-Surface Information Management and Technology Support (XGI)**

XGI team provides sub-surface information management and technology support services to all PDO asset teams to ensure that that the most appropriate information technology tools and methods are available to the subsurface user community. The team comprises staff from different disciplines, who support and continuously refine the entire subsurface application portfolio.

- **Exploration Business Services (XGB)**

XGB team provides the HSE and finance advice and support to all the assets within the Exploration Directorate. The team also provides the finance advice to the Corporate Affairs Directorate on exploration activities.

- **Reservoir Characterisation (XGR)**

XGR is a multi-disciplinary team comprising of geophysics, geology, reservoir engineering and petrophysics experts. The team combines their several functional capabilities to determine the reservoir properties, based on the data acquired and processed by other asset teams.

As seen from above, the field activities of geosolutions asset are almost entirely restricted to seismic data acquisition. Therefore, a detailed description of seismic data acquisition activities is presented below. In addition, a brief description of the exploration laboratory activities is also presented, since these activities may have potential environmental hazards.

3.2.2 Seismic Data Acquisition

- **Overview**

Approved contractors under the operational management of XGP/1 staff perform seismic data acquisition activities. Two types of seismic survey are carried out in PDO, *viz.*, 2-D seismic survey and 3-D seismic survey. Vibroseis vehicles consisting vibrators and geophones are used for both 2-D and 3-D seismic surveys. Prior to actual seismic survey, topographical surveys and earthmoving operations, if required, e carried out for access and positioning of the seismic survey equipment and vehicles. In order to minimise any potential environmental risks and for mitigation of any adverse effects, the asset team complies with the HSE requirements specified in PDO's guidelines GU-423 entitled "HSE in Seismic Bulldozing Operations Guideline" (Reference 3).

- **Land Survey and Earthmoving**

Topographical survey is carried out prior to seismic survey for identifying the locations for placing the vibrators and geophones. Land survey equipment and geographical positioning systems are used for mapping the survey area. Where necessary, earthmoving operations are carried out to give access to the vibrators and other vehicles during the seismic survey operations. Earthmoving operations may

involve the use of bulldozers. Vibrators locations are marked with biodegradable plastic bags filled with sand and geophone locations are marked with small flags.

- **Seismic Survey**

Both 2-D and 3-D surveys are carried out using vibrators and geophones. The vibrators are positioned at selected points and they generate vibrations over a frequency range of 8-60 Hz for a short duration of about 15 seconds. The signal reflected off sub-surface rock formations is picked up by the geophones. The signal picked up by the geophones is sent via receiver units to a central processing unit placed on the recording truck. Once the recording is completed, the vibrator truck moves to a new location and process continues.

Trucks are used for carrying the survey equipment. Normally, four trucks are used for this purpose, though it may vary depending on the crews. All the trucks use diesel oil as fuel.

- **Seismic Camp**

Typically, the on-site staff consist of about 150-200 persons. Therefore mobile accommodation camps are provided near the survey area for the seismic survey staff. Apart from the accommodation facilities, the other facilities provided in a seismic camp are kitchen, laundry, bathrooms and toilets, workshop and limited recreation facilities. Potable water is supplied from the potable water wells or nearby RO plant of PDO. Power is supplied from on-site diesel generators. In order to maintain a steady supply of fuel oil for the generators, diesel oil storage tanks are provided at each seismic camp site. Fuel is transported from PDO camp by trucks.

Wastewater from the toilets (sewage) is treated in a mobile sewage treatment plant. The wastewater from bathrooms and kitchens (grey water) is however discharged on to land without any treatment. Solid wastes generated from the camp is placed in the waste skips and collected by the waste management contractor for disposal. Waste oil from the workshop is stored in a drum and periodically transferred to the nearby waste management centre.

3.3 Facility Description

Geosolutions does not possess any major physical assets, fieldwork for seismic data acquisition is actually carried out by the contractors, who own all the survey equipment. Presently two contractors are engaged by the asset for seismic surveys. They include Veritas (two survey teams) and Western Geco (one survey team). The

physical assets owned by geosolutions include some vehicles, exploration laboratory equipment and the software and hardware for data processing.

The list of physical assets owned by geosolutions asset is presented below in Table 3.1.

Table 3.1: List of Physical Assets Owned by Geosolutions Asset

Asset Team	Major Equipment and Hardware Used
Seismic Data Acquisition (XGP)	- Vehicles - Workstations and personal computers - 40 MHz radios and satellite telephones - Recording tape and section storage facilities
Geological Support and Laboratory Services (XGL)	- Vehicles - Core storage facilities - Core lifting, slabbing, plugging and polishing equipment - Laboratory equipment (microscopes, fluroscopes, photographic equipment, etc.)
Geomatics Support (XGG)	- Vehicles - Total workstation and personal computers - Plotters

3.4 Materials and Utilities

Geosolutions asset is not a major consumer of materials and utilities. The materials and chemicals are consumed are not significant. The potable water and fuel consumed by the seismic crew in the camps are only the significant consumables. The consumption of utilities and materials in geosolutions asset for the current year (2002) is given in Table 3.2.

Table 3.2: Consumption of Utilities and Materials in Geosolutions Asset

Item	Description	Quantity Consumed (Jan-Dec 2002
Potable water	For domestic use in seismic camps	37600 m^3
Diesel	For internal power generation in seismic camps	1360 m^3
Diesel	Fuel for vehicles used by asset staff	4925 m^3
Lube oils etc.	Maintenance of vehicles	1.2 tonne

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 for geosolutions asset are discussed. From Chapter 3, it is evident that except for seismic surveys, none of the activities of the asset generate any significant waste products. It is also seen that only the field activities associated with seismic survey generate most of the wastes. Even though these activities carried out by contractors, since the contractor staff are under the operational management of geosolutions asset, all waste generated from these activities are attributed to geosolutions asset. The contribution from those activities that are directly handled by the other assets on behalf of geosolutions asset are not included here, since thy are included in the respective EIA reports.

The activities performed by geosolutions asset that generate waste products and energies may be classified under the following headings:

- Earthwork prior to seismic survey
- Mobilisation of seismic equipment
- Seismic survey
- Seismic camp operations
- Exploration laboratory operations
- Sample and data storage

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 and vibrations
- 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:

- Stationary source emissions
- Area source emissions
- Mobile source emissions

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

4.2.2 Stationary Source Emissions

The stationary sources of air emissions are the diesel generators (DGs) used by the seismic staff for on-site power supply. Currently, three seismic teams work simultaneously at different locations. Each seismic camp is provided with a DG. The DG uses diesel oil as the fuel and the combustion gases are released into the atmosphere through a stack attached to it.

