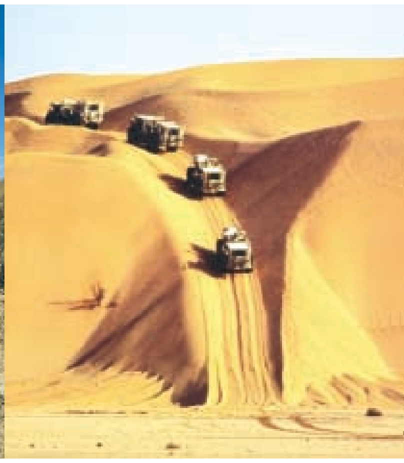
Joint E&P Forum/UNEP Technical Publication

Environmental management in oil and gas exploration and production

An overview of issues and management approaches

E&P Forum

UNEP

UNEP Industry and Environment (UNEP IE)

UNEP established its Industry and Environment office (UNEP IE) in 1975 to bring industry and government together to promote environmentally sound industrial development. UNEP IE is located in Paris. Its goals are: 1) to encourage the incorporation of environmental criteria in industrial development plans; 2) to facilitate the implementation of procedures and principles for the protection of the environment; 3) to promote preventive environmental protection through cleaner production and other pro-active approaches; and 4) to stimulate the exchange of information and experience throughout the world.

To achieve these goals, UNEP IE has developed programme elements such as: Accident Prevention (APELL), Cleaner Production, Energy, OzonAction, Industrial Pollution Management, Tourism. UNEP IE organizes conferences and seminars, undertakes training and cooperative activities backed by regular follow-up and assessment. To promote the transfer of information and the sharing of knowledge and experience, UNEP IE has developed three complementary tools: technical reports, the quarterly *Industry and Environment* review, and a technical query-response service.

UNEP Industry and Environment, Tour Mirabeau, 39–43 quai André Citroën, 75739 Paris Cedex 15, France
Tel: +33 1 44 37 14 50 Fax: +33 1 44 37 14 74 e-mail: unepie@unep.fr http://www.unepie.org

The E&P Forum
(Oil Industry International Exploration and Production Forum)

The E&P Forum is the international association of oil companies and petroleum industry organizations formed in 1974. It was established to represent its members' interests at the specialist agencies of the United Nations, governmental and other international bodies concerned with regulating the exploration and production of oil and gas. While maintaining this activity, the Forum now concerns itself with all aspects of E&P operations, with particular emphasis on safety of personnel and protection of the environment, and seeks to establish industry positions with regard to such matters.

At present the Forum has almost 60 members worldwide, the majority being oil and gas companies operating in 60 different countries, but with a number of national oil industry associations/institutes.

The work of the Forum covers:

- monitoring the activities of relevant global and regional international organizations;
- developing industry positions on issues;
- advancing the positions on issues under consideration, drawing on the collective expertise of its members; and
- disseminating information on good practice through the development of industry guidelines, codes of practice, checklists etc.

E&P Forum, 25–28 Old Burlington Street, London W1X 1LB, UK
Tel: +44 (0)171 437 6291 Fax: +44 (0)171 434 3721 http://www.eandpforum.co.uk

Environmental management in oil and gas exploration and production

An overview of issues and management approaches

Foreword

Awareness of the importance of environmental issues has become more and more central to the thinking of the oil industry and regulators in the last decades. Integration of development and environment, approached in partnership between stakeholders, was the theme of the UNCED Conference in Rio in 1992. Principle 4 of the Rio Declaration captures this challenge: "In order to achieve sustainable development, environmental protection shall constitute an integral part of the development process and cannot be considered in isolation from it".

These guidelines on environmental management in oil and gas exploration and production are based on the collective experience gained by UNEP and the oil industry. They should help meet the challenge of fully integrating protection of the environment in the regulatory and business processes that control the exploration and production of oil and gas. They can serve as a basis for preparing or improving regulations, policies and programmes to minimize the impact on the environment of these activities.

The document provides an overview of the environmental issues and the technical and management approaches to achieving high environmental performance in the activities necessary for oil and gas exploration and production in the world. Management systems and practices, technologies and procedures are described that prevent and minimize impact. The continued sharing of best practices, and the application of comprehensive management systems by oil companies and their contractors and suppliers are essential.

The role of government in setting and enforcing regulations is also key to minimizing the potential environmental impact. The trend towards performance-based regulations, rather the traditional command and control approach, has the potential to stimulate more innovative and effective environmental management in all areas of the world.

Consultation with local communities and other legitimate stakeholders is also an essential element of good environmental management.

Both UNEP and E&P Forum would appreciate feedback from industry and regulatory agencies on the use they have made of this document, and any other guidelines or assistance needed, as input to our programmes to further enhance the environmental performance of the oil industry.

J. P. (Koos) Visser
Chairman, E&P Forum Environmental Quality Committee (1993–6)

Jacqueline Aloisi de Larderel
Director, UNEP, Industry and Environment Centre (UNEP/IE)

Acknowledgements

These guidelines have been prepared by the Oil Industry International Exploration and Production Forum (E&P Forum) and the United Nations Environment Programme Industry and Environment Centre (UNEP IE).

The base text was prepared by Ian Borthwick (Borthwick and Associates) and its development was coordinated by Fritz Balkau (UNEP IE), Tony Read (E&P Forum) and Jennifer Monopolis (E&P Forum/Exxon).

Valuable comments on drafts have been received from:
Ingunn Valvatne (Norwegian State Pollution Control Authority)
David Macaulay (Environment Protection Authority, Victoria, Australia)
Jon Ward (Dubai Municipality)
Richard Arseneault (Natural Resources Canada)
Michael Waite (Environmental Protection Agency, Western Australia)
Mark Radka (UNEP ROAP)
Halifa Drammeh (UNEP Water Branch)
Janet Stevens (UNEP IE)
Koos Visser (Shell)
Joel Robins (Amoco)
Carlos Simon (Texaco)
Kit Armstrong (Chevron)
Jan Hartog (Shell)

Cover photographs were kindly supplied by Shell International Exploration and Production B.V.

This report was designed and produced by Words and Publications, Oxford, United Kingdom. It is printed on chlorine-free paper which is bleached without any damage to the environment.

UNEP IE/PAC Technical Report 37

E&P Forum Report 2.72/254

ISBN 92-807-1639-5

Contents

Part 1

Overview

1 Introduction

Background

The oil and gas industry is truly global, with operations conducted in every corner of the globe, from Alaska to Australia, from Peru to China, and in every habitat from Arctic to desert, from tropical rainforest to temperate woodland, from mangrove to offshore.

The global community will rely heavily on oil and gas supplies for the foreseeable future. World primary energy consumption in 1994 stood at nearly 8000 million tonnes of oil equivalents (BP *Statistical Review of World Energy*, June 1995); oil and gas represented 63 per cent of world energy supply, with coal providing 27 per cent, nuclear energy 7 per cent and hydro-electric 3 per cent. The challenge is to meet world energy demands, whilst minimizing adverse impact on the environment by conforming to current good practice.

The exploitation of oil and gas reserves has not always been without some ecological side effects. Oil spills, damaged land, accidents and fires, and incidents of air and water pollution have all been recorded at various times and places. In recent times the social impact of operations, especially in remote communities, has also attracted attention. The oil and gas industry has worked for a long time to meet the challenge of providing environmental protection. Much has already been achieved but the industry recognizes that even more can be accomplished.

The United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in June 1992—'The Earth Summit'—focused world attention on the close links that exist between the environment and socio-economic development. The Summit reviewed global environmental issues and resulted in two conventions (the Framework Convention on Climate Change and the Convention on Biological Diversity), as well as the Rio Declaration and Agenda 21—plan of action. The central message of Agenda 21 is one of interdependence and cross-sector partnership, and the plan of action provided a new approach to the wide-ranging socio-economic and environmental challenges facing the world community.

The various disparate environmental problems that had for many years been addressed individually were put into a general global context during UNCED, and Agenda 21 has structured issues to permit easy translation into national action plans. It also includes the important dimensions of social change and the impact on cultural values that accompany development projects, particularly those near remote communities. Overall, Agenda 21 has had a strong influence on national policies, with both structure and activity programmes following the framework of international initiatives.

Agenda 21 is also remarkable for its explicit mention of key actors and roles. The role of the business sector is outlined, as is partnership building between the private sector and governments. These proposals seem to have borne some fruit. Leading business groups such as the International Chamber of Commerce (ICC), as well as sectoral associations, including the E&P Forum and IPIECA representing the oil and gas industry, have undertaken a number of environmental initiatives, often in cooperation with other national or international bodies. UNEP has responded by reinforcing its contacts with industry associations to undertake joint publication and training projects.

Environmental issues in Agenda 21

- Protecting the atmosphere
- Managing land sustainably
- Combating deforestation
- Combating desertification and drought
- Sustainable mountain development
- Sustainable agriculture and rural development
- Conservation of biological diversity
- Management of biotechnology
- Protecting and managing the oceans
- Protecting and managing fresh water
- Safer use of toxic chemicals
- Managing hazardous wastes
- Managing solid wastes and sewage
- Managing radioactive wastes

The broad environmental issues faced by the oil and gas exploration and production industry are manifested at both local and global levels. They include: habitat protection and biodiversity, air emissions, marine and freshwater discharges, incidents and oil spills, and soil and groundwater contamination. The industry has responded to these issues. The challenge is to ensure that all operations conform to current good practice.

The continual evolution of the environmental agenda must also be taken into account. Industry places much emphasis on establishing effective management systems and has gone a long way to ensure that environmental issues are key components of corporate culture, with the issues related to health, safety and environment often being considered together, because they have much in common.

Through the Oil Industry International Exploration and Production Forum (E&P Forum), a common industry-wide Health, Safety and Environmental Management System (HSE-MS) has been agreed and published in 1994 as a guideline document, the fundamentals of which are presented in Section 5. The E&P Forum is recognized as the representative body facilitating the sharing of knowledge and information on best practice within the industry. While there are some important differences in handling health, safety and environmental issues, management is tending to converge towards system models such as those represented by ISO 9000 and 14000 series.

Purpose and scope

The purpose of this document is to provide an overview of environmental issues in the oil and gas exploration and production industry, and of the best approaches to achieving high environmental performance in all parts of the world. It should be noted that it covers only exploration and production activities and does not discuss large scale storage and transportation issues, or downstream processing. Nor does it attempt to cover social development issues in detail, although they are mentioned as important elements in the text, alongside ecological issues.

This document provides an overview for key stakeholders in industry and government. It is intended for use by managers in industry and government and, in addition, by other stakeholders, particularly those involved in the consultative process (see Annex 1).

Content of the document

This document provides both an initial source and a single point overview of environmental issues and management approaches in oil and gas exploration and production operations. It defines the framework for environmental management against a background of existing information developed by industry, the United Nations Environment Programme (UNEP), and a variety of non-governmental organizations. In the short space available it has not been possible to give a comprehensive discussion of all aspects. Instead, this document provides a framework within which the various technical reviews and guidelines that are already available from different sources can be applied. Accordingly, a comprehensive bibliography is provided and cross-referenced where applicable throughout the text.

The text gives a brief overview of the oil and gas exploration and production process, and examines the potential 'environmental effects' or, as they are increasingly known, 'impacts'. Strategic management issues are presented in terms of the regulatory framework and the corporate approach to environmental management. Operational aspects are discussed in terms of environmental protection measures. In order to simplify matters for the reader, operations, potential effects and control measures have been written as separate sections. However, they should not be used in isolation in drawing conclusions. For example, a range of potential impacts is presented in Section 3 (cf. Table 2), regulatory and management approaches are illustrated in Sections 4 and 5, and the operational approaches in Section 6, which describes how impacts can be avoided or minimized using Table 5.

2 Overview of the oil and gas exploration and production process

The oil and gas industry comprises two parts: 'upstream'—the exploration and production sector of the industry; and 'downstream'—the sector which deals with refining and processing of crude oil and gas products, their distribution and marketing. Companies operating in the industry may be regarded as fully integrated, (i.e. have both upstream and downstream interests), or may concentrate on a particular sector, such as exploration and production, commonly known as an E&P company, or just on refining and marketing (a R&M company). Many large companies operate globally and are described as 'multi-nationals', whilst other smaller companies concentrate on specific areas of the world and are often referred to as 'independents'. Frequently, a specific country has vested its interests in oil and gas in a national company, with its name often reflecting its national parenthood. In the upstream sector, much reliance is placed upon service and upon contractor companies who provide specialist technical services to the industry, ranging from geophysical surveys, drilling and cementing, to catering and hotel services in support of operations. This relationship between contractors and the oil companies has fostered a close partnership, and increasingly, contractors are fully integrated with the structure and culture of their clients.

Scientific exploration for oil, in the modern sense, began in 1912 when geologists were first involved in the discovery of the Cushing Field in Oklahoma, USA. The fundamental process remains the same, but modern technology and engineering have vastly improved performance and safety.

In order to appreciate the origins of the potential impacts of oil development upon the environment, it is important to understand the activities involved. This section briefly describes the process, but those requiring more in-depth information should refer to literature available from industry groups and academia. Table 1 provides a summary of the principal steps in the process and relates these to operations on the ground.

Exploration surveying

In the first stage of the search for hydrocarbon-bearing rock formations, geological maps are reviewed in desk studies to identify major sedimentary basins. Aerial photography may then be used to identify promising landscape formations such as faults or anticlines. More detailed information is assembled using a field geological assessment, followed by one of three main survey methods: magnetic, gravimetric and seismic.

The Magnetic Method depends upon measuring the variations in intensity of the magnetic field which reflects the magnetic character of the various rocks present, while the Gravimetric Method involves the measurements of small variations in the gravitational field at the surface of the earth. Measurements are made, on land and at sea, using an aircraft or a survey ship respectively.

A seismic survey, as illustrated in Figure 1 on page 6, is the most common assessment method and is often the first field activity undertaken. The Seismic Method is used for identifying geological structures and relies on the differing reflective properties of soundwaves to various rock strata, beneath terrestrial or oceanic surfaces. An energy source transmits a pulse of acoustic energy into the ground which travels as a wave into the earth. At each point where different geological strata exist, a part of the energy is transmitted down to deeper layers within the earth, while the remainder is reflected back to the surface. Here it is picked up by a series of sensitive receivers called geophones or seismometers on land, or hydrophones submerged in water.

Special cables transmit the electrical signals received to a mobile laboratory, where they are amplified and filtered and then digitized and recorded on magnetic tapes for interpretation.

Dynamite was once widely used as the energy source, but environmental considerations now generally favour lower-energy sources such as vibroseis on land (composed of a generator that hydraulically transmits vibrations into the earth) and the air gun (which releases compressed air) in offshore exploration. In areas where preservation of vegetation cover is important, the shot hole (dynamite) method is preferable to vibroseis.