The stack emissions contain air pollutants including sulphur dioxide (SO_2), oxides of nitrogen (NO_X), carbon monoxide (CO) and particulate matter (PM). The particulate matter is mostly due to the 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 monitored. The fuel analysis is also not available and it is assumed that the sulphur content will be less than 0.5% by mass. In the absence of the above data, the emissions rates are estimated based on empirical Tier 3 emission factors given in the Shell group specification EP 95-0377 on "Quantifying Atmospheric Emissions" (Reference 4), which are based on USEPA's AP-42 methods. The emission factors for diesel engines are as given below:

CO_2	: 3.2 tonne per tonne of fuel burned
CO	: 19 kg per tonne of fuel burned

NO_x as NO_2	: 70 kg per tonne of fuel burned
SO_2	: 10 kg per tonne of fuel burned
HC	: 2.04 kg tonne per tonne of fuel burned

The emission inventories for all the assets are summarized in Table 4.1 below.

Table 4.1: Stationary Source Emissions in Geosolutions Asset

Source and Location	Fuel Consumed (Tonnes per Year)	Quantity of Emissions (Tonnes per Year)				
		CO_2	CO	NO_x as NO_2	SO_2	HC
Diesel Generators in Seismic Camps	1156	3699.6	22.0	80.9	11.6	2.4

DGs are not provided with any specific emission control systems. Currently, there are no Omani standards for emissions from DGs. However, PDO's specification on air emissions (SP-1005) requires that NO_x concentration shall not exceed 200 mg/Nm^3 and PM concentrations shall not exceed 100 mg/Nm^3 in the emissions from stationary combustion sources. The specification also requires that SO_2 emission loads be such that the ambient air quality standards (refer Table 2.5 in Chapter 2) are not breached.

Currently, no stack emission monitoring data are available to check whether the concentration of the various pollutants comply with the applicable standards. However, based on past experience with similar systems, it is estimated that about 14 Nm^3 of flue gas will generated from 1 kg of fuel oil burned with about 10% excess air. For this assumption and the emission factors given above, the emission concentrations are will be as below for DGs:

CO	: 1360 mg/Nm^3
NO_x as NO_2	: 5000 mg/Nm^3
SO_2	: 715 mg/Nm^3 (max)
HC	: 145 mg/Nm^3
PM	: 1575 mg/Nm^3 (max)

The above estimated show that NO_x and PM emission concentrations will be in excess of maximum permissible limits as per PDO's specifications. As indicated earlier, there are no maximum permissible emission concentrations in Omani regulations. In the absence of detailed DG stack information or air quality data near seismic camp site, it is not possible to determine whether there is any non-compliance with ambient air quality standards.

4.2.3 Area Source Emissions

The diesel storage tanks are the only area sources of air emissions. Diesel storage tanks are provided at each seismic camp site to maintain steady supply of fuel for the DGs used in the seismic camps. The emissions from the storage tanks are due to the evaporation of the hydrocarbons under solar radiation. The storage tanks provided are fixed roof tanks with atmospheric vents.

The total hydrocarbon vapour emissions from fuel storage tanks are estimated based on Tier 3 emission factors given in the Shell group specification EP 95-0377 on "Quantifying Atmospheric Emissions" (Reference 4). For fixed roof tanks, the total hydrocarbon emission factor is given as 112.2 grams per tonne of throughput. Based on the above, the hydrocarbon vapour emissions from area sources of geosolutions asset are estimated as given in Table 4.2.

Table 4.2: Area Source Emissions in Geosolutions Asset

Parameter	**Area Source: Diesel Storage Tanks in Seismic Camps**
Total throughput	1156 tonnes per year
Total hydrocarbon emission load	0.13 tonnes per year

4.2.4 Mobile Source Emissions

The mobile sources of air emissions are the automobiles used by geosolutions asset and contractor staff, most of which are used by the seismic survey team. These vehicles may include light duty diesel vehicles (cars and 4-wheel drives), medium duty diesel vehicles (buses and vans) and heavy duty diesel vehicles (trucks). The emissions from the engines contain apart from CO_2, air pollutants including NO_x, CO, SO_2 and HC. 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 (Reference 4). EP 95-0377 specification uses common emission factors for all categories of land transport vehicles, irrespective of the type of the motor vehicle, type of the fuel, running speed, load conditions and environmental conditions, as given below:

CO_2	: 3.2 tonne per tonne of fuel
CO	: 27 kg per tonne of fuel
NO_x as NO_2	: 38 kg per tonne of fuel
SO_2	: 10 kg per tonne of fuel
HC	: 5.4 kg tonne 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 0.5% by mass.

The estimated total emissions from mobile sources in the asset are as given in Table 4.3 below.

Table 4.3: Mobile Source Emissions in Geosolutions Asset

Parameter	Quantity (Jan-Dec 2002)
Total quantity of fuel consumed (diesel oil)	4186 t
Total emission of CO_2	13395 t
Total emission of CO	113.0 t
Total emission of NO_x	159.1 t
Total emission of SO_2	41.9 t
Total emission of HC	22.6 t

4.3 Liquid Effluents

4.3.1 Sources of Generation

The liquid effluents generated from the activities performed by geosolutions asset are primarily due to the field activities associated with seismic survey. The major effluents generated from seismic survey activities are the sanitary effluents due to domestic use of water in the temporary seismic camps. Sanitary effluents are generated continuously from the camps. However for a given site, sanitary effluent generation shall be considered intermittent, since seismic survey activities last for couple of months at a given site. In the seismic camps, sanitary effluents are segregated into two streams *viz.,* high BOD stream and low BOD stream. High BOD stream, called as sewage refers to the wastewater generated from toilets. The low BOD stream, called as grey water refers to the wastewater generated from kitchens, bathrooms (showers) and laundries. The high BOD stream from each camp is treated in a mobile STP, while the low BOD stream is discharged on land without any treatment. The details of effluent treatment are presented in the following sections.

Apart from sanitary effluents, no other effluents are generated routinely. However, some accidental spills and leaks of hydraulic oils, chemicals and water may occur. Such accidental releases are discussed separately in Section 4.6.

4.3.2 Quantification and Characterisation of Liquid Effluents

Presently, geosolutions asset operates three seismic camps simultaneously. The raw effluent flow rates and the quality are not monitored. Only the flow rates and the

quality of the treated sewage (STP effluent) are presently monitored. In the absence of any monitoring data, based on past experience and water balance, estimates are made to quantify and characterise the effluents generated in the seismic survey camps.

The total annual domestic water consumption in all the three seismic camps currently (2002) is 37600 m^3. This gives an average consumption of 34.3 m^3/d per camp. Assuming that the quantity of wastewater generated is about 85% of water consumed, the total quantity of sanitary effluents is estimated as about 29 m^3/d per camp. Out of this, the average quantity of high BOD effluent (sewage) that is treated in the mobile STPs is measured as about 3 m^3/d per camp. Thus, the average quantity of low BOD effluent (grey water) is calculated as 26 m^3/d.

The typical characteristics of the two effluent streams, based on data available from similar effluents elsewhere are presented in Table 4.4 below.

Table 4.4: Liquid Effluents Generated from Geosolutions Asset Activities

Liquid Effluent	Source of Generation	Average Quantity Generated	Typical Nature and Characteristics of Raw Effluent
High BOD sanitary wastewater (sewage)	Toilet and kitchen sinks in seismic survey camps	3 m^3/d per camp (Based on actual flow rate measurements for year 2002)	Contains high BOD in the form of suspended and dissolved solids.
Low BOD sanitary wastewater (grey water)	All other domestic uses (bathrooms, laundries etc.) in seismic survey camps	26 m^3/d per camp (Estimated quantity based domestic water consumption for year 2002)	Contains detergents, but low in BOD content
Total sanitary effluents	Seismic survey camps	29 m^3/d per camp (Estimated average)	As above
Other efffluents	-	None	-

4.3.3 Effluent Treatment

In each seismic survey camp, the high BOD effluent (sewage) is treated in a mobile STP. The low BOD effluent (grey water) is not treated, but directly discharged on land. The mobile STPs are based aerobic treatment using rotating biological contactors, which are attached growth aerobic systems. A brief description of the operation of the mobile STPs is presented below.

At each seismic camp, raw sewage from the various points of generation flows into a sump. From the sump, raw sewage is macerated and then pumped to the primary settling tank of the STP. In the primary settling tank, the suspended solid matter present in the effluent is settled by gravity and the settled matter (primary sludge) is

drawn off intermittently using vacuum tankers and sent to the nearest permanent STP in PDO. The clarified sewage from the primary settling tank flows into the rotating biological contactor (RBC). RBC consists of banks of polypropylene discs attached to a slowly rotating central shaft and partially submerged in the effluent. Due to rotation, the discs on which aerobic micro-organisms grow as an attached film (slime layer) are exposed to effluent and atmospheric air alternatively. The nutrients (organic matter) in the effluent are biologically oxidised by the micro-organisms attached onto the discs. Atmospheric air supplies the oxygen necessary for oxidation to the micro-organisms. Sufficient retention time (exact details are not available) is allowed to complete the oxidation of the organic matter.

As a result of oxidation of nutrients in the effluents, there will be some growth of biomass. However, the thickness of the slime layer is self-regulating and therefore the excess bio-mass is retained in the effluent as sludge. From the RBC, the treated effluent is transferred to the secondary settling tank by bucket lift system. In the secondary settling tank, the excess biomass (sludge) is settled by gravity and the clarified effluent is pumped to the sand filter. In the sand filter, any fine solids present in the effluent are removed, and the clear effluent is then disinfected using an on-line chlorinator. Hypochlorite solution is used as the chlorination agent. Typically, a dosing rate of 1.0 to 0.5 ppm is maintained. After chlorination, the treated effluent is stored in a holding tank, prior to discharge.

The sludge settled in the secondary settling tank is returned to the primary settling tank automatically every 2-3 hours, from where it is removed intermittently using vacuum tankers and sent to the nearest permanent STP in PDO. The sand filter is backwashed automatically once a day using the treated effluent from the holding tank. The backwash is returned to the primary settling tank.

Since the seismic survey camps move from one location to another periodically, the STPs are also periodically relocated. Before relocation, the STPs are decommissioned, whereby all the tanks are emptied and dried out for 1-2 days. When an STP is re-commissioning at a new location, it takes a few days for the biological process to stabilise. In order to reduce the stabilisation time, biological agents (bio-treat AB and bio-activator) are added to the system.

4.3.4 Discharge of Treated Effluent

As stated earlier, the grey water (wastewater from bathrooms and laundries) generated from the seismic survey camps is not treated, since it contains very little organic matter (low BOD). The untreated effluents are discharged of on desert land adjacent

to the camp. The flow rates and characteristics of grey water are monitored once. It is reasonable to expect significant concentrations detergents in the effluent.

The treated effluent from the mobile STPs after chlorination is discharged on land adjacent to the camp. The STPs are designed such that the quality of the treated effluent meets the Omani standards (Standard A-2) for land irrigation (refer Table 2.7 in Chapter 2). The flow rates and characteristics of the treated effluents from the mobile STPs are monitored on bi-weekly basis. The data for year 2002 are summarised below in Table 4.5.

Table 4.5: Characteristics of Treated Effluents from Mobile STPs in Geosolutions Asset

Parameter	Units	STP-1	STP-2	STP-3
Average flow rate	m^3/d	2.2	4.0	2.7
pH	None	6.7-7.3 (XN=0/19)	Data not available	6.0-8.0 (XN=0/13)
Total suspended solids	mg/L	0.8-24.0 (XN=0/19)	Data not available	5.2-292.0 (XN=17/28)
Ammoniacal nitrogen	mg/L	0.1-1.2 (XN=0/19)	Data not available	0.1-2.9 (XN=0/13)
Biological oxygen demand	mg/L	2-16 (XN=0/19)	Data not available	1-110 (XN=16/28)
Chemical oxygen demand	mg/L	13-103 (XN=0/19)	Data not available	21-802 (XN=11/28)

XN = Number times regulatory standards exceeded per total number of times monitored.

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 in geosolutions asset, only a few types of wastes are generated. Their sources of generation, quantities and methods of disposal are shown in Table 4.6.

Table 4.6: Solid Wastes Generated by Geosolutions Asset Activities

Waste Type	Source of Generation	Quantity Generated (Jan-Dec 2002)	Method of Disposal
Domestic refuse	From seismic survey camps	52.2 t	Sent to the nearest waste management centre in PDO
Non-hazardous industrial refuse	Metal scrap and wood scrap from seismic surveys	53.5 t	Sent to the nearest waste management centre in PDO
Waste oils and lubricants	Seismic survey workshops	42.1 t	Sent to the nearest waste management centre in PDO
Contaminated oily sand	Oil leaks and spills from seismic survey equipments such as vibrators	56.9 t	Sent to nearest land farming facility in PDO.
Waste chemicals	From seismic survey camps	1.3 t	Sent to nearby waste management centre
Hazardous waste	Tyres, batteries and empty oil drums	129.9 t	Sent to nearby waste management centre

4.5 Noise and Vibration

The major sources of noise and vibration in the activities of geosolutions asset are the vibrators and the DGs used for power supply in the seismic survey camps. The other sources such as mobile STPs do not generate significant noise.

Noise and vibration from the vibrators are intermittent. They mostly affect the seismic survey staff and have limited impact on the public environment. Noise from the DGs is continuous and can potentially affect not only the seismic survey staff but also general public if any human settlements are nearby. The road vehicles such as cars, vans, buses and trucks used for the field activities of geosolutions asset constitute the mobile sources of noise and vibration.

The staff working in high noise areas are provided with ear muffs. Noise levels in workplace are available. Currently, there is no regular noise-monitoring programme for seismic camps. However, based on observations during the site visit, it is likely that Omani regulatory standards for ambient noise levels may be exceeded in the seismic camps, particularly during the night times.

4.6 Accidental Leaks and Spills

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

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

The main source of oil leaks and spills for the geosolution asset is the hydraulic fluid leak from the vibrators used in seismic survey. The use of chemicals is very limited in geosolutions asset activities. Water leaks and spills, though do not lead to any environmental consequences, are reported in PDO as a matter of water conservation issue. ODS include CFCs, halons, HFCs and HCFCs. The use of these substances is currently phased out in PDO due to their high ozone depletion potential. Some inventories of such substances may still be found in some air-conditioners. According to PDO's specification SP-1005, these substances are not permitted to be released into the atmosphere except in uncontrollable situations or emergencies.