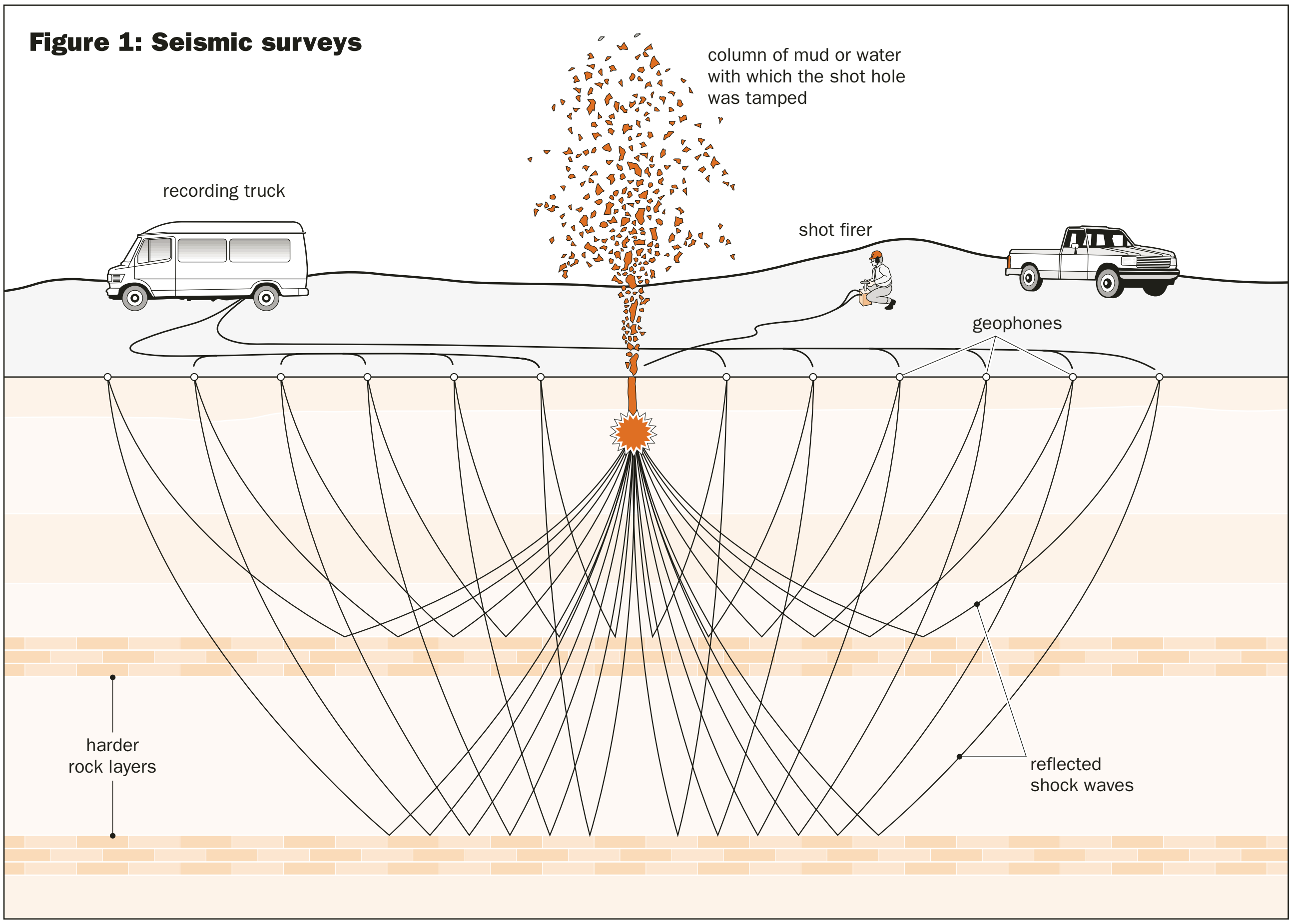
Exploration drilling

Once a promising geological structure has been identified, the only way to confirm the presence of hydrocarbons and the thickness and internal pressure of a reservoir is to drill

Table 1: Summary of the exploration and production process

Activity	Potential requirement on ground
Desk study: identifies area with favourable geological conditions	None
Aerial survey: if favourable features revealed, then	Low-flying aircraft over study area
Seismic survey: provides detailed information on geology	Access to onshore sites and marine resource areas Possible onshore extension of marine seismic lines Onshore navigational beacons Onshore seismic lines Seismic operation camps
Exploratory drilling: verifies the presence or absence of a hydrocarbon reservoir and quantifies the reserves	Access for drilling unit and supply units Storage facilities Waste disposal facilities Testing capabilities Accommodation
Appraisal: determines if the reservoir is economically feasible to develop	Additional drill sites Additional access for drilling units and supply units Additional waste disposal and storage facilities
Development and production: produces oil and gas from the reservoir through formation pressure, artificial lift, and possibly advanced recovery techniques, until economically feasible reserves are depleted	Improved access, storage and waste disposal facilities Wellheads Flowlines Separation/treatment facilities Increased oil storage Facilities to export product Flares Gas production plant Accommodation, infrastructure Transport equipment
Decommissioning and rehabilitation may occur for each of above phases.	Equipment to plug wells Equipment to demolish and remove installations Equipment to restore site

Figure 1: Seismic surveys

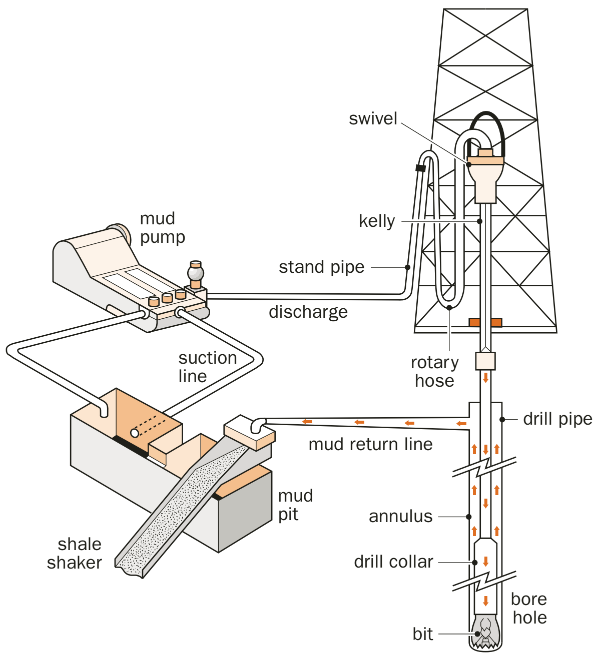


exploratory boreholes. All wells that are drilled to discover hydrocarbons are called ‘exploration’ wells, commonly known by drillers as ‘wildcats’. The location of a drill site depends on the characteristics of the underlying geological formations. It is generally possible to balance environmental protection criteria with logistical needs, and the need for efficient drilling.

For land-based operations a pad is constructed at the chosen site to accommodate drilling equipment and support services. A pad for a single exploration well occupies between 4000–15 000 m^2. The type of pad construction depends on terrain, soil conditions and seasonal constraints. Operations over water can be conducted using a variety of self-contained mobile offshore drilling units (MODUs), the choice of which depends on the depth of water, seabed conditions and prevailing meteorological conditions,—particularly wind speed, wave height and current speed. Mobile rigs commonly used offshore include jack-ups, semi-submersibles and drillships, whilst in shallow protected waters barges may be used.

Land-based drilling rigs and support equipment are normally split into modules to make them easier to move. Drilling rigs may be moved by land, air or water depending on access, site location and module size and weight. Once on site, the rig and a self-contained support camp are then assembled. Typical drilling rig modules include a derrick, drilling mud handling equipment, power generators, cementing equipment and tanks for fuel and water (see Figure 2). The support camp is self-contained and generally provides workforce accommodation, canteen facilities, communications, vehicle maintenance and parking areas, a helipad for

Figure 2: Drilling



remote sites, fuel handling and storage areas, and provision for the collection, treatment and disposal of wastes. The camp should occupy a small area (typically 1000 m^2), and be located away from the immediate area of the drilling rig—upstream from the prevailing wind direction.

Once drilling commences, drilling fluid or mud is continuously circulated down the drill pipe and back to the surface equipment. Its purpose is to balance underground hydrostatic pressure, cool the bit and flush out rock cuttings. The risk of an uncontrolled flow from the reservoir to the surface is greatly reduced by using blowout preventers—a series of hydraulically actuated steel rams that can close quickly around the drill string or casing to seal off a well. Steel casing is run into completed sections of the borehole and cemented into place. The casing provides structural support to maintain the integrity of the borehole and isolates underground formations.

Drilling operations are generally conducted around-the-clock. The time taken to drill a bore hole depends on the depth of the hydrocarbon bearing formation and the geological conditions, but it is commonly of the order of one or two months. Where a hydrocarbon formation is found, initial well tests—possibly lasting another month—are conducted to establish flow rates and formation pressure. These tests may generate oil, gas and formation water—each of which needs to be disposed of.

After drilling and initial testing, the rig is usually dismantled and moved to the next site. If the exploratory drilling has discovered commercial quantities of hydrocarbons, a wellhead valve assembly may be installed. If the well does not contain commercial quantities of hydrocarbon, the site is decommissioned to a safe and stable condition and restored to its original state or an agreed after use. Open rock formations are sealed with cement plugs to prevent upward migration of wellbore fluids. The casing wellhead and the top joint of the casings are cut below the ground level and capped with a cement plug.

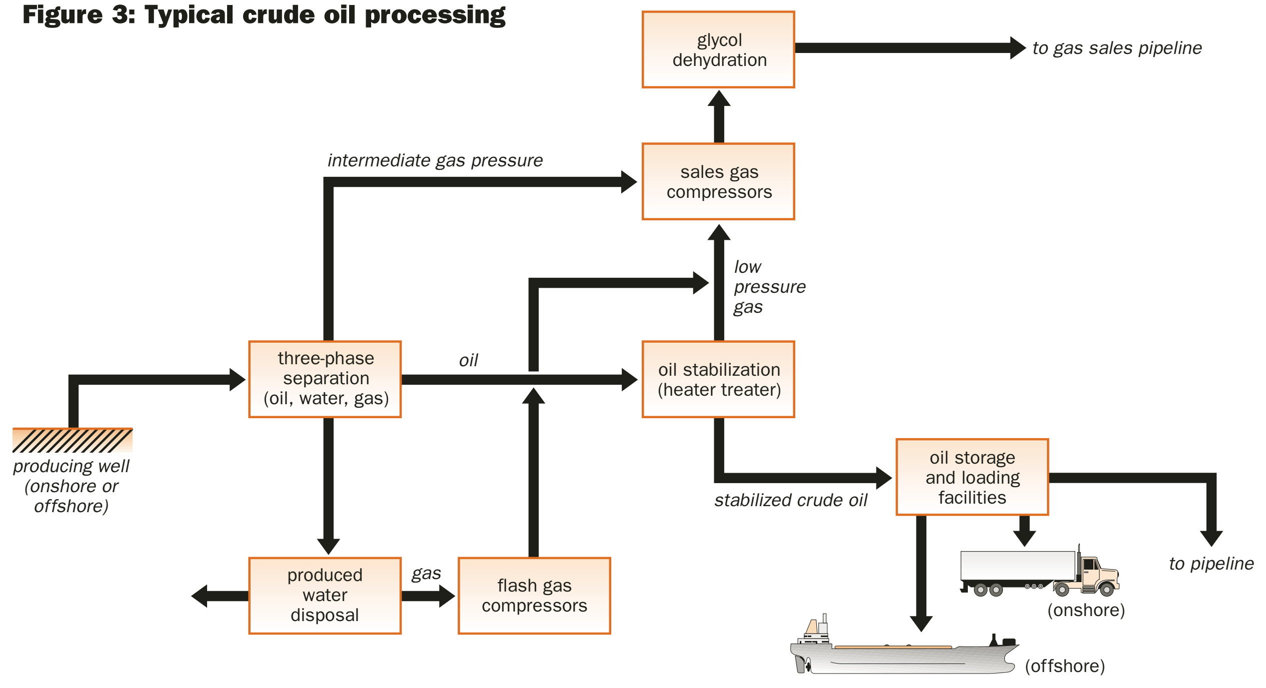
Appraisal

When exploratory drilling is successful, more wells are drilled to determine the size and the extent of the field. Wells drilled to quantify the hydrocarbon reserves found are called 'outstep' or 'appraisal' wells. The appraisal stage aims to evaluate the size and nature of the reservoir, to determine the number of confirming or appraisal wells required, and whether any further seismic work is necessary. The technical procedures in appraisal drilling are the same as those employed for exploration wells, and the description provided above applies equally to appraisal operations. A number of wells may be drilled from a single site, which increases the time during which the site is occupied. Deviated or directional drilling at an angle from a site adjacent to the original discovery borehole may be used to appraise other parts of the reservoir, in order to reduce the land used or 'foot print'.

Development and production

Having established the size of the oil field, the subsequent wells drilled are called 'development' or 'production' wells. A small reservoir may be developed using one or more of the appraisal wells. A larger reservoir will require the drilling of

Figure 3: Typical crude oil processing



additional production wells. Multiple production wells are often drilled from one pad to reduce land requirements and the overall infrastructure cost. The number of wells required to exploit the hydrocarbon reservoir varies with the size of the reservoir and its geology. Large oilfields can require a hundred or more wells to be drilled, whereas smaller fields may only require ten or so. The drilling procedure involves similar techniques to those described for exploration; however, with a larger number of wells being drilled, the level of activity obviously increases in proportion. The well sites will be occupied for longer, and support services—workforce accommodation, water supply, waste management, and other services—will correspondingly increase. As each well is drilled it has to be prepared for production before the drilling rig departs. The heavy drill pipe is replaced by a lighter weight tubing in the well and occasionally one well may carry two or three strings of tubing, each one producing from different layers of reservoir rock. At this stage the blowout preventer is replaced by a control valve assembly or 'Christmas Tree'.

Most new commercial oil and gas wells are initially free flowing: the underground pressures drive the liquid and gas up the well bore to the surface. The rate of flow depends on a number of factors such as the properties of the reservoir rock, the underground pressures, the viscosity of the oil, and the oil/gas ratio. These factors, however, are not constant during the commercial life of a well, and when the oil cannot reach the surface unaided, some form of additional lift is required, such as a pumping mechanism or the injection of gas or water to maintain reservoir pressures. It is now quite common to inject gas, water, or steam into the reservoir at the start of the field's life in order to maintain pressures and optimize production rates and the ultimate recovery potential of oil and gas. This in turn may require the drilling of additional wells, called injection wells. Other methods of stimulating production can be used, such as hydraulic fracturing of the hydrocarbon bearing formation, and acid treatment (particularly in limestones) to increase and enlarge flow channels.

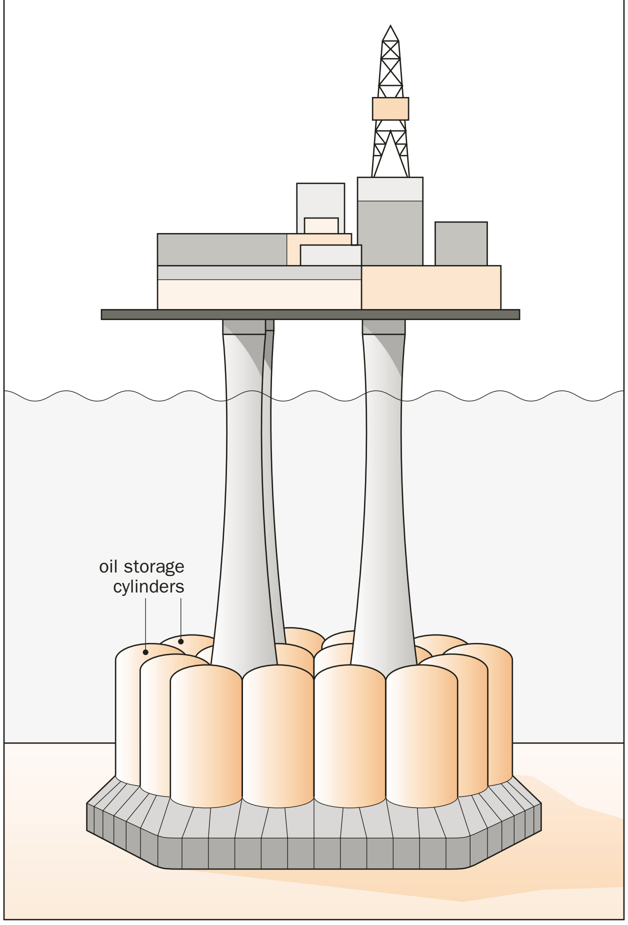
Once the hydrocarbon reaches the surface, it is routed to the central production facility which gathers and separates the produced fluids (oil, gas and water). The size and type of the installation will depend on the nature of the reservoir, the volume and nature of produced fluids, and the export option selected.

The production facility processes the hydrocarbon fluids and separates oil, gas and water. The oil must usually be free of dissolved gas before export. Similarly, the gas must be stabilized and free of liquids and unwanted components such as hydrogen sulphide and carbon dioxide. Any water produced is treated before disposal. A schematic representation of a typical crude oil processing facility is shown in Figure 3.

Routine operations on a producing well would include a number of monitoring, safety and security programmes, maintenance tasks, and periodic downhole servicing using a wire line unit or a workover rig to maintain production. The operator will be able to extract only a portion of the oil present using primary recovery (i.e. natural pressure and simple pumping) but a range of additional recovery methods are available as discussed above. For example, secondary recovery uses waterflood or gas injection, and tertiary methods employing chemicals, gases or heat may also be used to increase the efficiency of oil recovery.

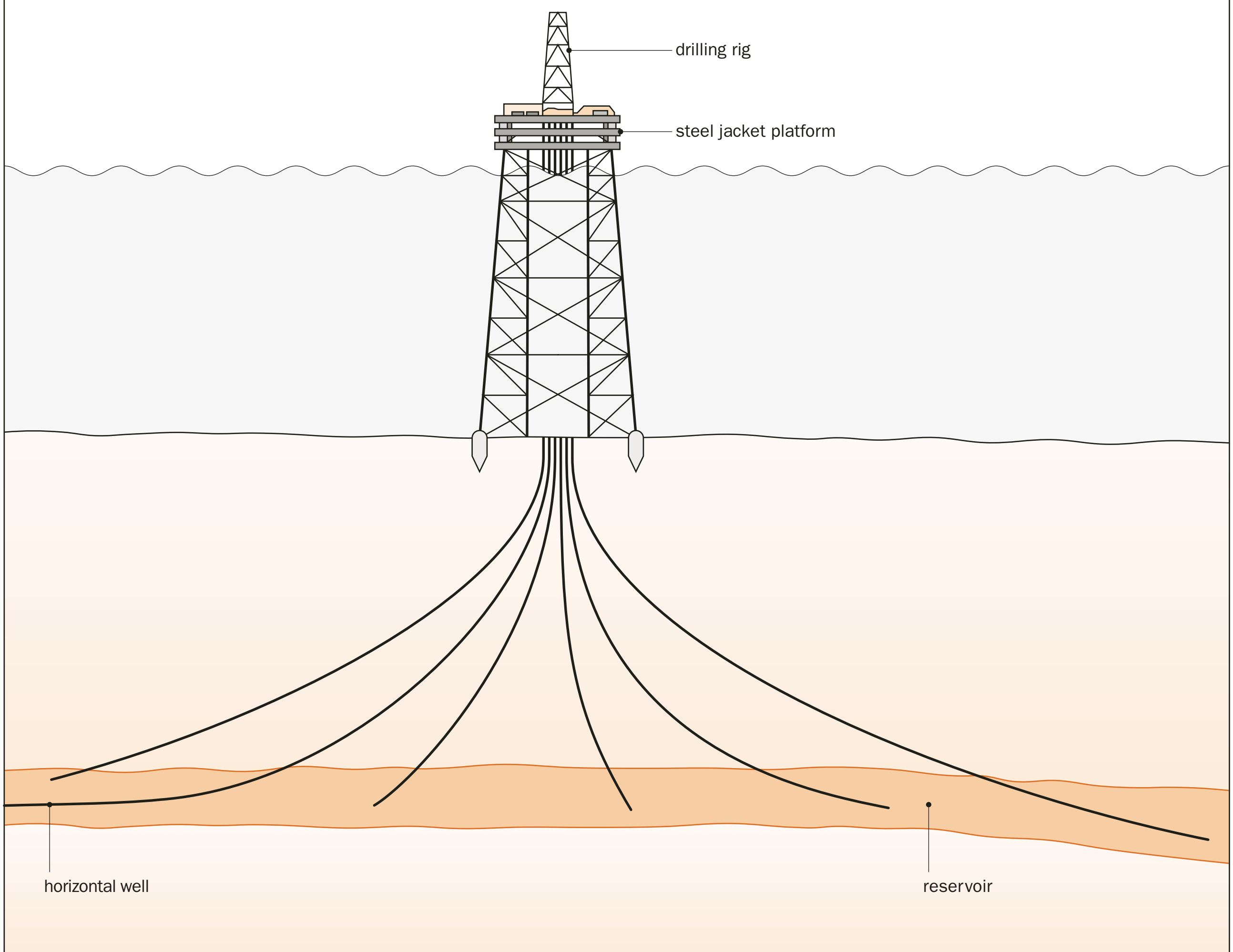
The infrastructure required for development drilling in onshore operations is similar to that described above for exploration. However, once drilling is completed, the individual wellhead assemblies and well sites are considerably smaller than when the drill rig was on site. Typically, each well requires an area of some 10 m^2 surrounded by a security fence. Often the well sites are concentrated within a central area, which includes processing facilities, offices and workshops, and this would typically occupy an area of several hectares, depending upon the capacity of the field. Since the production operation is a long-term development, the temporary facilities used in exploration are replaced by permanent facilities and are subject to detailed planning, design and engineering and construction. The temporary workforce associated with exploration activity is replaced by a permanent workforce, usually accommodated in the local area and, where desirable, fully integrated with the local community: indeed a large proportion of the workforce may be recruited locally and receive specialized training. Similarly, the local infrastructure will need to provide a variety of requirements in addition to labour, such as materials supplies, education, medical, etc.

Figure 4: Concrete gravity platform



In offshore production developments, permanent structures are necessary to support the required facilities, since typical exploration units are not designed for full scale production operations. Normally, a steel platform is installed to serve as the gathering and processing centre and more than 40 wells may be drilled directionally from this platform. Concrete platforms are sometimes used (see Figure 4). If the field is large enough, additional 'satellite' platforms may be needed, linked by subsea flowlines to the central facility. In shallow water areas, typically a central processing facility is supported by a number of smaller

Figure 5: Directional drilling



wellhead platforms. Recent technological developments, aimed at optimizing operations, include remotely operated subsea systems which remove the requirement for satellite platforms. This technology is also being used in deep water where platforms are unsuitable, and for marginal fields where platforms would be uneconomic. In these cases, floating systems—ships and semi-submersibles—'service' the subsea wells on a regular basis.

Recent advances in horizontal drilling have enhanced directional drilling as a means of concentrating operations at one site and reducing the 'footprint' on land of production operations (Figure 5) and the number of platforms offshore. The technology now enables access to a reservoir up to several kilometres from the drill rig, while technology is developing to permit even wider range. This further minimizes the 'footprint' by reducing the need for satellite wells. It also allows for more flexibility in selecting a drill site, particularly where environmental concerns are raised.

Decommissioning and rehabilitation

The decommissioning of onshore production installations at the end of their commercial life, typically 20–40 years, may involve removal of buildings and equipment, restoration of the site to environmentally-sound conditions, implementation of measures to encourage site re-vegetation, and continued monitoring of the site after closure. Planning for decommissioning is an integral part of the overall management process and should be considered at the beginning of the development during design, and is equally applicable to both onshore and offshore operations. Section 6 provides more detailed discussion on decommissioning and rehabilitation.

By their nature, most exploration wells will be unsuccessful and will be decommissioned after the initial one-to-three months of activity. It is, therefore, prudent to plan for this from the outset, and ensure minimal environmental disruption. Decommissioning and rehabilitation will, subsequently, be simplified.

3 Potential environmental impacts

Oil and gas exploration and production operations have the potential for a variety of impacts on the environment. These 'impacts' depend upon the stage of the process, the size and complexity of the project, the nature and sensitivity of the surrounding environment and the effectiveness of planning, pollution prevention, mitigation and control techniques.

The impacts described in this section are potential impacts and, with proper care and attention, may be avoided, minimized or mitigated. The industry has been proactive in the development of management systems, operational practices and engineering technology targeted at minimizing environmental impact, and this has significantly reduced the number of environmental incidents. Various initiatives are described in the UNEP/IPIECA publication *Technology Cooperation and Capacity Building*.[19] Examples include innovative technology applied by Mobil and Shell in Malaysia; commitment to the local community by Imperial Oil in Northern Canada and Canadian Occidental in Yemen; and various environmental protection programmes implemented by Chevron in Papua New Guinea, BP in Colombia, Amoco in Western Siberia and Caltex in Indonesia. Arco has applied an 'offshore' approach to operations in remote rainforest locations (see Hettler *et al.* [53]); and various novel technologies have been applied to the disposal of drilling wastes[49], produced water treatment[45] and atmospheric emissions[1, 46].

Several types of potential impacts are discussed here. They include human, socio-economic and cultural impacts; and atmospheric, aquatic, terrestrial and biosphere impacts. Table 2 on page 17 provides a summary of potential impacts in relation to the environmental component affected and the source and operational activity under consideration.

The early phases of exploration described in Table 1 on page 5 (desk studies, aerial survey, seismic survey and exploratory drilling) are short-term and transient in nature. The longest phase, drilling, typically lasts a matter of one to three months, although the period may be longer in certain situations. It is only when a significant discovery is made that the nature of the process changes into a longer term project to appraise, develop and produce the hydrocarbon reserves. Proper planning, design and control of operations in each phase will avoid, minimize or mitigate the impacts, and techniques to achieve this are set out in detail in Section 6. It is also important to understand that through the management procedures set out in Section 5, the environmental implications of all stages of the exploration and development process can be assessed systematically before a project starts, and appropriate measures taken.

In assessing potential impacts, it is important to consider the geographic scale, (global, regional, local) over which they might occur. Similarly, it is important to consider perception and magnitude of potential impacts, which will frequently depend on subjective interpretation of acceptability or significance. Consultation, negotiation and understanding are vital in addressing the problem, and will assist in moving from positions of confrontation, dependence or isolation among stakeholders to positions of mutually agreed and understood interdependence between partners.

Human, socio-economic and cultural impacts

Exploration and production operations are likely to induce economic, social and cultural changes. The extent of these changes is especially important to local groups, particularly indigenous people who may have their traditional lifestyle affected. The key impacts may include changes in:

- land-use patterns, such as agriculture, fishing, logging, hunting, as a direct consequence (for example land-take and exclusion) or as a secondary consequence by providing new access routes, leading to unplanned settlement and exploitation of natural resources;
- local population levels, as a result of immigration (labour force) and in-migration of a remote population due to increased access and opportunities;
- socio-economic systems due to new employment opportunities, income differentials, inflation, differences in per capita income, when different members of local groups benefit unevenly from induced changes;
- socio-cultural systems such as social structure, organization and cultural heritage, practices and beliefs, and secondary impacts such as effects on natural resources, rights of access, and change in value systems influenced by foreigners;

- availability of, and access to, goods and services such as housing, education, healthcare, water, fuel, electricity, sewage and waste disposal, and consumer goods brought into the region;
- planning strategies, where conflicts arise between development and protection, natural resource use, recreational use, tourism, and historical or cultural resources;
- aesthetics, because of unsightly or noisy facilities; and
- transportation systems, due to increased road, air and sea infrastructure and associated effects (e.g. noise, accident risk, increased maintenance requirements or change in existing services).

Some positive changes will probably also result, particularly where proper consultation and partnership have developed. For example, improved infrastructure, water supply, sewerage and waste treatment, health care and education are likely to follow. However, the uneven distribution of benefits and impacts and the inability, especially of local leaders, always to predict the consequences, may lead to unpredictable outcomes. With careful planning, consultation, management, accommodation and negotiation some, if not all, of the aspects can be influenced.

Atmospheric impacts

Atmospheric issues are attracting increasing interest from both industry and government authorities worldwide. This has prompted the oil and gas exploration and production industry to focus on procedures and technologies to minimize emissions.

In order to examine the potential impacts arising from exploration and production operations it is important to understand the sources and nature of the emissions and their relative contribution to atmospheric impacts, both local and those related to global issues such as stratospheric ozone depletion and climate change.

The primary sources of atmospheric emissions from oil and gas operations arise from:

- flaring, venting and purging gases;
- combustion processes such as diesel engines and gas turbines;
- fugitive gases from loading operations and tankage and losses from process equipment;
- airborne particulates from soil disturbance during construction and from vehicle traffic; and
- particulates from other burning sources, such as well testing.

The principal emission gases include carbon dioxide, carbon monoxide, methane, volatile organic carbons and nitrogen oxides. Emissions of sulphur dioxides and hydrogen sulphide can occur and depend upon the sulphur content of the hydrocarbon and diesel fuel, particularly when used as a power source. In some cases sulphur content can lead to odour near the facility.

Ozone depleting substances are used in some fire protection systems, principally halon, and as refrigerants. Following substantial efforts by industry, unplanned emissions have been significantly reduced and alternative agents for existing and new developments have been engineered.

The volumes of atmospheric emissions and their potential impact depend upon the nature of the process under consideration. The potential for emissions from exploration activities to cause atmospheric impacts is generally considered to be low. However, during production, with more intensive activity, increased levels of emissions occur in the immediate vicinity of the operations. Emissions from production operations should be viewed in the context of total emissions from all sources, and for the most part these fall below 1 per cent of regional and global levels.

Flaring of produced gas is the most significant source of air emissions, particularly where there is no infrastructure or market available for the gas. However, where viable, gas is processed and distributed as an important commodity. Thus, through integrated development and providing markets for all products, the need for flaring will be greatly reduced.

Flaring may also occur on occasions as a safety measure, during start-up, maintenance or upset in the normal processing operation. The World Resources Institute Report *World Resources 1994–95* indicates that total gas flaring in 1991 produced a contribution of 256 x 10^6 tonnes of CO_2 emissions which represent some 1 per cent of global CO_2 emissions (22 672 x 10^6 tonnes) for that year. The E&P Forum[46] similarly reports that emissions from the North Sea exploration and production industry is less than 1 per cent of the total emissions generated by the European Union countries, and that significant reductions have occurred as a result of improved infrastructure. The report provides practical examples of techniques for improving performance with emerging technologies and good practice.

Flaring, venting and combustion are the primary sources of carbon dioxide emissions from production operations, but other gases should also be considered. For example, methane emissions primarily arise from process vents and to a lesser extent from leaks, flaring and combustion. The World Resources Institute indicates total methane emissions from oil and gas production in 1991 was 26×10^6 tonnes compared to a global total of 250×10^6, representing approximately 10 per cent of global emissions. Total methane emissions from the North Sea E&P industry are 136 000 tonnes, i.e. 0.5 per cent of worldwide industry emissions or 0.05 per cent of global methane emissions[46]. This low level derives from the significant improvement in operational practice in recent years: principally, reduction in flaring and venting as a result of improved infrastructure and utilization of gas in the North Sea. Other emission gases such as NO_x, CO and SO_x from North Sea production operations are similarly all less than 1 per cent of the emissions generated within the European Union (EU). Volatile Organic Carbon (VOC) levels are the only exception, but they still account for less than 2 per cent of the EU total emissions.

The industry has demonstrated a commitment to improve performance as indicated, for example, by a significant reduction of emissions in the North Sea. There are a number of emerging technologies and improved practices which have potential to help to improve performance further, both for existing fields and new developments. The environmental benefits and relative costs depend heavily on the specific situation for each installation e.g. on some fields there is no economic outlet for gas. In general, new installations offer more scope for implementing new technologies. Practical examples of techniques for improving performance have been pursued by the industry[46], in particular relating to reducing flaring and venting, improving energy efficiency, development of low NO_x turbines, controlling fugitive emissions, and examining replacements for fire fighting systems.

Aquatic impacts

The principal aqueous waste streams resulting from exploration and production operations are:

- produced water;
- drilling fluids, cuttings and well treatment chemicals;
- process, wash and drainage water;
- sewerage, sanitary and domestic wastes;
- spills and leakage; and
- cooling water.

Again, the volumes of waste produced depend on the stage of the exploration and production process. During seismic operations, waste volumes are minimal and relate mainly to camp or vessel activities. In exploratory drilling the main aqueous effluents are drilling fluids and cuttings, whilst in production operations—after the development wells are completed—the primary effluent is produced water.

The make-up and toxicity of chemicals used in exploration and production have been widely presented in the literature (see for example [2, 3]), whilst the E&P Forum *Waste Management Guidelines*[4] summarize waste streams, sources and possible environmentally significant constituents, as well as disposal methods. Water-based drilling fluids have been demonstrated to have only limited effect on the environment. The major components are clay and bentonite which are chemically inert and non-toxic. Some other components are biodegradable, whilst others are slightly toxic after dilution[5]. The effects of heavy metals associated with drilling fluids (Ba, Cd, Zn, Pb) have been shown to be minimal, because the metals are bound in minerals and hence have limited bioavailability. Oil-based drilling fluids and oily cuttings, on the other hand, have an increased effect due to toxicity and redox potential. The oil content of the discharge is probably the main factor governing these effects.

Ocean discharges of water-based mud and cuttings have been shown to affect benthic organisms through smothering to a distance of 25 metres from the discharge and to affect species diversity to 100 metres from the discharge. Oil-based muds and cuttings effect benthic organisms through elevated hydrocarbon levels to up 800 metres from the discharge. The physical effects of water-based muds and cuttings are often temporary in nature. For oil-based mud and cuttings the threshold criteria for gross effects on community structure has been suggested at a sediment base oil concentration of 1000 parts per million (ppm), although individual species showed effects between 150 ppm and 1000 ppm[6]. However, work is under way to develop synthetic muds to eventually replace oil-based muds.

The high pH and salt content of certain drilling fluids and cuttings poses a potential impact to fresh-water sources.

Produced water is the largest volume aqueous waste arising from production operations, and some typical constituents may include in varying amounts inorganic salts, heavy metals, solids, production chemicals, hydrocarbons, benzene, PAHs, and on occasions naturally occurring radioactive material (NORM). In the North Sea environment the impact of produced water has been demonstrated to range from minor to non-existent[7], particularly given rapid dilution factors of 200 within 1 minute, 500 within 5 minutes and 1000 in an hour at a distance corresponding to 1km from the source. The environmental impact of produced waters disposed to other receiving waters other than open ocean is highly dependent on the quantity, the components, the receiving environment and its dispersion characteristics. The extent of the impact can only be judged through an environmental impact assessment. However, discharge to small streams and enclosed water bodies is likely to require special care.

Produced water volumes vary considerably both with the type of production (oil or gas), and throughout the lifetime of a field. Typical values for North Sea fields range from 2400–40 000 m^3/day for oil installations and 2–30 m^3/day for gas production.[7] Frequently the water cut is low early in the production life of a field, but as time passes more water is produced from the reservoir and may increase to 80 per cent or more towards the end of field life.

Other aqueous waste streams such as leakage and discharge of drainage waters may result in pollution of ground and surface waters. Impacts may result particularly where ground and surface waters are utilized for household purposes or where fisheries or ecologically important areas are affected.

Indirect or secondary effects on local drainage patterns and surface hydrology may result from poor construction practice in the development of roads, drilling and process sites.

Terrestrial impacts

Potential impacts to soil arise from three basic sources:

- physical disturbance as a result of construction;
- contamination resulting from spillage and leakage or solid waste disposal; and
- indirect impact arising from opening access and social change.

Potential impacts that may result from poor design and construction include soil erosion due to soil structure, slope or rainfall. Left undisturbed and vegetated, soils will maintain their integrity, but, once vegetation is removed and soil is exposed, soil erosion may result. Alterations to soil conditions may result in widespread secondary impacts such as changes in surface hydrology and drainage patterns, increased siltation and habitat damage, reducing the capacity of the environment to support vegetation and wildlife.

In addition to causing soil erosion and altered hydrology, the removal of vegetation may also lead to secondary ecological problems, particularly in situations where many of the nutrients in an area is held in vegetation (such as tropical rainforests); or where the few trees present are vital for wildlife browsing (e.g. tree savannah); or in areas where natural recovery is very slow (e.g. Arctic and desert ecosystems). Clearing by operators may stimulate further removal of vegetation by the local population surrounding a development.

Due to its simplicity, burial or land-filling of wastes in pits at drilling and production sites has been a popular means of waste disposal in the past. Historically, pits have been used for burial of inert, non-recyclable materials and drilling solids; evaporation and storage of produced water, workover/completion fluids; emergency containment of produced fluids; and the disposal of stabilized wastes. However, the risks associated with pollutant migration pathways can damage soils and usable water resources (both surface and groundwater), if seepage and leaching are not contained.