The seismic team have an excellent leak reporting and follow-up system, which is effectively implemented. All the incidents, minor or major, are reported. For the current year (2002), the leaks and spills reported by geosolutions asset are summarized in Table 4.7.

Table 4.7: Accidental Leaks and Spills Reported by Geosolutions Asset

Description	Jan – Dec 2002			
	Oil Leaks and Spills	Chemical Leaks and Spills	Water Leaks and Spills	Releases of ODS (CFCs and Halons)
Total number of incidents	17	0	1	Unknown
Number of spills into wadis	0	0	0	-
Total volume leaked / spilled	0.73 m^3	0	36.0 m^3	177.8 kg
Total land area impacted	93 m^2	0	40 m^2	-
Total quantity of soil contaminated	56.9 t	0	0	-

5 ENVIRONMENTAL SETTING

5.1 Introduction

Geosolutions asset is one of the eight technical service providers in PDO. The asset is provides geo-services to frontier exploration and production assets for the identification and development of hydrocarbon reserves within PDO's concession area. Among the various services provided by geosolutions asset, the seismic data acquisition and processing services almost entirely account for the field activities of the asset. The areas of operation of seismic survey cover the entire interior concession area of PDO. The other services of the asset are performed mostly from the offices located on coast in Mina Al Fahal (MAF).

As seen from these maps, the areas of operation of geosolutions asset (particularly the seismic survey team) stretch from Marmul in south Oman to Lekhwair north Oman, covering a vast land area of 113,550 km^2. From an environmental viewpoint, the terrestrial environment is of interest in the areas of operation of geosolutions asset and the coastal environment (PDO's MAF area) is not of much relevance and significance.

The detailed description of environment throughout the PDO concession area is given in the individual environmental impacts assessment reports prepared for all the production assets. In this chapter, a brief description of the environment within the interior areas of operation of geosolutions asset is presented.

5.2 Topography

The topographical features of the PDO's concession area shows two distinct zones as below:

- Desert plains with very low populations within most of the concession area
- Low to medium altitude hills over the southernmost and northernmost parts

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.

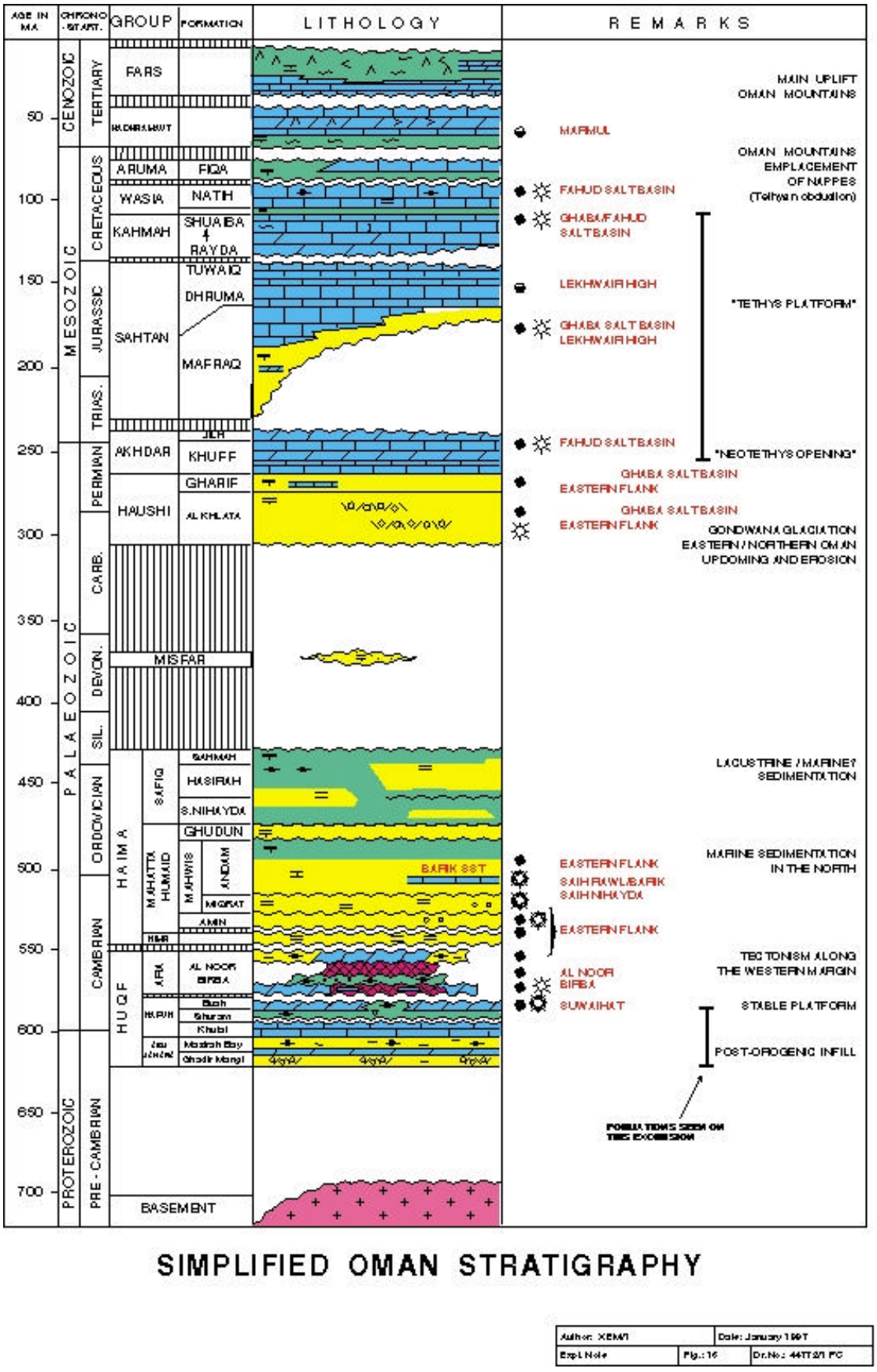
5.3 Geology and Soil

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. 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.

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.