Land farming and land spreading have also been extensively practised in the past for the treatment of oily petroleum wastes, and water-based muds and cuttings. However, there are potential impacts where toxic concentrations of constituents may contaminate the soil or water resources, if an exposure pathway is present. In the case of muds and cuttings, the most important consideration is the potential for the waste to have a high salt content. Arid regions are more prone to adverse effects than wetter climes, as are alkaline soils or those with high clay content compared with acid, highly organic or sandy soils. During the drilling of a typical well in the region of 3000m in depth, some 300–600 tonnes of mud may be used, and 1000–1500 tonnes of cuttings produced. Land farming and land spreading, however, remain viable treatment options provided a proper assessment is made, and correct procedures are followed. Considerations include the site topography and hydrology, the physical and chemical composition of the waste and resultant waste/soil mixture. With proper assessment, engineering, design, operation and monitoring, land farming provides a cost effective and viable technique for waste disposal.

Soil contamination may arise from spills and leakage of chemicals and oil, causing possible impact to both flora and fauna. Simple preventative techniques such as segregated and contained drainage systems for process areas incorporating sumps and oil traps, leak minimization and drip pans, should be incorporated into facility design and maintenance procedures. Such techniques will effectively remove any potential impact arising from small spills and leakage on site. Larger incidents or spills offsite should be subject to assessment as potential emergency events and, as such, are discussed under 'Potential emergencies' (below) and also under 'Oil spill contingency planning' on page 50.

Ecosystem impacts

Much of the preceding discussion has illustrated where potential impacts may occur to various components of the biosphere from a variety of operational sources (e.g. atmospheric, aquatic and terrestrial) if not properly controlled using appropriate best operational practice (see Section 6).

Plant and animal communities may also be directly affected by changes in their environment through variations in water, air and soil/sediment quality and through disturbance by noise, extraneous light and changes in vegetation cover. Such changes may directly affect the ecology: for example, habitat, food and nutrient supplies, breeding areas, migration routes, vulnerability to predators or changes in herbivore grazing patterns, which may then have a secondary effect on predators. Soil disturbance and removal of vegetation and secondary effects such as erosion and siltation may have an impact on ecological integrity, and may lead to indirect effects by upsetting nutrient balances and microbial activity in the soil. If not properly controlled, a potential long-term effect is loss of habitat which affects both fauna and flora, and may induce changes in species composition and primary production cycles.

If controls are not managed effectively, ecological impacts may also arise from other direct anthropogenic influence such as fires, increased hunting and fishing and possibly poaching. In addition to changing animal habitat, it is important to consider how changes in the biological environment also affect local people and indigenous populations.

Potential emergencies

Plans for all seismic, drilling and production operations should incorporate measures to deal with potential emergencies that threaten people, the environment or property. However, even with proper planning, design and the implementation of correct procedures and personnel training, incidents can occur such as:

- spillage of fuel, oil, gas, chemicals and hazardous materials;
- oil or gas well blowout;
- explosions;
- fires (facility and surrounds);
- unplanned plant upset and shutdown events;
- natural disasters and their implications on operations, for example flood, earthquake, lightning; and
- war and sabotage.

The E&P Forum has compiled statistics on well blowout frequencies, based on available information from the USA, Gulf of Mexico and the North Sea.[54] The data, in simplistic terms, illustrate a higher probability of blowouts during exploration, of around one shallow gas blowout per 200 wells, compared with development drilling of approximately one per 500 wells. In production operations the blowout frequency drops, so that for well completions one blowout per thousand completions is quoted, whilst one blowout per 20 000 well years is predicted for producing oil wells, and one blowout per 10 000 well years for gas wells. The statistics for workover operations show a frequency of one blowout in every 2500 oil well workover operations, and one per 1000 for gas well operations. Workover is a maintenance procedure which requires entry into a producing well after the hydrocarbon flow is stopped. A typical well is worked over every five years.

Planning for emergency events (see 'Oil spill contingency planning' on page 50) should properly examine risk, size, nature and potential consequences of a variety of scenarios, including combination incidents. A variety of documents is available to describe risk and hazard assessment, contingency planning and effects of emergency events.[8, 9, 10, 11, 12, 13, 14, 15, 16. 17, 33, 34, 35, 36]

Environmental impacts in the context of protection policies and requirements

This Section has provided a broad overview of potential impacts related to exploration and production activities. The potential for oil and gas operations to cause impact must be assessed on a case-by-case basis, since different operations, in different environments, in different circumstances may produce large variations in the magnitude of a potential impact. With the proper application of management techniques and best environmental practice, many, if not all, potential impacts will be eliminated or mitigated. The assessment of potential impacts and management measures is commonly carried out through an environmental assessment, either conducted independently or within the framework of an HSE management system, and as may be required by formal EIA procedures where they apply. In some countries, EIA is a requirement before approval can be given, and frequently the results of the EIA determine the conditions of approvals and permits (see Sections 4 and 5).

The potential impact of exploration and production activities must also be considered in the context of national and global protection policies and legislation. Frequently, such policy objectives will provide clear guidance on the relative importance of a given issue or potential impact. For example, an assessment may identify an apparently small level of impact, which, when seen in the context of national objectives, may acquire an increased significance and importance and require especially careful management.

Table 2: Summary of potential environmental impacts *(this table should be cross-referenced with Table 5, 'Environmental Protection Measures')*

Activity	Source	Potential impact	Component affected	Comments
Aerial survey	Aircraft	Noise	H/At/B	Low-level flights, disturbance to humans and wildlife (consider seasonality). Short-term, transient.
Seismic operations (onshore)	Seismic equipment	Noise	H/At/B	Shot-hole drilling; acoustic sources (vibrations, explosions); disturbance to humans and wildlife (consider seasonality). Short-term, and wildlife
	Base camps	Noise/light	H/At/B	Low level noise and light from camp activities; disturbance to local environment. Short-term, transient.
		Access/ footprint	H/At/B/Aq/T	Vegetation cleared; possible erosion and changes in surface hydrology; immigration of labour; waste disposal; effluent discharges (sewage); emissions from power generation; spillages; fire risk; land use conflict; secondary impacts—influx/settlement through new access routes. Mainly short-term, transient. Potential long-term impact from access.
	Line cutting	Access/ footprint	H/B/Aq/T	Removal of vegetation, possible erosion, changes in drainage patterns and surface hydrology, secondary impacts—influx/settlement through new access routes. Mainly short-term and transient. long-term potential impact from access.
Seismic operations (offshore)	Seismic equipment	Noise	B	Acoustic sources, disturbance to marine organisms (may need to avoid sensitive areas and consider seasonality). Short-term and transient.
	Vessel operations	Emissions and discharges	At/Aq/T	Atmospheric emissions from vessel engines; discharges to ocean: bilges, sewage; spillages; waste and garbage disposal to shore. Low-level, short-term, transient.
		Interference	H	Interaction with other resource users (e.g. fishing). Short-term, transient.
Exploration and appraisal drilling (onshore)	Roads	Access	H/At/B/Aq/T	Vegetation cleared, possible erosion and changes in surface hydrology; emissions, vibration and noise from earth moving equipment; disturbance of local population and wildlife. Secondary impacts related to influx and settlement through new access routes. Mainly short-term, transient impacts. Potential long-term impacts from access construction
	Site preparation	Footprint	H/At/B/Aq/T	Requirement for proper site selection to minimize possible impact. Removal of vegetation and topsoil; possible erosion and changes in surface hydrology; drainage and soil contamination; land use conflict; loss of habitat; construction noise, vibration and emissions from vehicles; disturbance to local population and wildlife, aesthetic visual intrusion. Short-term provided adequate decommissioning and rehabilitation is conducted.

continued …

H = Human, socio-economic and cultural; T = Terrestrial; Aq = Aquatic; At = Atmospheric; B = Biosphere

Table 2 (continued): Summary of potential environmental impacts

Activity	Source	Potential impact	Component affected	Comments
	Camp and operations	Discharges Emissions Waste	H/At/B/Aq/T	Water supply requirements; noise, vibration and emissions from plant equipment and transport; extraneous light; liquid discharges—muds and cuttings; wash water; drainage; soil contamination—mud pits, spillages, leakages; solid waste disposal; sanitary waste disposal, sewage, camp grey water; emissions and discharges from well test operations; additional noise and light from burning/flare. Disturbance to wildlife. Short-term, transient.
		Socio-economic Cultural	H	Land-use conflicts, disturbance and interference to local population, special considerations required for native and indigenous population; interactions between workforce and local population; immigration; potential effects on local infrastructure—employment, education, roads, services; hunting, fishing, poaching. Short-term, transient.
	Decommissioning and aftercare	Footprint	H/B/Aq/T	Proper controls during construction and operations and careful decommissioning and aftercare should effectively remove risk of long-term impacts. Improper controls can result in soil and water contamination; erosion and changes in surface hydrology; wildlife disturbance; loss of habitat; impacts to bio-diversity; human and cultural disturbance; secondary impacts to socio-economic infrastructure, immigration, changes in land and resource use.
Exploratory and appraisal drilling (offshore)	Site selection	Interactions	H/B/Aq	Consider sensitivities in relation to biota, resource use, cultural importance, seasonality. Secondary impacts related to support and supply requirements and potential impact on local ports and infrastructure.
	Operations	Discharges Emissions Wastes	H/At/B/Aq/T	Discharges to ocean—muds, cuttings, wash water, drainage, sewage, sanitary and kitchen wastes, spillages and leakages. Emissions from plant equipment; noise and light; solid waste disposal onshore and impact on local infrastructure. Disturbance to benthic and pelagic organisms, marine birds. Changes in sediment, water and air quality. Loss of access and disturbance to other marine resource users. Emissions and discharges from well test operations, produced water discharges, burning and flare, additional noise and light impact. Short-term and transient. Effects of vessel and helicopter movements on human and wildlife.
	Decommissioning	Footprint	B/Aq	Proper controls during operations and careful decommissioning should effectively remove risk of long-term impact. Improper controls can

continued …

H = Human, socio-economic and cultural; T = Terrestrial; Aq = Aquatic; At = Atmospheric; B = Biosphere

Table 2 (continued): Summary of potential environmental impacts

Activity	Source	Potential impact	Component affected	Comments
				result in sediment and water contamination, damage to benthic and pelagic habitats, organisms, biodiversity. Onshore in terms of solid waste disposal, infrastructure and resource conflicts.
Development and production (onshore)	Roads	Access	H/Aq/B/T	Long-term occupation of sites requires access to facilities. Long-term loss of habitat and land use, possible barriers to wildlife movement; increased exposure to immigration and secondary effects; long-term effects from vegetation clearance, erosion, changes to surface hydrology, introduction of barriers to wildlife movement. Increased disturbance from transportation, traffic volumes, density, impact on local infrastructure, disturbance to local population and wildlife. Long-term effects require proper planning and consultation.
	Site preparation	Footprint	H/At/Aq/B/T	Long-term occupation of sites requires permanent facilities. Long-term loss of habitat and land use. Permanent facilities require increased size of site, increased footprint, more intensive construction methods. Long-term effects from vegetation clearance, erosion, changes in surface hydrology. Larger scale, construction activities, noise, vibration, emissions related to earth works. Aesthetic and visual intrusion. Proper site selection to avoid socio-economic, cultural impacts and due consideration of local/indigenous populations. Possible requirement for pipelines—construction, access, long-term occupation of land resource, introduction of barriers to wildlife movement.
	Operations	Discharges Wastes Emissions	H/At/Aq/B/T	Long-term occupation of sites and permanent production facilities lead to long-term and increased potential for impact. Increased demand on local infrastructure water supply, sewage, solid waste disposal. Increased discharges and emissions from: production processes (waste water, produced water, sewerage and sanitary wastes, drainage); and power and process plant (waste gases, flaring, noise, vibration, light). Potential effects on biota, wildlife disturbance, habitats, biodiversity, water, soil and air quality. Increased risks of soil and water contamination from spillage and leakage.
		Socio-economic Cultural	H	Long-term permanent presence of facilities and workforce; increased demand on local infrastructure, socio-economic and cultural impacts (labour force, employment, education, medical and other services, local economy, effects on indigenous populations. Land-use conflicts. Visual and aesthetic intrusion.

continued …

H = Human, socio-economic and cultural; T = Terrestrial; Aq = Aquatic; At = Atmospheric; B = Biosphere

Table 2 (continued): Summary of potential environmental impacts

Activity	Source	Potential impact	Component affected	Comments
Development and production (offshore)	Site selection	Interactions	H/B/Aq	Long-term site selection based upon biological and socio-economic sensitivities and minimum disturbance. Risk of impact to sensitive species, commercially important species, resource conflict, access. Long-term support and supply base requirement and impacts on local port infrastructure.
	Operations	Discharges Emissions Waste	H/At/B/Aq/T	Long-term, chronic effects of discharges on benthic and pelagic biota; sediment and water quality. Impact of drill cuttings and mud discharges, produced water, drainage, sewage, sanitary and kitchen wastes, spillage and leakage. Emissions from power and process plant and impact on air quality. Noise and light impact from facilities and flaring. Solid waste disposal and impact on onshore infrastructure. Increased vessel and helicopter movements.
		Socio-economic Cultural	H	Loss of access and resource use interactions. Local port, harbour and community interactions related to supply and support functions.

H = Human, socio-economic and cultural; T = Terrestrial; Aq = Aquatic; At = Atmospheric; B = Biosphere

Part 2

Management

This part provides a background to the strategic aspects of environmental management. Section 4 describes some of the international and national regulatory frameworks that exist and the infrastructure that may be required to regulate protection of the environment. Different regimes exist in different countries and not all of the elements described may be in place. Indeed, in some countries other structures may exist.

Section 5 provides a description of existing approaches to environmental management within the oil and gas industry, and draws principally from the E&P Forum *Guidelines for the Development and Application of Health, Safety and Environmental Management Systems* (HSE-MS).[23] The industry is fully committed to integrated HSE-MS and recognizes the existence of international standards for systems models, such as the International Standards Organization ISO 9000 for quality management, and ISO 14000 for environmental management.

4 Regulatory framework, institutional factors and infrastructure

This Section describes the regulatory framework that exists under international (regional and global) regimes, and examines some of the approaches that may be adopted under national regimes. Regulatory control and enforcement is strictly the responsibility of competent national authorities. International requirements are implemented by national authorities through primary legislation. This is often supported by a set of subordinate regulations and guidelines which provide more detailed information on specific requirements. Regulations in turn may be further refined by a framework of standards and consents, determining, for example, quantitative controls on emissions by prescription, by negotiated agreement, or by goal-setting. The traditional approach of prescriptive legislation is gradually being complemented by performance assessment, goal-setting, negotiated agreements and self regulation. Consents may exert definitive controls on planning, development, and operating conditions, each of which must be met before a licence or consent to proceed is granted. Consents for major activities are increasingly based on the results of a formal Environmental Impact Assessment (EIA)—see 'Evaluation and risk management' on page 31.

Typically, the factors required for the effective application of environmental legislation include:

- appropriate international and national laws, regulations and guidelines;
- coherent procedures for decisions on projects/activities;
- legislation with clearly defined responsibilities and appropriate liabilities;
- enforceable standards for operations;
- appropriate monitoring procedures and protocols;
- performance reporting;
- adequately funded and motivated enforcement authorities;
- existence of adequate consultation and appeal procedures; and
- appropriate sanctions and political will for their enforcement.

International and regional frameworks

Global and regional treaties and conventions are, in principle, binding in the first instance on national governments, which are obliged to implement such arrangements through national legislation. The speed and timing of implementation at the national level is, however, highly variable. It is prudent, therefore, for the international exploration and production industry to ensure that the intent of such treaties is respected, regardless of whether or not at that time a particular country in which it is operating has enacted the relevant legislation. This ensures that eventual changes in legislation to meet international requirements can be fully respected. The Introduction to this document provided a background to some major conventions formulated before and at the UNCED 'Earth Summit' in 1992, including climate change and biodiversity conventions. The latter was directed at halting the worldwide loss of animal and plant species and genetic resources. Other important international instruments include: the Montreal Protocol aimed at the phase out of ozone depleting substances; and the Basel Convention on transfrontier movement of hazardous wastes. A number of conventions have been adopted on the protection of migratory and endangered species; and several conventions and agreements concerning the marine environment.

The various Conventions on Regional Seas (OSPAR, Barcelona, Kuwait etc.), whilst international in nature, form

Some important international environmental conventions*

- Montreal Protocol of the Vienna Convention
- Basel Convention
- Convention on Migratory Species
- Framework Convention on Climate Change
- Biodiversity Convention
- UN Law of the Sea
- MARPOL
- Regional Sea Conventions (Barcelona, OSPAR, Kuwait etc.)

* formal names are cited in Annex 3

the basis of a regional regulatory framework. For example 'OSPAR' applies to the North-East Atlantic and North Sea; 'Barcelona' to the Mediterranean; and 'Kuwait' to the Middle East Gulf region.

Regional environmental frameworks based largely on common social and economic considerations are becoming increasingly important. The European Union (EU) is a prime example where regional environmental principles and objectives are implemented through member states' national legislation, the key environmental principles for the EU being: preventative action, the 'polluter pays' principle, the rectification-at-source of environmental damage, and the integration of environment in other community policies. Similar socio-economic groupings are emerging in other regions of the world, for example the Pacific Rim and the Americas.