SIMPLIFIED OMAN STRATIGRAPHY

Author: XEM/1		Date: January 1997
Expl. Note	Fig.: 16	Dr.No.: 44TT2/1 PC

Figure 5.1: Simplified Stratigraphy Map of Oman

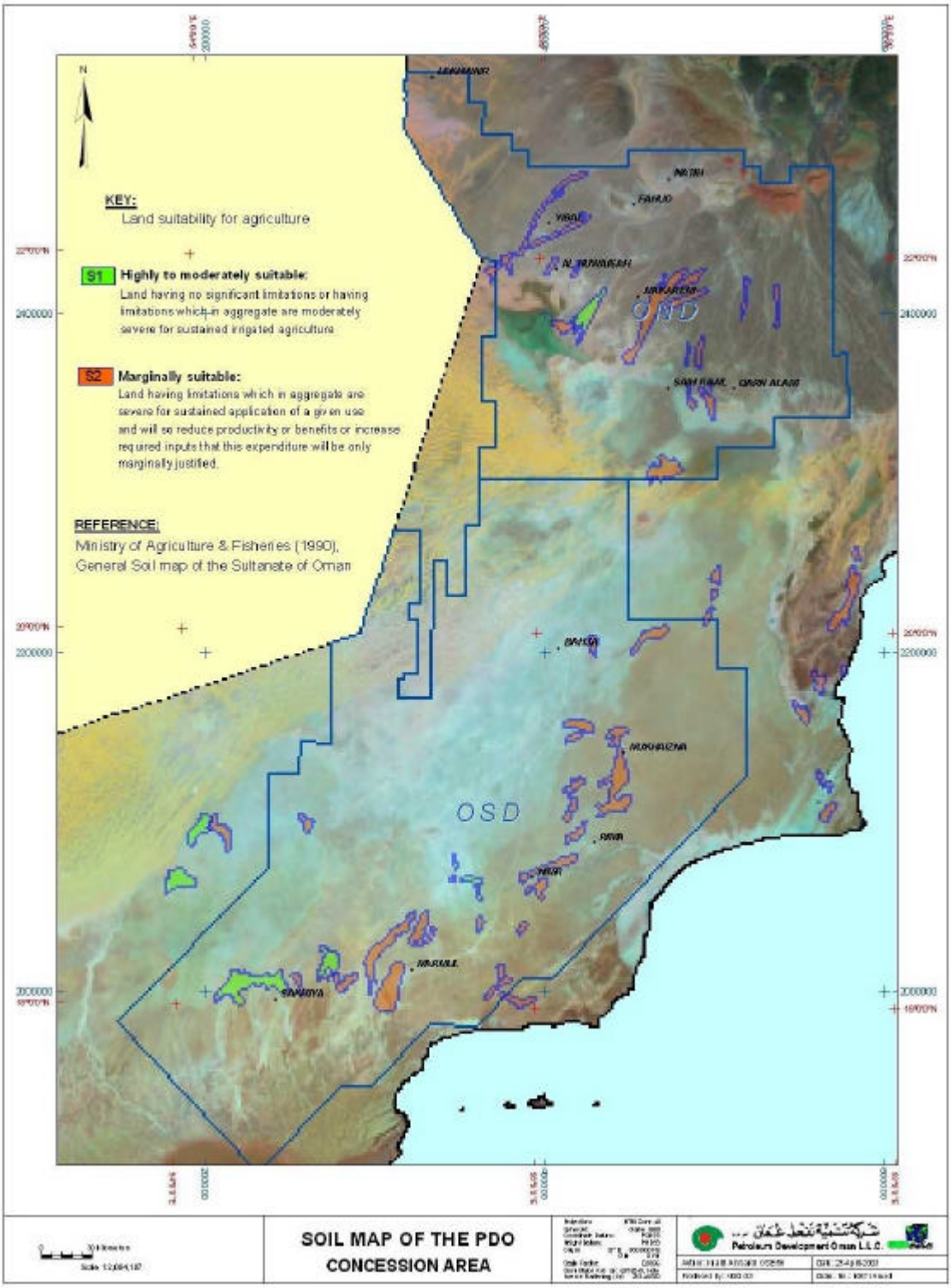


Figure 5.2: Soil Map of PDO's Concession Area

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 water 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 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.

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^{o}C in December/ January (with mean minimum of about 12^{o}C and mean maximum of about 28^{o}C) to about 35^{o}C in July (with mean minimum of about 24^{o}C and mean maximum of about 45^{o}C). The maximum absolute temperature will be as high as 50^{o}C and the minimum absolute temperature will be as low as 5^{o}C.