European Union policy and other international environmental legislation have traditionally been based on a broadly prescriptive approach. However, the concept of 'goal-setting' is becoming a second foundation on which future environmental law will be based. The EU, for example, has established Environmental Quality Objectives (EQO), embraces the precautionary principle, has adapted the concept of Integrated Pollution Control (IPC), and endorses the concept of sustainable development.

The international exploration and production industry has made its own contribution to the principle of goal-setting and self-regulation at the international level by taking independent action to promote a good level of environmental performance through the establishment of industry guidelines and various international business charters (e.g. International Chamber of Commerce[42], E&P Forum[17]). However, such guidelines are not always applicable from area to area, region to region, or ecosystem to ecosystem, and they should be applied with due regard to specific circumstances. Individual companies are increasingly adopting policies and codes to guide their personnel, contractors and suppliers. Government regulations and enforcement nevertheless remain the cornerstone for protection of the environment, not least because of the difficulty of monitoring and enforcing voluntary industry codes.

National frameworks

Environmental regulations may be found under a variety of national laws. In some cases these are included in clauses inserted into petroleum laws and planning laws; in others, specific legislation has been developed dealing with such matters as environmental assessment, pollution, water and air quality, protection of waterways, environmental health and safety, protected areas, nuisance and noise.

Some examples of industry guidelines on the environment

Environmental principles/objectives and general guidelines

- Environmental principles (E&P Forum/ EUROPIA)[17], (UKOOA)[18]
- Management systems (E&P Forum)[23], (API)[24], (UNEP)[29]
- Chemical usage (API)[2]
- Waste management (E&P Forum)[4]
- Drilling muds (E&P Forum)[49]
- Oil spills (UNEP)[8] (IPIECA)[11,13]
- Decommissioning (E&P Forum)[37,38]

Technical Guidelines

- Seismic operations (IAGC)[27]
- Chemical usage (OLF)[3]
- Drilling muds (UNEP)[5], (E&P Forum)[6,47,48]
- Atmospheric emissions (OLF)[1], (E&P Forum)[46]
- Produced water (E&P Forum)[7,44,45]
- Oil spills (IMO/IPIECA)[12], (IPIECA)[14,15,16,36], (ITOPF)[33] (CONCAWE)[34,35]
- Arctic (IUCN/E&P Forum)[21], (E&P Forum)[30]
- Mangroves (IUCN/E&P Forum)[22]
- Tropical rainforests (IUCN)[25], (E&P Forum)[26]
- Auditing (ICC)[42], (UNEP)[43]
- Cleaner production (UNEP)[50,51]
- Decommissioning (E&P Forum)[52]

Petroleum laws rarely impose detailed requirements for environmental control programmes, but do provide the framework for subordinate regulations incorporating, for example, a requirement to prepare environmental assessments, plans for waste disposal and control of emissions and discharges, preparation of emergency plans, control of hazardous substances, and reclamation and rehabilitation of sites at completion of operations and following accidents. The regime for granting rights to conduct petroleum operations (e.g. concession/licence, production sharing contracts) may place certain requirements and obligations on an operator in regard to environmental protection, and it is common that other consents will be required as the project develops.

Examples of common legislation that may apply to oil operations

- Petroleum laws
- Planning laws
- Environmental Protection Acts
- Environmental impact assessment
- Clean Air and Water Acts
- Water catchment protection
- Marine pollution
- Standards for noise, radiation, chemical exposure
- Integrated Pollution Control (IPC)
- Discharge and management of wastes
- Land contamination or land disturbance
- Permitted chemicals
- Safety and fire regulations
- Control of major hazards
- Storage and usage of chemicals
- Public and worker health and safety
- National Park or Protected Area laws
- Forest Protection laws
- Protection of indigenous and cultural heritage
- Fishery protection, marine navigation and safety

The acquisition of these rights primarily provides the operator/contractor with the authority to explore and exploit a given area of land or seabed. If hydrocarbons are discovered the operating or contracted company will have to meet the requirements of various authorities and obtain, for example, a development consent approving the detailed development plans; a planning consent which usually incorporates the environmental assessment; and operational consent which provides detailed information on operational activities, controls and limits, and often specifies the enforcement regime.

Individual administrative jurisdictions may administer laws in different ways. Hence effective liaison and communication is required with various government bodies at several levels. Where a country is party to international conventions and environmental treaties, further obligations may arise. The regulatory infrastructure varies widely. In some countries sophisticated mechanisms exist with single source agencies which act as a focal point for environmental control, whilst in others infrastructure is virtually non-existent and considerable institutional capacity building is still necessary.

Considerable commitment and resources are required to make environmental programmes effective. Baseline surveys, development of environmental framework policies, maintenance of inspection, monitoring and enforcement functions, and a continuing ability to manage assessments and other approval and review functions, all require adequate and appropriate governmental infrastructure and human resources in order to be effective. In many cases, government and local services and technical infrastructure do not exist. For example, specialized water, power and waste services, laboratories, public emergency response systems, transportation systems and local service industries may be lacking. The exploration and production industry has a role to play in these situations by avoiding, through self-regulation and management, overburdening the limited service infrastructure. It can also play a valuable supporting role by fostering, through training and capacity building, the government infrastructure until the development process catches up sufficiently to make the authorities more self-sufficient.

Examples of infrastructure needed for environmental protection

- Policy formulation and regulations
- Baseline environmental surveys
- Assessment and approvals
- Inspection, monitoring, enforcement
- Services—water, power, waste disposal
- Emergency response
- Logistics and transportation
- External supplies/services—construction, materials, engineering, consultants, etc.
- Technical services—laboratories, laboratory supplies, equipment
- Training institutions, standards associations

The enforcement of applicable laws and permits is a crucial factor in their effectiveness. Companies should be committed to complying with the law whether or not it is being rigorously enforced.

Public involvement in environmental policy and regulation has increased markedly in recent years. Even where current legislation does not provide for this, local action has, in many cases, made public communication and consultation a de facto practice by companies. Public involvement may be through review and comment of EIA and permit applications, negotiation for greater local benefits from operations, regular reports and consultations, or other means.

Management has to ensure compliance with the various environmental regulations, standards, objectives and goals as specified under legislation or in official guidelines, for each project. Environmental standards for air, water, soil, noise and chemical exposure are among the common standards encountered and are sometimes developed with reference to the carrying capacity of the environment or a view of what technology can achieve. Some commonly applied standards are presented in Annex 2, including for example, the World Health Organization Water and Air Quality Standards; a comparison of operational discharge limits as prescribed in various Regional Sea Conventions; and a comparison of various national offshore discharge limits for oil in produced water.

The concepts of self regulation, goal-setting and negotiated agreements are beginning to complement prescriptive legislation. Authorities are placing increasing responsibility on industry to provide assurance that the law is met. In addition, more emphasis is placed on the pre-approval of operations, substances, materials and processes. Decisions are guided by concepts such as: Best Available Technology not Entailing Excessive Cost (BATNEEC); Best Available Techniques (BAT), Economically Viable Application of Best Available Technologies (EVABAT); and Best Practicable Environmental Option (BPEO). The recent availability and application of assessment methodologies, formal management systems and other tools, has increasingly led to regulatory requirements, or options, that these should be used in specific situations (e.g. EIA for large projects, risk assessment for permitting). More recently there have been attempts to reduce reliance upon 'Command and Control' requirements where approved environmental management systems are adopted by companies.

The targets for protection of landscape, natural values, and wildlife may be more difficult to interpret in operational terms than those for water and air quality because they are often phrased in qualitative terms. More often than not, standards, whether quantitative or qualitative, are enshrined in the approval and permitting process, with the Environmental Impact Assessment (EIA) forming an important tool, particularly in the context of land use planning. The approval process may consist of several stages with land use, siting and planning approvals being granted, following the acceptance of the EIA. Further permits may be required under specific legislation such as fire, safety and emergency procedures, waste disposal, construction methods, engineering codes etc. Such approvals need to be obtained before operations begin, and this, given the different administrative jurisdictions, is frequently a complex process. In a small but increasing number of countries, permits are being combined into a single approval, but this is not yet widespread.

Once operations start, monitoring regimes are required, whether by legislation, through authority inspection and enforcement, or through industry commitment to management systems and self-regulation. Depending on the terms of reference of agreement between the oil company and the host government, responsibility for decommissioning and rehabilitation may fall on the company or the government, or be shared between the two. A continued 'licence to operate' is dependent on the periodic approval of key stakeholders through statutory reporting and audit programmes. Once operations cease and rehabilitation and decommissioning is completed, final approval will be required to meet legislative conditions. It is common practice for decommissioning requirements to be specified in licence approvals and related to the environmental baseline described in the EIA process. There is little doubt that stabilization of sites to a non-polluting and acceptable risk standard are now considered essential conditions.

5 Environmental management in the oil and gas industry

Oil and gas development activities are expected to grow to meet the need of rapidly industrializing countries, and can be carried out safely with minimum adverse environmental impact, only through a strong company commitment to environmental protection. The host government also needs to have a solid understanding of exploration and production operations and how they may affect the environment. The activities on both sides should ideally be complementary to achieve the most cost-effective and environmentally sound approach. It is now generally acknowledged that this approach:

- systematically integrates environmental issues into business decisions through use of formal management systems;
- integrates health, safety and environmental management into a single programme;
- considers all environmental components (air, water, soil, etc.) in decision making at strategic and operational levels;
- prevents waste at its source through pollution prevention techniques and making maximum re-use of waste components, rather than installing expensive treatment for discharges;
- evaluates alternatives on a cost/benefit/risk basis that includes environmental values;
- aims at minimizing resource inputs; and
- innovates and strives for continual improvement.

Exploration and production operations involve a variety of relationships, from company and contractor partnerships, and joint ventures, to dealing with other stakeholders such as government and the public. This, together with the fact that environmental issues are now so numerous, complex, interconnected and continuously evolving, means that an *ad hoc* approach to problem solving is no longer considered effective. There is, therefore, a need for a systematic approach to management of health, safety and environmental (HSE) issues. The E&P Forum, prompted by the high degree of common ground in handling the three components, has developed a generic Health, Safety and Environment Management System (HSE-MS).[23] The basic elements are presented in this Section. Various national and international standards such as the ISO 9000 and 14000 series also provide systems models that can be used by companies and by government agencies.

Corporate management principles

- Define corporate strategies and environmental objectives
- Adopt health, safety environmental management system
- Pursue technical cooperation and capacity building
- Develop partnerships and communications
- Initiate prevention and cleaner production techniques
- Develop and maintain accident preparedness
- Ensure proper assessment, evaluation and planning of projects
- Training
- Review and audit

ISO 14000 consists of an evolving series of generic standards developed by the International Standards Organization (ISO), that provides business management with the structure for managing environmental impacts. The standards include a broad range of environmental disciplines, including the basic management system (14001); auditing (ISO 14010); performance evaluation; labelling (ISO 14020 and 14024); life-cycle analysis; and product standards. Any standard may be used in its basic form or be further adapted and incorporated into national standards systems. Companies will need to consider how the various standards apply to their operations. Currently (1996) only 14001 has been formally adopted; the remainder are still being considered by ISO working groups.

Because it was specifically developed by and for the oil industry, the text that follows describes the basic elements presented in the E&P Forum's *Guidelines for the Development and Application of Health, Safety and Environmental Management Systems*.[23]

Key Elements of the HSE-MS Model (E&P Forum[23])

HSE-MS element	Addressing
Leadership and commitment	Top-down commitment and company culture, essential to the success of the system
Policy and strategic objectives	Corporate intentions, principles of action and aspirations with respect to health, safety and environment
Organization, resources and documentation	Organization of people, resources and documentation for sound HSE performance
Evaluation and risk management	Identification and evaluation of HSE risks, for activities, products and services, and development of risk reduction measures. EIA process
Planning	Planning and conduct of work activities, including planning for changes and emergency response
Implementation and monitoring	Performance and monitoring of activities, and how corrective action is to be taken when necessary
Auditing and reviewing	Periodic assessments of system performance, effectiveness and fundamental suitability
Review	Senior management review of HSE-MS

Management systems

Policy and commitment alone cannot provide assurance that environmental performance will meet legislative and corporate requirements or best industry practice. To be effective, they need to be integrated with the formal management activity and address all aspects of desired environmental performance including the principles referred to above.[17,18] The model Health, Safety and Environmental Management System (HSE-MS) outlined by the E&P Forum[23] includes seven key elements as illustrated here.

The E&P Forum HSE-MS model is compatible with the requirements of the ISO 14000 series. In fact ISO 14001 acknowledges that many companies will have such an integrated HSE-MS. The ISO 14001 standard, however, is not intended to address, and does not include, requirement for aspects of occupational health and safety management, neither does it seek to prevent an organization from incorporating such issues into it's environmental management system.

Effective implementation of a management system requires the following: clear analysis of current practice, total

Figure 6: The Model Health, Safety and Environmental Management System (HSE-MS) (*E&P Forum HSE-MS Guidelines*[23])

Table 3: Some company environmental management tools related to the exploration and production process

Activity	Environmental management requirement
Desk study: identifies area with favourable geological conditions	Establish environmental management system Environmental profile
Aerial survey: if favourable features revealed, then	Environmental profile
Seismic survey: provides detailed information on geology	Preliminary environmental assessment/review Environmental training Operational procedures*
Exploratory drilling: verifies the presence or absence of a hydrocarbon reservoir and quantifies the reserves	Preliminary environmental assessment/review or Environmental impact assessment Environmental training Environmental monitoring Operational procedures*
Appraisal: determines if the reservoir is economically feasible to develop	Preliminary environmental assessment/review or Environmental impact assessment Environmental training Environmental monitoring Operational procedures*
Development and production: produces oil and gas from the reservoir through formation pressure, artificial lift, and possibly advanced recovery techniques, until economic reserves are depleted	Environmental impact assessment Environmental training Environmental monitoring Environmental audit Waste management Operational procedures*
Decommissioning and rehabilitation may occur for each of above phases.	Site assessment Implementation of site restoration plan Environmental monitoring Operational procedures*

* Operational procedures include the establishment and implementation of waste management, emergency preparedness and hazardous material handling and disposal programmes, and will include any additional programmes as specified in the impact and risk assessments.

commitment from all staff which in turn implies the need for good communication within organizations; timely and relevant training (see UNEP/ICC/FIDIC Environmental Management Systems Training Resource Kit). The most common starting point in the evolution of a management system is a review of the existing situation and practice. This must be initiated by the highest level of management and involve total senior management commitment.

Commitment to and demonstration of continual improvement in performance is vital in ensuring that management is effective and maintained. Under the HSE-MS, standards, procedures, programmes, practices, guidelines, goals, and targets have to be established, and where necessary agreed with regulators and other stakeholders. Monitoring and auditing will show how well an operation performs and provide a measure of effectiveness.

Many companies operate in widely varying climatic, geographic, social and political circumstances. Sometimes legislative frameworks, and socio-economic and physical infrastructures are highly sophisticated, sometimes they are non-existent. Companies need a consistent management approach but must allow sufficient flexibility to adapt to the sophistication of the existing infrastructure. Clear examples are provided in the references.[19,20]

In addition to the seven elements of the HSE-MS described above, several management tools are used at the operational level, and Table 3 provides an example of how the operational activities described in Section 2 call into use different tools under the company management system. It is important to remember that the HSE-MS applies not only to company personnel, but also to contractors and service providers who support operations.

It is also important to consider how the management system applies with respect to contractors, suppliers and consultants. In an industry where much of the service and fieldwork is carried out by non-company personnel it is important to ensure effective communication, monitoring, auditing and reporting links with the suppliers of services. Surveillance of operations is not the only mechanism to be considered. The criteria for choosing suppliers, checking of their own environmental record and of their own internal management systems, and incorporation of their activities in company reports and other review mechanisms, are important considerations if the total management system is to function. It is here that the use of formal management standards and auditors plays a major role.

Leadership and commitment

Senior management should provide strong and visible leadership and commitment, and ensure that this commitment is translated into the necessary resources to develop, operate and maintain the HSE-MS, and to attain the policy and strategic objectives. Management should ensure that full account is taken of HSE policy requirements during operations and should provide support for local actions taken to protect health, safety and the environment.

Management commitment

- Communicate the objectives and policy
- Allocate necessary resources
- Ensure participation
- Provide motivation
- Delegate responsibility and accountability
- Ensure communications

Policy and strategic objectives

A requirement of the HSE-MS is that a company defines and documents its health, safety and environmental policies and strategic objectives and ensures that such policies are consistent, relevant and of equal importance with other company policies and objectives. The underlying tenet is commitment: commitment to define and implement corporate strategies aimed at the protection of health and safety of individuals and of the environment; commitment to respond to the concerns of the community as a whole and develop partnerships with stakeholders.[19,20] The policies must be implemented and maintained, and be communicated to employees and the public. Under an HSE-MS, a company should commit to meet, or exceed, all relevant regulatory and legislative requirements, and to apply responsible standards where laws and regulations do not exist. An HSE-MS commits a company to the setting of HSE objectives and to continuous efforts to improve performance, including the reduction of risks and hazards to health, safety and the environment to levels which are as low as reasonably practicable.

Organization, resources and documentation

The organizational structure and allocation of resources is a key element of the management system.[23] It acknowledges that environmental management is a line responsibility. It is vital that, from the first stages of field activity, the roles, responsibilities, authorities, and relationships necessary to implement environmental management are clearly defined, documented and communicated. Line staff in all aspects of operational activity must be assigned environmental responsibility and authority within their spheres of control, and must be competent to perform their duties effectively. This requires adequate and appropriate training and periodic review of company staff, contractors and external parties involved in the activity. Environmental training should foster, in each person, an awareness of environmental, social and cultural concerns and ensure that they are able to meet their defined role and job requirements, and to apply environmental operating procedures correctly. Emphasis should be placed on individual responsibility for the environmental performance of the project management, a summary of relevant legislative requirements, detailed procedures and work instructions for key activities and tasks, and should describe emergency plans and the means of responding to incidents. Table 5 in Section 6 provides an example of documents available within a typical exploration and production company. Finally, responsibilities and procedures for controlling, reviewing and updating system documentation should be clearly established.

Environmental training

- Policy, plans and management
- Objectives, targets, performance
- Issues: global, national, local
- Legislation, consents and compliance
- Operational procedures
- Pollution prevention
- Chemical usage and waste controls
- Contingency and emergency response
- Reporting

Evaluation and risk management

A company should maintain procedures to identify systematically the hazards and effects which may affect or arise from its activities, and from materials employed in them. The scope of the identification should encompass all activities from inception through to decommissioning.

One of the basic methods of assessing the implications is an environmental impact assessment (EIA). The EIA process has become formalized over time and although variations exist, the common component steps are shown in the table. The depth to which each step is undertaken depends upon the situation. Preliminary screening and scoping steps will help to identify the depth required. While some companies still see EIA largely as a regulatory hurdle, it has in fact the potential to be a valuable tool that the company can use to streamline its operation. Its full value in this sense is only realized if it is undertaken early in the project cycle.

The environmental assessment process should begin during the early stages of pre-project planning, and continue, as an iterative process, throughout project feasibility and specification phases, detailed design, construction and operations. The findings of the assessment can at each stage be incorporated into the next phase of the project design. Any changes in project specification must be re-evaluated in terms of impact assessment. The need to integrate the findings of the assessment process into engineering design is self-evident and many potential impacts can be mitigated or removed with proper design consideration.

The techniques of environmental risk evaluation and risk management are in their early stages of development[10,29].

Environmental impact assessment

- Identify legislation
- Describe environmental baseline
- Identify sensitive environments
- Incorporate risk assessment
- Identify project effects
- Quantify impacts
- Evaluate alternatives
- Select Best Practicable Environmental Options (BPEO)
- Investigate mitigation
- Evaluate residual impact
- Establish basis for standards, targets and operational procedures and other plans
- Develop basis for contingency planning
- Recommend management plan—consultation, monitoring, review and audit
- Recommend basis for documentation and training

Note: legislation will in many cases prescribe EIA requirements and procedures.

Risk evaluation and management

- Description of project
- Hazard identification
- Identification of consequences
- Magnitude of consequences
- Probability of consequences
- Risk management

However, the concepts are already well founded in the oil industry in the area of safety management.[39, 40] Evaluation and analysis of risk should form an important component of all developments and should be an integral element in all stages of the planning process, in particular EIA and contingency planning.

Risk evaluation is considered by many inside and outside the industry as a fundamental requirement in addressing the notion of sustainable development. Investment, management and control decisions should be based on the best possible scientific information and analysis of risks.[9,10,29] Perception of risk and value must also form part of the assessment, because different groups will regard risk and value from different viewpoints.

Risk management is the process whereby decisions are made to accept a known or assessed risk and/or the implementation of actions to reduce the consequences or probability of an occurrence. Frequently the decision makers are not those who evaluated the risk. Indeed, in many regimes, government authorities will be responsible for granting approvals, often after public consultation. However, the industry must be in a position to present its case in a clear and defensible manner. In the absence of legislative controls, it will effectively make many risk management decisions itself, and will need suitable acceptability criteria.

Planning

The results of the evaluation and risk management studies now become an integral part of the planning process. The existing publications and guidelines[4,9,10,19,21,22,25,26,27,28,29,30,31,32] provide details of key elements of the process, including environmental profile, impact and risk assessment, consultation, waste management and broader issues of environmental management. Contingency planning and emergency response are covered in other documents.[8,11,12,33,34,35,36]

By incorporating the results of the assessments, project specific environmental plans and compliance programmes are developed, which should include detailed guidance on measures to prevent or minimize adverse impacts and enhance possible beneficial impacts. They should also set internal standards and targets for waste control, specify site specific operating procedures, establish consultation and communications programmes, recommend monitoring programmes for the project, and establish a compliance pro-

Environmental planning principles

- Prepare environmental profile
- Conduct impact assessment
- Evaluate risk
- Integrate environment with design
- Prepare project environmental plans
- Formulate compliance programmes
- Establish monitoring programmes
- Specify contractors' obligations

gramme to ensure statutory requirements are met. Frequently, all relevant environmental information is incorporated into the site environmental manual.

The implications and needs of decommissioning should be considered during initial project planning[37,38], and a detailed decommissioning and restoration plan should be developed before the end of field life. As far as possible, rehabilitation should be progressive during the operational life of a site. Details of decommissioning and rehabilitation requirements are provided in the various guidance documents.[21,22,25,26,27,28,29]

Environmental plans, programmes and procedures

- Consultation and communication
- Construction and infrastructure
- Pollution prevention and control procedures
- Waste management
- Performance standards and targets
- Contingency and emergency response
- Monitoring
- Compliance
- Decommissioning and rehabilitation

Implementation and monitoring

Development of the programmes during the planning process will have been conducted or supported by environmental specialists. However, the implementation responsibility rests with line managers, who should, therefore, ensure they fully understand and subscribe to the commitments being made. These commitments will include the legal and statutory controls imposed on the operation as well as other corporate commitment to responsible environment management.

Monitoring will confirm that commitments are being met. This may take the form of direct measurement and recording of quantitative information, such as amounts and concentrations of discharges, emissions and wastes, for measurement against corporate or statutory standards, consent limits or targets. It may also require measurement of ambient environmental quality in the vicinity of a site using ecological/biological, physical and chemical indicators. Monitoring may include socio-economic interaction, through local liaison activities or even assessment of complaints.

The preventative approach to management may also require monitoring of process inputs, for example, type and stocks of chemical use, resource consumption, equipment and plant performance etc.

The key aims of monitoring are, first, to ensure that results/conditions are as forecast during the planning stage, and where they are not, to pinpoint the cause and implement action to remedy the situation. A second objective is to verify the evaluations made during the planning process, in particular in risk and impact assessments and standard and target setting, and to measure operational and process effi-

Monitoring objectives

- Verify effectiveness of planning decisions
- Measure effectiveness of operational procedures
- Confirm statutory and corporate compliance
- Identify unexpected changes

ciency. Monitoring will also be required to meet compliance with statutory and corporate requirements. Finally, monitoring results provide the basis for auditing. A more detailed approach to monitoring and performance measurement is provided in various publications.[10,19,21,22,23,25,26,27,28,29,30]

Audit and review

An environmental audit has been defined by the International Chamber of Commerce (ICC)[42] as:

'A management tool comprising a systematic, documented, periodic and objective evaluation of how well environmental organization, management and equipment are performing, with the aim of helping to safeguard the environment by: (i) facilitating management control of environmental practices; (ii) assessing compliance with company policies, which would include meeting regulatory requirements.'

A wide variety of publications provide background and information on auditing in the exploration and production industry.[21,22,23,25,26,27,28,29,30] The audit process itself is addressed in others.[42,43]

Review and audit is essentially a management tool.[23] However, its application is crucial at the operational level for verification and feedback on the effectiveness of organization system and environmental performance.

Audit

- Line management system
- Awareness and training
- Procedures, standards, targets
- Plans: waste, contingency, pollution control, compliance
- Monitoring programmes
- Verify EIA
- Verify mitigation
- Reporting and communication
- Documentation
- Feedback

Audit serves to substantiate and verify monitoring programmes and compliance, and to ensure that site environmental plans, procedures and standards are both effective and fit for purpose. Other benefits of auditing include increased internal and external awareness, communication, and credibility of company environmental activities by demonstrating commitment to and achievement of responsible environmental management.

In addition to management and compliance audits, a number of technical or process audits, sometimes termed assessments or evaluations, may be conducted. Thus, waste and emissions audits, energy audits, site (contamination) audits, emergency countermeasure audits, worker health and safety audits, may be instigated independently or as part of a broader management audit.

Increasingly, companies are now preparing reports on their environmental performance for a wide public readership, including shareholders and financing bodies. An important audience is also the company employee, who benefits from having the company's environmental position and activities described in a way that allows him or her to be an ambassador in a general sense for the company.

The contents of these reports still vary greatly, with a gradual but noticeable tendency to quantify environmental performance, and include mention of a range of environmental and sustainability indicators such as pollution and safety incidents, greenhouse gas emissions, and even noncompliance statistics. Each company will need to consider its own operations and what and how to report.

Some industry associations, for example the American Petroleum Institute (API) are also beginning to prepare public reports on sector-wide performance of their members.

Reporting is becoming increasingly sophisticated, and more closely linked with the total environmental programme of companies.

Part 3

Operational practices and procedures

Part Two described the framework within which environmental management is established, and some of the tools that can be used to implement the policies. Translating policy and commitment into practice at the operational level is the critical next step. This section of the document provides guidance on the practical elements and operational techniques which should be applied on site. It is important that the reader cross-references the practical considerations presented here with the potential impacts discussed in Section 3 and, in particular, cross-references Table 2, 'Potential environmental effects', with Table 5, 'Environmental Protection Measures'.

Section 6 identifies some useful environmental practices within the exploration and production industry drawn from existing guidelines for environmental protection[21,22,25,26,28,30] many of which deal with activities in specific environmentally sensitive habitats: the tropics, mangroves, arctic and sub-arctic and coastal waters. For further details concerning geophysical operations the reader is referred to the IAGC guidelines.[27] The intent here is to build upon these guidelines and to provide an overview for operations in all parts of the world, both onshore and offshore.

Table 5 on page 39 provides a summary of environmental protection measures that can be applied in each of the principal steps of the exploration and production process. They describe practical measures that can be implemented to avoid or mitigate potential environmental effects and interactions. It should be noted that in order to avoid a piecemeal approach, protection measures are often combined into a variety of 'programmes, procedures, instructions', such as waste management, occupational hygiene, contingency planning, monitoring, energy conservation, water pollution, decommissioning, (see for example Table 4 on page 38). At a higher level, a pollution prevention programme (termed 'Cleaner Production' within UNEP[50,51]) gives a clear conceptual and methodological context for individual measures that are needed.

Operational considerations

- Footprint
- Pollution prevention
- Social/cultural interactions
- Waste
- Efficient use of resources
- Use of local resources
- Consultation and communication
- Risks and impacts
- Secondary and indirect impacts
- Infrastructure implications
- Training

6 Environmental protection measures

Implementation on site

Senior management **leadership** and **commitment** has to be converted into action by the provision of adequate financial and personal resources to ensure that environmental protection measures are incorporated in on-site routine operations. The management system will function effectively through the promotion of a company culture conducive to good environmental performance, and fostering active involvement of employees and contractors.

Company **policy and strategic objectives** must be prominently displayed at all operating sites and, as necessary, adapted to include any site specific requirements. Each operating site may need to develop its own specific objectives, and relevant operational targets in line with the company's broader strategic objectives. This should be initiated by the site manager, and achieved through a formal communication and consultation process that involves staff, contractors and local stakeholders.

The **organization, resources and documentation** necessary to implement the management system are critical. In each case the site manager and line staff are responsible for implementing and communicating policy. The roles, responsibilities, authorities, accountabilities and relationships necessary to implement environmental management must be clearly defined, documented and communicated in a document prepared specifically for that site. Line staff in all aspects of operational activity should be assigned specific environmental responsibility and authority within their spheres of control, and must be competent to perform their duties effectively. Each site should assign a management representative or representatives with sufficient knowledge of the company and its activities, and of environmental issues to undertake their role effectively. Whilst maintaining overall responsibility for coordinating environmental management activities across all functions and groups, representative(s) will act in conjunction with line management in all functions, activities and processes. Some companies may divide the management role among several line positions (often supported by an environmental adviser) or define it as a significant part of a line manager's duties. Contractors and sub-contractors play a substantial role in exploration and production operations and must be covered and made accountable in the company's management system.

Documentation provides an adequate description of the management system and a permanent reference to the implementation and maintenance of that system. To implement this on-site a wide variety of documentation is usually prepared, some describing the structure and function of the management system, some providing detailed guidance on environmental protection measures, procedures, programmes and plans, communications and consultative requirements. Others provide information on local regulations and standards and how to monitor and report performance effectively, including requirements for accident and incident reporting and follow-up. Table 4 provides an example of documents available within a typical exploration and production company.

Through the formal processes of evaluation and risk management and planning, a series of site or project specific environmental plans will be developed. These plans will incorporate the relevant environmental protection measures presented in Table 5, whilst ensuring that all aspects of international, national and local legislation are met, as described in Section 4. Some key areas for which specific plans may be prepared include Pollution Prevention (UNEP—Cleaner Production); Waste Treatment and Disposal Techniques; Contingency Planning; Decommissioning, Rehabilitation and Aftercare; and Environmentally Sensitive Areas (see 'Operational considerations' on page 49).

The effective practical implementation and monitoring of these planned arrangements requires that procedures and instructions are followed at all levels. Company and contractor staff need to be familiar with relevant procedures and instructions before they start work. Training programmes and definition of responsibilities in job descriptions and contracts are therefore of paramount importance.

Monitoring provides the means of measuring performance against established requirements through inspection, surveillance and analysis. The detail and frequency of measurement should reflect the nature and extent of the risks involved.

Other key elements of implementation and monitoring include reporting mechanisms, record systems, and follow-up—in particular, non-compliance and corrective action, and incident reporting and follow-up.

Finally, audit and review procedures should be established in line with the company's overall programme. However, in addition to this procedure, it is frequently beneficial to encourage line management to carry out self-assessment programmes, independent of, but allied to, the overall company programme.

Table 4: Typical environmental documentation within an E&P company

Heading	Title
General	Statement of general business principles Policy statement on health, safety and the environment Environmental policy objectives
Environmental management	Environmental management principles Environmental challenge in operations Environmental management guidelines
Technical guidelines	Environmental screening Baseline surveys Environmental impact assessment guide Environmental guidelines for forestry projects Environmental guidelines for onshore oil and gas exploration Environmental guidelines for offshore oil and gas exploration Environmental guidelines for oil and gas exploration in tropical rain forests Consultation and communication guidelines Oil spill contingency planning Oil spill clean up techniques Monitoring programmes Contractor selection and environmental responsibilities Accident and incident reporting, investigation and follow-up guidelines Waste management guide Safe handling and disposal of PCBs Recommendations for alternatives to fire-fighting halons Non-operated joint ventures Environmental reporting guide Environmental auditing guide Site decommissioning and restoration Environmental training guide

Table 5: Environmental protection measures

Activity	Source of potential impact	Environmental protection measures
Aerial survey	Aircraft	● Use environmental assessment to identify protected areas/ sensitivities. Schedule operations during least sensitive periods.
Seismic operations (onshore)	Seismic equipment	● Shot-hole method should be considered in place of vibroseis where preservation of vegetation cover is required and where access is a concern. Ensure charge is small enough and deep enough to avoid cratering. Consider aquifer protection and proper plugging. Use offsets to avoid specific sensitivities. Ensure misfired charges are disabled. Mobilize clean-up crew after operations. ● Vibroseis—avoid excessive compaction on soft ground both by access of vehicles and from baseplate. Use adequate noise attenuation on engines. Carry spill clean-up material in case of fuel and hydraulic fluid leaks. Ensure proper storage of fuels.
	Base camps and access	● Consult local authorities and other stakeholders regarding preferred location. ● Choose site to encourage natural rehabilitation by indigenous flora/avoid removal of vegetation and topsoil/preserve topsoil, and seed source for decommissioning. ● Select site to minimize effects on environment and local communities/minimize clearing. ● Use existing access if available. ● Avoid or minimize road construction/minimize clearing and disturbance/minimize footprint, use existing infrastructure. ● Use hand cutting techniques/avoid use of heavy machinery e.g. bulldozers/selectively use machinery. ● Minimize size of camp/facilities consistent with operational, health and safety requirements. ● Take account of topography, natural drainage and site runoff. Ensure adequate and proper drainage. ● Ensure proper handling and storage of fuels and hazardous materials (e.g. explosives). ● Use helicopters within safety limits where minimization of ground transport is required (e.g. access, clearing etc.) ● Construct helipads to minimize disturbance consistent with operational, health and safety requirements. ● Block and control access. ● Control workforce activities e.g. hunting, interaction with local population. ● Minimize waste, control waste disposal (solids, sewerage). ● Prepare contingency plans for spillages, fire risk. ● Minimize extraneous noise and light sources. *continued …*