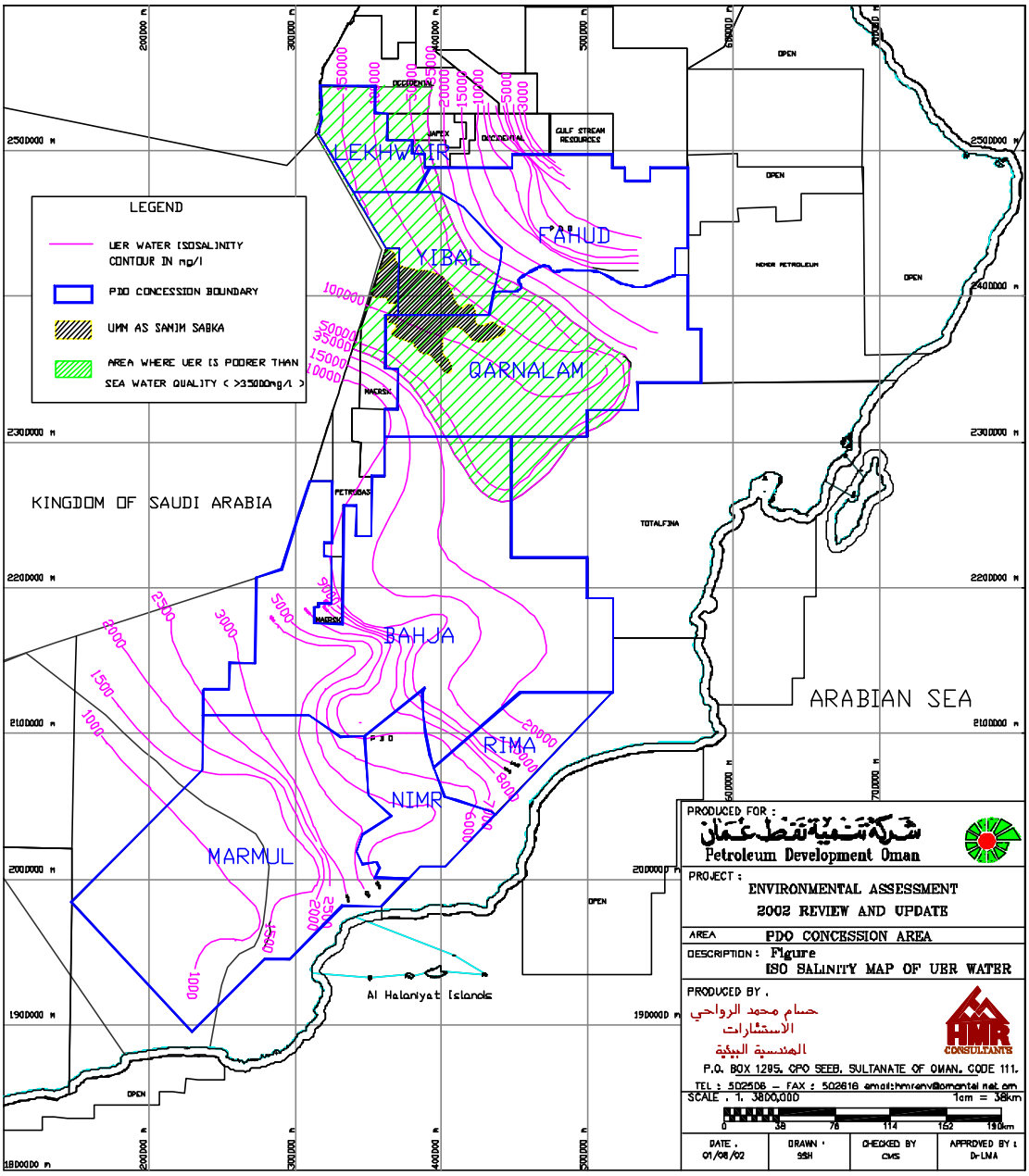


Figure 5.3: Iso-salinity Map of UeR Aquifer in Oman

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 (permanent and temporary) at sometimes. Particularly, due to the use of diesel oil fired DGs for power generation in the camp sites, it is likely that the concentrations of some pollutants such as NO_x, CO and particulates are significantly high compared to the baseline concentrations. 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, drilling units 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.

With specific reference to seismic survey sites, several high noise generating sources are concentrated at a point. The DGs, vibrators and heavy duty vehicles generate high level noise. It is likely that Omani regulatory standards for ambient noise levels may be exceeded in the seismic camps, particularly during the night times.

Therefore, it is necessary that noise surveys be undertaken at periodic intervals at selected locations to determine whether the noise levels in the seismic campsites 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.

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 Fuana

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 into 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 Exploration 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.

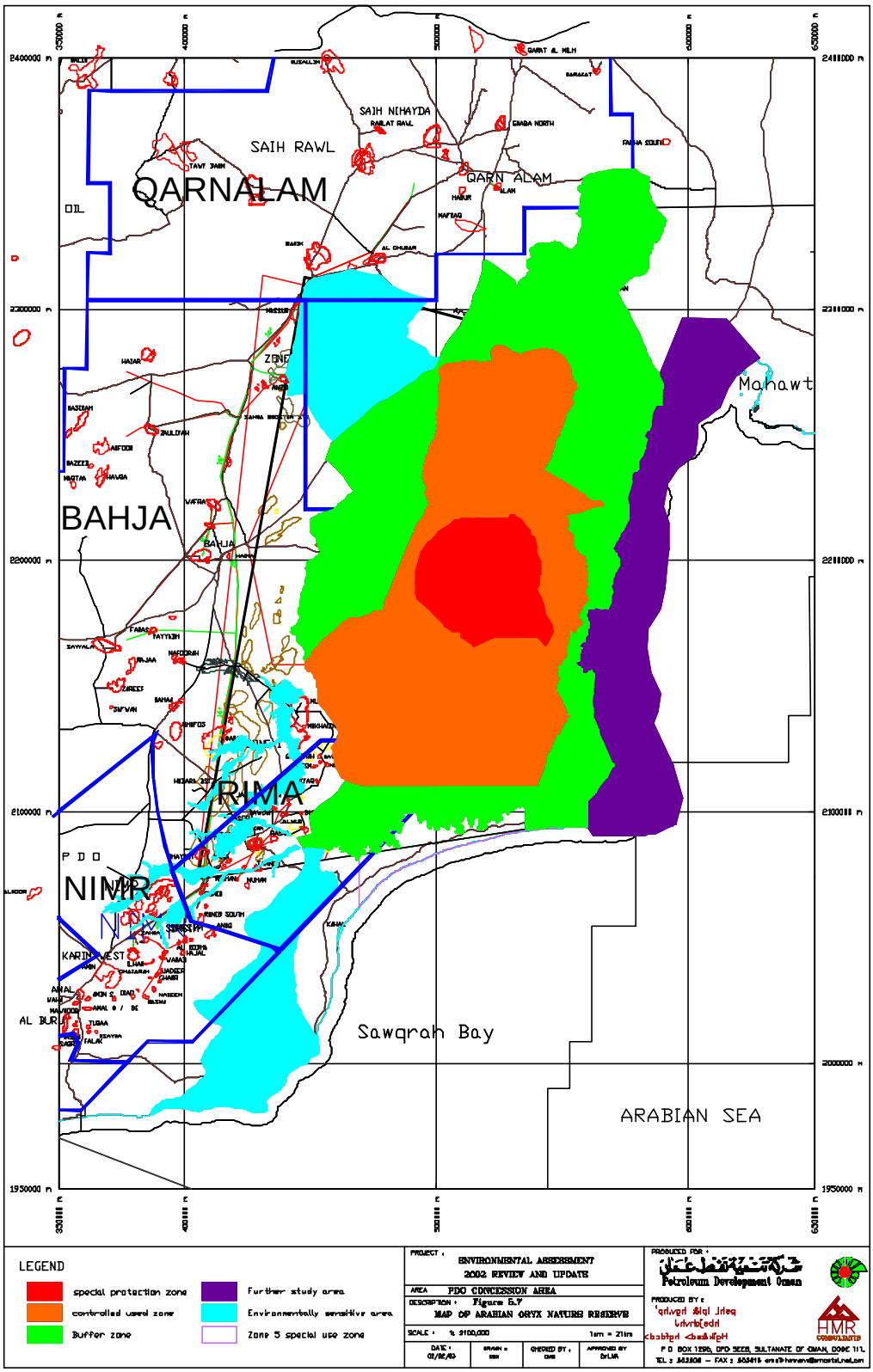


Figure 5.4: Map of Arabian Oryx Nature Reserve

5.9 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.

5.10 Archaeological, Cultural and Recreation Resources

There are no forts or other archeological declared sites in PDO concession area. However, abundant marine fossils are present in Jabal Fahud and Natih areas (Fahud asset). Recent archaeological survey carried out for PDO in the Ghaba East area uncovered one significant archaeological site and two lesser area of archaeological interest. The significant archaeological site is a large surface scatter site with a wide range of artifacts such as several Acheulean hand axes and a large blade industry reminiscent.

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.

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 2.*

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 3*. 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. geosolutions 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
- Water consumption
- Land take

Potential Environmental Effects
- Depletion of groundwater
- Claim of local assets

- **Depletion of Groundwater**

Water is consumed in geosolutions asset for domestic purposes only. The seismic survey camps account for most of water consumption. The total potable water consumption in geosolutions asset currently (2002) is 37,600 m^3 annually. Potable water for the asset is supplied mainly from the water wells and some times from RO plants operated by the production assets. In the RO plants saline groundwater is demineralised with about 50% yield of potable water. In a worst case scenario, if all water was taken from RO plant, the total extraction of groundwater to meet the potable water requirement in will be to the order of 75,000 m^3 per year or about 205 m^3 per day on average.

This quantity is not considered to be very significant with reference to its potential for groundwater depletion. It may also be noted that since the seismic survey camps move from location to location throughout PDO's concession area, different water wells are used for extraction of the groundwater. Based on the above discussion, the overall impact on groundwater resources is rated as below:

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

 # Even though groundwater abstraction for a given site is of short duration, considering that the same aquifer feeds to large number of water wells in a region, the duration of impact is taken as of long term.