Table 5 (continued): Environmental protection measures

Activity	Source of potential impact	Environmental protection measures
Seismic operations (onshore) *(continued)*	Line cutting	● Hand-cut lines to minimize disturbance. ● Minimize width compatible with operational, health and safety requirements. ● Do not cut trees of a diameter greater than local regulations permit (or, in the absence of regulations, greater than 20 cm). ● Minimize clearing of vegetation. Leave in place smaller vegetation, topsoil, root stock, seeds, and endangered or protected species and species used by local communities for commercial or subsistence use (identified by environmental assessment). ● Use 'dog-legs' to minimize use as access.
	Decommissioning and restoration	● Consult with local authorities and other stakeholders, particularly if any infrastructure is to remain. ● Render access routes, campsites, seismic lines inaccessible. ● Break-up compacted surfaces/replace topsoil, brash, seed source, leaf litter etc. ● Remove non-native materials. ● Stabilize all slopes. If necessary re-vegetate to avoid erosion. ● Keep photographic record. ● Review success of restoration at a later date.
Seismic operations (offshore)	Seismic equipment	● Use environmental assessment to identify protected areas and local sensitivities. Schedule operations during least sensitive period.
	Vessel operations	● Consult local authorities and other stakeholders regarding survey programme, permitting and notifications. ● Remain on planned survey track to avoid unwanted interaction. ● Dispose all waste materials and oily water properly to meet local, national and international regulations (Refer to MARPOL). ● Apply proper procedures for handling and maintenance of cable equipment particularly cable oil. ● All towed equipment must be highly visible. ● Make adequate allowance for deviation of towed equipment when turning. ● Prepare contingency plans for lost equipment and oil spillage (see IMO guidance *Shipboard Oil Pollution Emergency Plans 1992*). ● Attach active acoustic location devices to auxiliary equipment to aid location and recovery. ● Label all towed equipment.

continued …

Table 5 (continued): Environmental protection measures

Activity	Source of potential impact	Environmental protection measures
Seismic operations (offshore) *(continued)*	Vessel operations *(continued)*	● Store and handle explosives according to operators' procedures and local regulations. ● Consider using guard boat in busy areas. ● Report all unplanned interactions with other resource users or marine life to the authorities. ● Use local expertise to support operations e.g. spotting marine mammals, wildlife etc.
Exploration and appraisal drilling (onshore)	Site selection	● Use environmental assessment to identify protected areas/ sensitivities. Schedule operations during least sensitive periods. ● Select least sensitive location within confines of bottom target/drilling envelope. Consider directional drilling to access targets beneath sensitive areas. ● Siting to minimize impacts on water resources, conservation interests, settlement, agriculture, sites of historical and archaeological interest and landscape. Consider using site that has been cleared/disturbed previously or of low ecological value, or which may be more easily restored, e.g. agricultural land. ● Consult local authorities and other stakeholders regarding preferred location for drilling sites, camps and access/maximize use of existing infrastructure. ● Select location to be as unobtrusive as possible, with minimal visual intrusion. ● Take account of topography, natural drainage and site run-off. Avoid areas prone to flooding. ● Select site close to established good access. ● Plan subsequent restoration requirements. ● In remote locations, consider best use of transport 'helirigs'/ slim-hole drilling/helicopter/water transportation, consistent with operational, health and safety requirements. ● Consider cluster drilling to minimize footprint.
	Access	● Consult with local authorities regarding preferred routings. ● Where possible use existing road/water infrastructure. ● Plan routing to minimize subsequent disturbance to natural resources and people. ● Limit road width and footprint consistent with operational, health and safety requirements. ● Minimize vegetation loss and disturbance. ● Limit erosion potential/avoid steep slope and drainage courses/avoid cut and fill techniques/incorporate proper drainage, culverting and bridging techniques.

continued …

Table 5 (continued): Environmental protection measures

Activity	Source of potential impact	Environmental protection measures
Exploration and appraisal drilling (onshore) *(continued)*	Access *(continued)*	● Road construction should use local material, but minimize cutting of timber. ● Block and control access/prevent unauthorized use.
	Site preparation	● Minimize cleared area and size of site/maximize perimeter to area ratio to aid natural revegetation. ● Use hand cutting to clear vegetation initially—where necessary be selective in using machinery. ● Conserve root stock and topsoil, store for later rehabilitation. ● Limit levelling activity. ● Do not burn brush and uprooted materials. ● Where vegetation and soil are removed ensure proper separation and storage/collect seed, rootstock, brash for subsequent revegetation. ● Incorporate drainage and minimize disturbance to natural drainage patterns. Engineer slopes and drainage to minimize erosion. Design for storm conditions/ensure offsite natural run-off does not wash over site/use perimeter drainage ditches. ● Seal bund and ensure proper drainage of machinery areas, fuel and chemical storage, and mud mixing areas. ● Provide base material compatible with local ground conditions. Hard core should be laid on geotextile membrane. Avoid concreting sites. ● Protect water courses from contamination and siltation. ● Protect groundwater from drill stem penetration and shallow aquifers from possible site contamination. ● Where water courses and aquifers are deemed sensitive, consider a fully sealed site, avoid use of mud pits, preferentially use steel tanks, but if used must be lined. Pits if used must be lined. ● Mud and burn pits, if used, must have adequate contingency capacity especially in areas of high rainfall, and must be fully lined and bunded.
	Camp and operations	● **Water supply.** Carefully consider water supply sources (ground water, surface or marine). In areas of water shortage consider water separation/recycling package in mud system. If marine sources are used care must be taken with regard to disposal. ● **Aqueous discharges.** Exploration sites rarely incorporate sophisticated effluent treatment systems, therefore treat contaminated water as liquid waste. ● Treat surface drainage water in an interceptor with hay filter or similar. *continued …*

Table 5 (continued): Environmental protection measures

Activity	Source of potential impact	Environmental protection measures
Exploration and appraisal drilling (onshore) *(continued)*	Camp and operations *(continued)*	● Utilize local sewerage disposal facilities where available. For small, isolated sites, soak away/septic field system can be utilized, biodegradable solids may be buried, liquid discharges should be controlled to ensure that local water resources, both surface and ground water, are not contaminated. ● Containerize spent oils and lubes for proper disposal or recycling. ● Any produced water from well test operations must be properly disposed of. Ensure disposal options are addressed in planning phase and requirements are met. ● **Solid wastes**. Where approved disposal sites are available and suitable these should be used for all offsite waste disposal. On-site disposal may be considered for inert materials. Ensure proper documentation and manifesting. Ensure adequate consultation with local authorities regarding nature, type and volumes of wastes arising and capability and capacity of local resources. ● Do not discard litter and debris around sites. All wastes to be containerized on-site. ● In isolated/remote areas, with no local disposal facilities, putrescible, non-toxic waste may be buried at a depth of 1m or more during decommissioning. Ensure local water resources are not at risk from contamination. ● In isolated/remote areas, with no local disposal facilities, non-toxic dry and liquid wastes may be burnt, giving due consideration to atmospheric effects. If necessary portable incinerators can be used to provide a cleaner burn. ● Containerize contaminated soils which cannot be treated *in situ* and remove offsite for treatment. ● Consider bulk supply of materials to minimize packaging wastes. Return unused materials to suppliers where possible. ● Preferentially use non-toxic water-based muds. Minimize use of oil (OBM) and synthetic muds to where required for operational reasons. Mud make-up and mud and cuttings disposal options must be addressed during planning phase, ensure all requirements are met. Consider downhole disposal of OBM wastes otherwise treat as hazardous waste. ● Requirements of oil spill and emergency plans must be met before operations commence. ● Hazardous materials usage, storage and disposal requirements must meet planning requirements. ● **Atmospheric emission/noise/light.** Ensure requirements from planning phase are met to minimize effects from engine exhausts and extraneous noise and light. Ensure any H_2S problems are addressed. Ensure well test procedures are followed. Any burn pits utilized for well test operations must be lined. If possible produced oil should be stored for subsequent use. ● Noise levels at the site boundary should meet local or company specified. Ensure all machinery and equipment are properly cladded. *continued …*

Table 5 (continued): Environmental protection measures

Activity	Source of potential impact	Environmental protection measures
Exploration and appraisal drilling (onshore) *(continued)*	Camp and operations *(continued)*	● Light sources should be properly shaded and directed onto site area. ● **Socio-economic/cultural.** Ensure all requirements addressed in planning phase are fully met. ● Initiate consultation and liaison with local authorities. Use local expertise. ● Workforce should keep within defined boundary and to the agreed access routes. ● Control workforce activities, e.g. hunting, interaction with local population. Purchase food from recognized local suppliers, not directly from local people without evaluating implications.
	Decommissioning and restoration	● Restoration plan must be followed and site restored to its original condition. ● Remove all debris and contaminated soils. ● Reform contours to natural surroundings. ● Restore natural drainage patterns. ● Break-up base material/re-spread topsoil and brash, vegetation, leaf litter and organic material. Use specialized techniques where sensitivities dictate, e.g. brushwood barriers, seeding, turf, etc. ● Mud pits, where used, should be de-watered and filled in to 1m cover. Infill burn and waste pits to 1m. ● Block access routes, or if required, hand over to local authorities. ● Document and monitor site recovery.
Exploration and appraisal drilling (offshore)	Site selection	● Use environmental assessment to identify protected areas and sensitivities. Schedule operations during least sensitive periods. ● Consult with local authorities regarding site selection and support infrastructure—ports, vessel and air traffic. ● Select least sensitive location within confines of bottom target/drilling envelope. Consider directional drilling to access targets beneath sensitive areas. Consider cluster well drilling. ● Local conditions must be fully assessed—wave, wind and currents. ● In coastal areas, select site and equipment to minimize disturbance, noise, light and visual intrusion.
	Access	● Exercise strict control on access and all vessel and rig activity. ● In coastal areas where sensitivities dictate use vessels in preference to helicopters.

continued …

Table 5 (continued): Environmental protection measures

Activity	Source of potential impact	Environmental protection measures
Exploration and appraisal drilling (offshore) *(continued)*	Operations	● Consult with local authorities regarding emissions, discharges and solid waste disposal/notifications in regard to other resource users. ● Requirements specified in planning process must be met including supply vessel operations. ● **Aqueous discharges.** Oily water from deck washing, drainage systems, bilges etc. should be treated prior to discharge to meet local, national and international consents. ● Sewerage must be properly treated prior to discharge to meet local and international standards. Treatment must be adequate to prevent discolouration and visible floating matter. ● Biodegradable kitchen wastes require grinding prior to discharge, if permitted under local regulations. ● Most spills and leakage occur during transfer operations—ensure adequate preventative measures are taken and that spill contingency plan requirements are in place. ● Store oils and chemicals properly in contained, drained areas. Limit quantities stored to a minimum level required for operational purposes. Ensure proper control documentation and manifesting and disposal. Do not dispose of waste chemicals overboard. ● Produced water from well tests must meet local regulations or company specified standards prior to discharge. ● Preferentially separate and store oil from well test operations. If burnt, ensure burner efficiency is adequate to prevent oil fallout onto sea surface. ● **Solid wastes.** Ensure requirements specified in the planning process are met with regard to waste treatment and disposal. ● Collect all domestic waste and compact for onshore disposal. Ensure proper documentation and manifesting. Ensure onshore receiving and disposal meet local requirements. ● Consider waste segregation at source for different waste types—organic, inorganic industrial wastes etc. ● No debris or waste to be discarded overboard from rig or supply vessels. ● Waste containers must be closed to prevent loss overboard. ● Spent oils and lubes should be containerized and returned to shore. ● Consider bulk supply of materials to minimize packaging wastes. ● **Muds and cuttings.** Preferentially use low toxicity water-based drilling muds. Minimize use of oil-based muds (OBM). ● Mud make-up and mud and cuttings disposal requirements addressed in the planning process must be met. ● Do not dispose of whole OBM to sea. Any oily cuttings discharged must meet local regulations or company specified standards. *continued …*

Table 5 (continued): Environmental protection measures

Activity	Source of potential impact	Environmental protection measures
Exploration and appraisal drilling (offshore) *(continued)*	Operations *(continued)*	● Consider downhole disposal of OBM wastes. ● **Atmospheric emission/noise/light**. Ensure requirements addressed in the planning phase are met with regard to emissions, noise and light. ● Well test burners must be efficient, maintained and effectively burn gas and oil. ● H_2S emissions must be effectively controlled.
	Decommissioning and restoration	● All debris must be removed from seabed. ● Decommissioning of onshore support facilities must meet planning requirements.
Development and production (onshore)	Access	● Requirement for permanent long-term access routes—appropriate design and engineering considerations required, in particular consideration of long-term disturbance from vehicle traffic volume and density in terms of environmental infrastructure and local population. ● All aspects identified for exploration drilling should be applied to permanent access routes. ● Consultation with local authorities is required.
	Site preparation	● Long-term occupation of sites and permanent structures and infrastructure—appropriate design and engineering considerations required, in particular consideration of long-term disturbance and effect on environment, infrastructure and local population. ● All aspects identified for exploration drilling should be applied to permanent sites. ● Consultation with local authorities is required. ● Site selection procedures must avoid long-term disturbance and impact on local environment and infrastructure. ● Consider locating all facilities at single site to minimize footprint. ● Consider maximizing use of satellite/cluster drilling sites, horizontal wells, extended reach drilling in sensitive areas. ● Use consolidated, impermeable base to all facilities with permanent inbuilt drainage systems. ● Segregate drainage systems for offsite and non-contaminated/clean site areas and oily drainage system for process areas. ● Consider construction and drilling activities and impacts separately from operational activities. Construction and drilling will utilize intensive methods and will be longer term compared to exploration construction and drilling requirements. *continued …*

Table 5 (continued): Environmental protection measures

Activity	Source of potential impact	Environmental protection measures
Development and production (onshore) *(continued)*	Site preparation *(continued)*	● Flowlines and pipeline routing will require consideration in terms of disturbance and effects (bury/surface). ● Site selection and preparation planning should include consideration of eventual decommissioning and restoration.
	Operations	● Assess implications of well treatment and workover, process, storage, power generation and other support and accommodation facilities in terms of long-term disturbance and impact. ● Assess implications of development on local infrastructure in particular water supply, power supply, waste disposal and socio-economic considerations—housing, education, welfare, medical, employment/economy etc. ● Install proper waste treatment facilities, particularly if local infrastructure cannot support requirements. In particular, treatment of waste waters—wash water, process water, drainage, sewage, produced water. Reinjection of produced water is a preferred option. ● Assess treatment of waste gases and emission limits, particulary where gas flaring is necessary. Avoid gas venting ● Solid wastes, particularly toxic and hazardous substances, will require full assessment in terms of treatment and disposal options. If local facilities unavailable, proper incineration facilities may be required and a full assessment of implications will be necessary. ● Prepare a detailed waste management plan. ● Install oil sumps, interceptors and oily water treatment system. ● Provide contained storage areas for produced oil, chemicals and hazardous materials, including treatment of tank sludges. ● Prepare detailed contingency plans, personnel training and regular exercise of response. ● Establish consultation and local liaison activities. ● Monitor waste streams in order to meet compliance requirements.
	Decommissioning and aftercare	● Develop full decommissioning, restoration and aftercare plan in consultation with local authorities. ● Hand over any facilities and infrastructure to local authorities with proper instructions for use, maintenance and include proper training procedures. ● Remove, if appropriate, all permanent structures, foundations and bases, roads etc. ● Restore the site to its original condition, levelled and contoured for drainage and erosion control and prepared for revegetation.

continued …

Table 5 (continued): Environmental protection measures

Activity	Source of potential impact	Environmental protection measures
Development and production (onshore) *(continued)*	Decommissioning and aftercare *(continued)*	● If replanting is undertaken, select indigenous species compatible with the surrounding habitat. ● Successful reinstatement will require proper planning and implementation and should not be viewed as an afterthought or a short-term commitment. ● Record and monitor site recovery.
Development and production (offshore)	Site selection and access	● Long-term occupation of sites, including supply and support base, will require detailed assessment of environmental implications, particularly where resource use conflicts arise and commercially important species may be affected. ● All aspects identified for exploration drilling should be applied to permanent sites. ● Consult with local authorities. ● Consider site and route selection for flowlines and pipelines.
	Operations	● Evaluate construction and drilling activities and impacts separately from operational activities. ● Maximize use of central processing facility and use of satellite and cluster wells to minimize footprint. ● All aspects identified for exploration drilling should be applied to permanent sites. ● Consult with local authorities. ● Assess full implications of well treatment and workover, process, storage, power generation and other support and accommodation facilities in terms of long-term disturbance and impact. ● Evaluate implications of development on local infrastructure, in particular, infrastructure related to onshore service functions—port and harbour operations, resource use conflicts, waste treatment and disposal, socio-economic implications, employment, local services and supply, support infrastructure for employee and family accommodation etc. ● Incorporate oily water treatment system for both produced water and contaminated water treatment to meet local, national and international discharge limits. ● Include sewerage treatment system, particularly if close to shore, to meet local requirements. ● Assess treatment of waste gases and emission limits, particularly where gas is flared. Avoid gas venting. ● Treatment and disposal of solid, toxic and hazardous wastes onshore will require proper planning, particularly if local infrastructure is limited in capacity and capability. A detailed waste management plan will be required.

continued …

Table 5 (continued): Environmental protection measures

Activity	Source of potential impact	Environmental protection measures
Development and production (offshore) *(continued)*	Operations *(continued)*	● Prepare detailed contingency plans, personnel training and regular exercise of response, taking into consideration storage and export systems. ● Establish consultation and local liaison activities. ● Monitor waste streams in order to meet compliance requirements.
	Decommissioning and rehabilitation	● Develop a full decommissioning and rehabilitation plan in consultation with local authorities. ● Any facilities and infrastructure handed over to local authorities must include proper instructions for use, maintenance and include proper training procedures. ● Decommissioning of offshore structures is subject to international and national laws, and should be dealt with on a case by case basis with local authorities. ● Record and monitor site as required after appropriate decommissioning activities.