- **Claim on Local Assets**

The local populations within the asset are very few and their demands or claim on local assets is low. Occasionally local people claiming camp are in their grazing land (e.g. Mukhaizna Camp). Land may be considered to have competing users. However, the entire area of land on which PDO operates has no alternate use, due to the poor soil quality, lack significant vegetation and harsh environmental conditions. Further, the land take for seismic survey and survey camps is temporary. Once the survey is completed, the land is restored to near natural state and vacated. 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)	Short term
Likelihood of occurrence (very low / low / medium / high / very high)	Low
Significance of impact (slight / minor / localized / major / massive)	Minor
Potential risk level (low, medium, high and extreme)	Low

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 geosolutions asset, most of the CO_2 emissions are from the DGs used for power generation in the seismic camps and the vehicles. The total CO_2 emissions from all the sources in the asset are

estimated to be of the order of 17100 tonnes per year. The quantities of global warming gases released as a result of the asset activities 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)	Long 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**

The air emissions are mostly from DGs and vehicles used in the seismic survey staff. The major pollutants released into the atmosphere from these sources are NO_x, CO, SO_2, and unburnt HC. The total emission loads for the asset per year are estimated to be about 240 tonnes for NO_x, 135 tonnes for CO, 54 tonnes for SO_2 and 25 tonnes for HC. Considering that they 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.

The seismic survey staff are however exposed to these pollutants continuously, since they move from one site to another along with the survey camps. Therefore, while the impact on air quality at a given site may not be of much significance (short term effect) for any local populations, it is of great significance for the survey staff. It is noted in Section 4.2.2 that the emission concentrations of some pollutants from DGs are in excess of PDO's permissible limits (refer SP-1005). Further, the heights of the stacks through which DG emissions are released into the atmosphere are short; generally 6-9 m from ground level. This might adversely affect the dispersion of the DG emissions in the environment leading to elevated concentrations of pollutants in the ambient air. In the absence of any air quality data in the survey camp sites, the compliance with ambient air quality cannot be assumed.

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)	Minor
Potential risk level (low, medium, high and extreme)	Medium

 # Even though air emissions are of short duration for a given drilling site, the drilling personnel are continuously exposed to them and therefore the duration of impact is taken as of long term.

- **Noise Pollution**

The major sources of noise in the activities of geosolutions asset are the seismic survey vehicles, vibrators and the DGs used for power supply in the seismic survey camps. Noise from the vehicles and vibrators are intermittent. They mostly affect the seismic survey staff and have limited impact on the public environment. Noise from the DGs is continuous. The potential effect on general public (if any human settlements are nearby) is short term since the survey camps move from one location to another. However for the seismic survey staff, their effect is long term since the survey team move from one location to another along with the camps.

Noise data for the vibrator's are available. While no data are available at camp site on ambient noise levels, it is reasonable to expect that their impacts will be highly localized and limited to less than 1 km distance. Observations during the site visit to the survey camps indicate that the ambient noise in camps may sometimes exceed the permissible limits, particularly during the night times. 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

 # Even though noise emissions are of short duration for a given seismic survey site, the survey staff are continuously exposed to them and therefore the duration of impact is taken as of long term.

6.6 Impacts on Land Environment

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

Environmental Hazards
- Earthworks during seismic survey
- Land discharge of sanitary effluents
- Accidental spills and leaks of hazardous liquids (oils and chemicals)

Potential Environmental Effects
- Land contamination
- Loss of vegetation
- Visual intrusion

- **Land Contamination**

The land discharge of sanitary effluents and accidental leakage and spillage of oil and chemicals from the seismic survey camps may lead to land contamination. The high BOD sanitary effluent (sewage) generated in the seismic camps is discharged on land

after treatment in mobile STPs. However, the low BOD sanitary effluent (grey water) is discharged on land without any treatment. The current (2002) STP monitoring data show that out of the two STP, only one STP shows repeated non-compliance before October. This STP shows compliance after October. The discharge of grey water without any treatment may contaminate land. However, since the survey camps are operated at a given site for short duration only, any adverse effects will be transient and very likely reversible.

The accidental leaks and spills of oils reported in the asset are insignificant (total oily sand: 57 t in 2002) and no chemical spills are reported. Based on the above discussion, the impact on land contamination is assessed as below:

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

- **Loss of Vegetation**

Seismic surveys are carried out over large areas throughout PDO's concession area. Prior to seismic survey, earthmoving operations are carried out wherever necessary to provide access to the sites for the heavy vehicles (trucks) and equipment such as vibrators used in the seismic survey operations. Earthwork may result in the loss of any vegetation present at site. In general, there are very few areas in PDO's concession area with any significant vegetal cover. Moreover, most of the vegetation is restricted to desert scrub.

PDO's specification SP-1012 on land management requires that earthmoving shall be minimised to reduce any environmental damage and no trees shall be cut or felled. There is evidence to suggest that the seismic survey team takes all efforts to minimise damage to vegetation during survey operations. Further, since after the completion of the survey the site is abandoned, any loss of vegetation is may be considered temporary. Based on the above discussion, the impact on loss of vegetation as rated as below:

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

 # Considering that the discharges are short term at a given location and the pollutants can be naturally degraded over a period of time, the duration of impact on of land is taken as short term.

- **Visual Intrusion**

Earthmoving operations prior to seismic survey may have adverse effects on the visual quality. The dust clouds generated from bulldozing operations may result in temporary visual intrusion. The tracks and tyre marks left behind in virgin areas by the movement of heavy duty vehicles used by the seismic survey teams may last for a long time and may be potentially undesirable. However, most of PDO's concession area is barren, uninhabited and not considered to be of significant visual amenity value. Based on the above discussion, the impact on visual intrusion is rated as below:

Impact Rating	**Loss of Vegetation**
Nature of impact (beneficial / adverse)	Adverse
Duration of impact (short term / long term)	Short 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

6.7 Impacts on Water Environment

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

Environmental Hazards
- Land discharge of sewage effluents
- Accidental spills and leaks of hazardous liquids (oils and chemicals)

Potential Environmental Effects
- Groundwater pollution

Any potential adverse effect on the water environment may be expected only as a consequence of land contamination (refer Section 6.6 above). Further, land contamination can lead to groundwater pollution only if the quantities of release are significant and shallow groundwater conditions exist. The groundwater table is at least 150 m deep in PDO's concession area. Therefore, the potential risk on groundwater pollution is considered to be low.

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

 # Considering the migration of groundwater over a large area, the duration of impact is taken as long term even though the duration of impact on of land is short term at a given location.

6.8 Impact on Terrestrial Ecology and Wildlife

Seismic surveys are not conducted in any the ecologically sensitive areas, since such areas are prohibited for exploration at present. Further, wildlife is rarely encountered throughout PDO's concession area. Some native fauna such as camels and goats and wild fauna such as gazals, foxes and scorpions may occasionally be encountered. The seismic survey activities may cause temporary obstruction to their movement during the period of survey. 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. The only adverse impact on social environment that may result directly from the activities of geosolutions asset is the impact on public safety and health from vehicular traffic and storage of hazardous substances. Occasional thefts are reported from the campsites.

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

Environmental Hazards
- Vehicular traffic
- Storage of fuels in seismic survey camps

Potential Environmental Effects
- Public safety and health

The seismic survey staff operate throughout PDO's concession area and transport personnel, equipment and materials by road. The number of vehicles required for survey operations is not very large. Further, most of PDO's concession area is uninhabited. Therefore the potential risk to public safety due to accidents involving the road vehicles is considered very low.

At each seismic survey camp, diesel oil is stored in a fixed roof tank of about 6000 L capacity. Diesel oil has a fire risk, due to its high flammability. Since the seismic camps are located far away from any human settlements and the quantity of storage is not significant, any effects from fire will be highly localised. Based on the above discussion, the impacts on public health and safety are assessed as below:

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

7 SUMMARY OF SIGNIFICANT ENVIRONMENTAL EFFECTS AND MITIGATION MEASURES

The identification and assessment 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 • Minor significance	• Medium risk	• Stack emissions from DGs used for power generation in seismic survey camps are suspected to exceed the permissible concentration limits prescribed in SP-1005 for stationary combustion sources. • Stack emissions from DGs may not disperse well in the atmospheric due to short stack heights. • No monitoring data are available demonstrating compliance with ambient air quality standards in seismic survey camps.
Land contamination	• Adverse • Short term • High occurrence • Minor significance	• Medium risk	• Grey water (wastewater from kitchens, bathrooms and laundries), which is discharged on land without any treatment will contain high concentration of detergents and hence will not comply with the land discharge standards.
Noise pollution	• Adverse • Long term • Low occurrence • Minor significance	• Medium risk	• DGs used for power generation in seismic survey camp generate high level noise. • No monitoring data are available demonstrating compliance with ambient noise standards in seismic survey camps.

Environmental Effect	Impact Rating	Potential Risk Level	Comments
Loss of vegetation	• Adverse • Short term • Low occurrence • Minor significance	• Medium risk	• Earthmoving operations involving bulldozers prior to seismic survey may cause damage to vegetation on sites. • The rate of revegetation may be slow due to scanty rainfall in most places.
Visual intrusion	• Adverse • Long term / Short term • Low occurrence • Minor significance	• Medium risk	• Bulldozing operations prior to seismic survey may generate dust clouds. • The tracks and tyre marks left behind in virgin areas by the movement of heavy duty vehicles used by the seismic survey teams may last for a long time.

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.

Specification	Areas of Non-compliance or Concern	Recommended Additional Mitigation Measures
SP-1005: Specification for Emissions to Atmosphere	• Stack emissions from DGs used for power generation in seismic survey camps are suspected to exceed the permissible concentration limits prescribed in SP-1005 for stationary combustion sources. • Stack emissions from DGs may not disperse well in the atmospheric due to short stack heights. • No monitoring data are available demonstrating compliance with ambient air quality standards in seismic survey camps.	• SP-1005 may require an amendment since standard designs of DGs are unlikely to meet these emissions standards. • Ambient air quality shall be monitored in seismic survey camps to check for compliance. • If ambient air standards are not met, mitigation measures such as increasing the stack height, retrofitting the DGs with air pollution control devices, using better fuels etc. may need to be implemented.
SP-1006: Specification for Aqueous Effluents	• Grey water (wastewater from kitchen, bathrooms and laundries), which is discharged on land without any treatment will contain high concentration of detergents and hence will not comply with the land discharge standards.	• The causes for operational deficiency of the STPs shall be identified and corrected immediately. • Grey water shall not be discharged without any treatment.
SP-1007: Specification for Accidental Releases to Land and Water	• None	• None
SP-1008: Specification for Use of Energy, Materials and Resources	• Efficient use of fuel and water in the field activities of the asset is not demonstrated.	• Fuel conservation measures shall be promoted. • Water conservations measures shall be promoted.

Specification	Areas of Non-compliance or Concern	Recommended Additional Mitigation Measures
SP-1009: Specification for Waste Management	• None	• None
SP-1010: Specification for Environmental Noise and Vibration	• DGs used for power generation in seismic survey camp generate high level noise. • No monitoring data are available demonstrating compliance with ambient noise standards in seismic survey camps.	• Work place and ambient noise levels shall be monitored in seismic survey camps to check for compliance with the standards. • If warranted, noise attenuation measures shall be taken.
SP-1011: Specification for Flora and Fauna	• Earthmoving operations involving bulldozers prior to seismic survey may cause damage to vegetation on sites.	• Earthmoving operations shall be minimised to the extent possible. • Care shall be taken to avoid areas with dense vegetation.
SP-1012: Specification for Land Management	• Bulldozing operations prior to seismic survey may generate dust clouds. • The tracks and tyre marks left behind in virgin areas by the movement of heavy duty vehicles used by the seismic survey teams may last for a long time.	• Areas of visual significance shall be avoided to the extent possible. • Efforts shall be made to restore the worked-over areas to near natural state after completion of survey.
SP-1170: Specification for Management of Naturally Occurring Radioactive	• None	• None

8 REFERENCES

1. WS/Atkins, *Geosolutions Asset Environmental Assessment Report*, PDO, November 1999

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

3. PDO, *HSE in Seismic Bulldozing Operations Guideline* GU 423, July 2002

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

APPENDIX 1: DETAILS OF PERSONNEL RESPONSIBLE FOR PREPARATION AND REVIEW OF THE REPORT

HMR Environmental Engineering Consultants, Oman are responsible for the preparation of this report on environmental assessment for geosolutions asset. 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

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
XGS	Mark Peach	HSE Advisor - GeoSolutions

APPENDIX 2: 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 3: ENVIRONMENTAL HAZARDS AND EFFECTS IDENTIFICATION MATRIX: GEOSOLUTIONS 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 construction of accommodation facilities										**X**	**X**										
For seismic survey			**X**							**X**	**X**		**X**	**X**	**X**						**X**
Utilization of Mineral Resources																					
Fuel for vehicles and DG sets	**X**																				
Utilization of Groundwater Resources																					
For domestic purpose		**X**						**X**													
Utilization of Human Resources																					
Employment of migrant construction workers																				**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 Air Pollutants																					
Dust from seismic 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**															**X**	
Release of Energy into Atmosphere																					
Hot gases from DG stacks					**X**																
High level noise from stationary sources						**X**															
High level noise from mobile sources						**X**															
Discharges of Liquid Effluents																					
Land discharge of treated effluent												**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
Discharge of gray water												**X**									
Accidental spillage of hazardous liquids								**X**				**X**									
Disposal of Solid Wastes																					
Handling and transport of hazardous wastes												**X**								**X**	
Functional Activities																					
Seismic Survey					**X**	**X**					**X**			**X**	**X**						**X**
Bulk storage of hazardous substances																				**X**	
Road travel														**X**							

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