Operational considerations

Pollution prevention and cleaner production

Many practical measures with regard to operational aspects are described in Table 5. These vary from planning considerations and integration of environmental issues into engineering design, to application of on-site procedures aimed at reducing the risk of pollution. Pro-active, preventative techniques are often more effective and efficient. In this text reference is made to 'Pollution Prevention', a concept endorsed by the international oil and gas exploration and production industry. The term 'Cleaner Production', first coined by the UNEP Industry and Environment Centre in 1989, is synonymous, and has become the recognized term used by many international and national organizations.[50,51]

Proactive and preventative measures are most effective when they are coordinated through a special programme that has a high visibility with personnel. 'Pollution Prevention', 'Cleaner Production' or 'Eco-Efficiency' programmes (see box on page 50 for definitions) are now becoming more common within leading companies. They usually include a programme coordinator and plan of action that has been developed with the participation of employees at all levels.

These programmes are aimed at making both organizational and technological changes in operations.

Engineering and operational techniques are now available to avoid or reduce pollution (see 'Technology considerations' on page 53). These cover produced water treatment technologies[7,44,45]; atmospheric emissions reduction techniques[1,46]; and oil-based drilling mud wastes[47,48,49]. A broad ranging discussion on a variety of waste treatment technologies is provided in the E&P Forum *Waste Management Guidelines*.[4]

Achievement of pollution prevention goals will occur over time, partly through a transition to a process that encourages the industry to conduct a critical review of its use of materials, processes and practices, and search for ways to eliminate pollution. The evolution of technology and improved procedures are among the many factors that will affect this transition. A practical approach to implementation encourages managers in striving to conduct operations in an environmentally sound manner, and to move up the environmental management hierarchy (that is, from treatment to environmentally sound recycling and beneficial use to source reduction). The table in Annex 3 on page 66 illustrates some management practices developed in line with industry commitment to the environment.[17]

A critical element in the adoption of pollution prevention relates to technical cooperation and capacity building. The oil and gas industry recognizes that new technologies

Prevention approaches

Pollution prevention is an integrated concept that reduces or eliminates pollutant discharges to air, water or land and includes the development of more environmentally acceptable products, changes in processes and practices, source reduction, beneficial use and environmentally sound recycling.

American Petroleum Institute Step Programme

Cleaner production is the continuous use of industrial processes and products to increase efficiency, to prevent pollution of air, water and land, to reduce wastes at source, and to minimize risks to the human population and the environment.

UNEP Cleaner Production Programme

The delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with the earth's estimated carrying capacity.

WBCSD Eco-Efficiency Programme

must not be transferred in isolation, but require corresponding human skills and management systems to apply them. Numerous practical examples of such transfers from the oil industry are provided in reference 19, and similar examples from wider industry in references 20 and 29. UNEP, through its Cleaner Production programme has applied the concept to government strategy and policy development.[50] The World Business Council for Sustainable Development (WBCSD) introduced the concept of Eco-Efficiency. UNEP and WBCSD are working together in the policy development and implementation of both concepts.[51]

Waste treatment and disposal techniques

If elimination of waste is not possible through pollution prevention, then waste management must be accomplished through application of another series of measures—reduction, re-use, recycling, recovery, treatment and responsible disposal—the approach inherent in UNEP's Cleaner Production programme. The methodologies which apply these principles are fully described in the E&P Forum *Waste Management Guidelines*.[4] The following text describes the development of area-specific waste management plans, which can be directly implemented at the site level.

An area-specific waste management plan directly relates the choice of waste handling and disposal options to the ecological sensitivities, regulatory requirements and available facilities/infrastructure of the geographical area involved. The plan should be written from the field perspective and provide guidance for handling each waste stream. In developing a plan, an exploration and production company could follow the ten general steps outlined in Table 6.

Area waste management planning, implementation and review offers reassurance with regard to:

- protection of the environment and ongoing compliance with regulatory requirements;
- ongoing training of field personnel;
- appropriateness of the plan itself; and
- minimization of the volume and toxicity of the wastes.

The waste management plan should be a living 'evergreen' document which requires periodic review and revision.

Oil spill contingency planning

All operations should properly examine the risk, size, nature and potential consequences of oil spills and develop appropriate contingency plans, including informing the community of any hazards involved. Various documents are available.[8,9,10,11,12,13,14,15,16,33,34,35,36] The bases of contingency planning are the identification of risk; the planning and implementation of actions to manage risks; procedures for reviewing and testing of preparedness; and training of personnel.

Contingency planning should facilitate the rapid mobilization and effective use of manpower and equipment necessary to carry out and support emergency response operations. Exercises and training should be conducted regularly to ensure preparedness. Communications should be maintained with appropriate authorities, local communities, media, neighbouring operators, contractors and employees.

Table 6: Site or area-specific waste management plan

Step 1: Management approval

Management approval and support for the plan should be obtained. Management should be aware of the timing and scope of the plan. The goal(s) of the waste management plan should be established with measurable objectives for each goal.

Step 2: Area definition

The plan should be site- or area-specific and should include a description of the geographical area and operational activities addressed.

Step 3: Waste identification

Operations personnel should identify all the wastes generated within the area defined for each exploration and production activity (i.e. production, drilling, completion/workover, natural gas plants). A brief description for each waste (sources, per cent oil and/or saltwater content and approximate volume) will assist in further management steps.

Step 4: Regulatory analysis

Review international, regional and host country laws and regulations to determine the types of wastes for which management practices should be highlighted. Waste types for which the regulations do not adequately define management requirements should also be identified.

Step 5: Waste categorization

The physical, chemical and toxicological properties of each waste should be identified via Material Safety Data Sheets (MSDS), manufacturers information, process knowledge, historic information or lab analyses. Wastes can be grouped according to their health and environmental hazards.

Step 6: Evaluation of waste management and disposal options

Waste management option(s) for each waste should be compiled, and available options identified. Each option should be reviewed by appropriate operations personnel and management. Evaluation should include: environmental considerations; location; engineering limitations; regulatory restrictions; operating feasibility; economics; potential long-term liability; etc.

Step 7: Waste minimization

Waste, volume or toxicity reduction, recycling and reclaiming, or treatment should be evaluated. Revision of the waste management plan should be made to reflect any minimization practices implemented.

Step 8: Selection of preferred waste management practice(s)

Select the best practice for the specific operation and location. Life-cycle analysis including use, storage, treatment, transport and disposal should be considered.

Step 9: Implementation of an area waste management plan

Waste management and disposal options for each waste should be compiled into one comprehensive waste management plan.

Waste management practices should be summarized, including waste descriptions, indicating the chosen waste management and disposal practice.

Step 10: Plan review and update

Effective waste management is an ongoing process. The plan should be reviewed whenever new waste management practices or options are identified. A procedure to review and update the waste management plan should be established, and practices modified to reflect changing technologies, needs or regulations.

Source: E&P Forum *Waste Management Guidelines*[4]

Contingency plans

- Identify risks and objectives
- Establish response strategy
- Establish communications and reporting
- Determine resource requirements
- Determine action plans
- Define training and exercise requirements
- Provide data directory and supporting information

Plans should clearly identify the actions necessary in the event of a spill: the communications network, the organization structure, the individual responsibilities of key emergency personnel, together with the procedures for reporting to the relevant authorities. The plan should clearly identify vulnerable and sensitive locations and tackle the problem of the disposal of recovered material, contaminated waste and debris.

Responsibility for contingency plans, their implementation, training and exercise and periodic audit and review should be clearly delegated to site staff as required under the environmental management system.

Decommissioning and rehabilitation

Many exploration wells will be unsuccessful and decommissioned after the initial one to three months activity. It is worth planning for this from the outset, and ensuring minimal environmental disruption. Decommissioning and rehabilitation will, subsequently, be simplified.

Site decommissioning and rehabilitation is an important part of environmental management. The main purpose is to rehabilitate a site to a condition that meets certain agreed objectives. To be successful, rehabilitation plans need to be developed early in the planning process using information gathered during the assessment phase. The site needs to be prepared and managed in such a way as to ease eventual rehabilitation. In most cases progressive rehabilitation is preferable to leaving everything to the end.

Discussions with appropriate authorities and/or local communities should have been held during the planning phase to determine a preferred and feasible after-use for the site, but may need to be reviewed and updated when decommissioning is imminent. Such discussions should occur periodically through the life of the project to check that circumstances have not resulted in a change of opinion regarding the preferred after-use. Once final agreement has been reached, a reclamation plan should be prepared. A number of rehabilitation options are available.

Rehabilitation options

- Rehabilitation to pre-development condition.
- Partial rehabilitation.
- Rehabilitation to an acceptable alternative condition.
- No action.

In general reclamation should be based on a risk assessment process to ascertain the level required, and in some cases no rehabilitation or partial rehabilitation may be appropriate. In cases where operations have taken place in the vicinity of existing human settlements, there may be a local wish to retain roads or other useful infrastructure. Partial restoration would then involve the removal of all equipment and contaminants, but not the agreed infrastructure. The environmental consequences of retaining roads and therefore access into the area, however, need to be taken into consideration before such partial rehabilitation can be approved. The E&P Forum decommissioning guidelines[52] describe in detail the recommended decommissioning processes for onshore E&P sites, including dealing with contaminated sites and soils clean-up.

A wide range of international, regional and national legislation regulates the decommissioning of offshore structures.[37,38] The offshore oil and natural gas exploration and production industry has provided a briefing paper assessing the implications of decommissioning.[38]

Environmentally-sensitive areas

The framework presented in this document should allow operators and stakeholders to understand the development and practice of environmental management and to appreciate some ecological, social and cultural sensitivities related to operations. However, not all measures discussed in this framework document will necessarily be appropriate for implementation in all geographic areas or under all conditions. The reader is referred to existing guidance for activities in sensitive environments—Arctic and sub-Arctic,[21,30] mangroves,[22] tropics,[25] tropical rain forests,[26] coastal waters,[28] geophysical operations.[27]

Other environments also have peculiar sensitivities and may warrant special approaches: for example, temperate woodlands, boreal forests, wetlands and marshes, freshwater and inland seas, coral reefs, arid areas.

Technology considerations

The oil and gas exploration and production industry has been pro-active in evaluating and introducing new engineering and operational techniques aimed at pollution prevention. Specific examples are given in Table 5. Improved management approaches and operational practices have been described previously, and the aim of this section is to illustrate some technological approaches to prevent and reduce pollution.

Atmospheric emissions

A principal target for emissions reduction is flaring and venting which provide the most significant source of air emissions in the industry. Many process optimization studies have been conducted by industry to identify opportunities for emissions reductions. This has led to the development of improved process control procedures, design and maintenance systems. Technological advances in valve design have the potential to reduce fugitive emissions, whilst improved flare design has increased combustion efficiency. Flare gas recovery and increased NGL recovery have resulted from evolving new technologies.

Various technological initiatives have been introduced to reduce emissions as a result of combustion processes related to power production. More efficient gas turbines have been developed together with improved turbine maintenance regimes. Efficiency improvements have also resulted from gas turbine optimization considerations. Other technologies to improve fuel efficiency include: steam injection; combined cycle power generation; electric power distribution (phase compensations); pump and compressor optimization; waste heat recovery; coordinated, shared power generation; and the application of energy conservation principles.

Other technologies being introduced are aimed at improved combustion performance: for example, dry low NO_x combustion (DLN) technology, selective catalytic reduction (SCR) technology, as well as water and steam injection, all aimed at reducing NO_x emissions. Improved injection systems and pre-combustion in diesel engines also have the potential to reduce NO_x emissions.

Various improvements in well testing procedures and technology have resulted in reduced emissions from this source. Again optimization work has included examination of better fluid properties to improve combustion, and better operating procedures. Significant advances in burner technology and design have improved performance, such as the Schlumberger 'Green Dragon' burner, the Expro 'Super Green' Crude Oil Burner and Charbonnages de France incinerator feasibility study. The technologies discussed above are assessed in more detail in references 1 and 46.

Produced water

The second major waste resulting from the oil production process is produced water. Since water is naturally produced with the oil there is limited potential to eliminate the source. However, some progress has been made to limit water production. Water shut-off technology such as diverting gels can provide an efficient way of reducing the quantities of water requiring treatment. Reinjection of produced water, either into the reservoir, or into another formation, may provide a practical and optimum solution if suitable geological formations are available.

New technologies are emerging for the treatment of produced water, particularly related to the removal of dispersed oil. These include: skimming/gas flotation; static hydrocyclones; mechanical centrifugation; and gas stripping. Most of these technologies are currently in normal operation or have reached the stage of prototype testing. Other processes are currently being examined for potential application onshore and include: bio-oxidation and biological treatments; activated carbon filtration; solvent extraction; wet oxidation and ozonation. More detailed assessment of these technologies is provided in references 44 and 45.

Solid wastes

Many aspects of waste management are examined in reference 4, which includes examination of the potential for source reduction. However, opportunities to eliminate or decrease waste are limited because frequently their volumes primarily result from the level or longevity of activity or the state of reservoir depletion. Opportunities for reduction arise principally through process and procedure modifications. In the case of drilling fluid discharge, improved solids control equipment and new technology can reduce the volumes discharged to the environment. The development of more effective drillbits can reduce the need for chemical additions, whilst gravel packs and screens may reduce the volume of formation solids/sludge produced. Improved controls, procedures and maintenance can help minimize mud changes, engine oil changes and solvent usage.

The search for chemicals with lower potential environmental impacts has resulted in the generation of less toxic wastes, for example mud and additives that do not contain significant levels of biologically available heavy metals or toxic compounds. It has also resulted in the development and use of mineral and synthetic drilling fluids.

Re-use, recycling and recovery of waste materials has also been examined, including the use of drill cuttings for brick manufacture and road bed material, use of vent gas for fuel, and the use of produced or process water as wash water. Wastes such as tank bottoms, emulsions, heavy hydrocarbons, and contaminated soils may be used in road building.

Several new technologies are being applied to waste treatment such as: biological treatment (land spreading, composting, tank-based reactors); thermal methods (thermal desorption and detoxification); chemical methods (precipitation, extraction; neutralization); and physical methods discussed above (gravity separation, filtration, centrifugation). Downhole disposal of wastes has received attention recently,[47,48,49] not only for produced water but also for oil-based mud drilling wastes.

Techniques

In evaluating and introducing new practices, the industry examines not just technologies as described above, but also techniques aimed at minimizing and eliminating environmental effects. Some drilling techniques that have been developed recently include horizontal drilling, heliportable rigs, and slim-hole drilling. Each provides a number of direct environmental advantages, such as minimizing land take and footprint, and reduction in waste material. In seismic activities the development of vibroseis on land and air guns at sea have considerably reduced the dependence upon explosives. However, it should be borne in mind that newer technologies do not always necessarily lead to best environmental practice, and an environmental assessment of which technologies or techniques are least damaging should always be undertaken. For example, in operations in forests, shot-hole techniques may be preferable to vibroseis, since there is less requirement for cutting and vegetation clearance.

The way operations are approached logistically can also provide environmental advantage. Exploration in remote and environmentally sensitive locations on land may be accessed, operated and serviced using techniques normally applied to offshore drilling, thus eliminating the need to construct access roads. However, a balanced assessment is required in each case to determine best environmental practice, examples of which are given in Table 5.

Glossary

Information contained in this Glossary has been abstracted from *Nature Conservation Guidelines for Onshore Oil and Gas Development* (UK Nature Conservancy Council, 1986).

abandon (a well)
To cease work on a well and seal it off with cement plugs.

aftercare
A management programme which follows decommissioning and restoration of a site to ensure full restoration to a predetermined after use.

annular space
The space surrounding a cylindrical object within a cylinder; the space around a pipe in a wellbore, the outer wall of which may be the wall of either the borehole or the casing, sometimes termed the annulus.

appraisal well
A well drilled after a hydrocarbon discovery to delineate the extent of a reservoir, and to test its productivity and properties.

bentonite
A naturally occurring clay, which is often a major constituent of drilling muds.

blowout
The uncontrolled flow of gas, oil or other well fluids into the atmosphere which occurs when formation pressure exceeds the pressure applied to it by the column of drilling fluid. Shallow gas blowout relates to uncontrolled flow of gas from gas pockets located above the intended reservoir prior to the installation of a blowout preventer.

borehole
See wellbore.

BPEO
Best Practical Environmental Option: considers activities as a whole and requires that the environmental implications of all the options available be evaluated and that the option chosen results in the least environmental damage and which is consistent with the prevailing regulations.

casing
Steel tube which is cemented into an oil well to prevent the collapse of the well, the flow of fluids between formations, possible contamination of groundwater, and to protect permafrost layers.

crude oil
Oil produced from a reservoir after any associated gas and/or water has been removed, often simply referred to as 'crude'.

cuttings
The fragments of rock dislodged by the bit and brought to the surface in the drilling mud.

development well
Well drilled in a formation for the purpose of producing oil and gas. Also called a production well.

deviated or directional
Controlled progressive deviation of a well away from the vertical to reach different parts of a reservoir from a single drilling site.

drilling muds
Specialized fluid made up of a mixture of clays, water (sometimes oil) and chemicals, which is pumped down a well during drilling operations to lubricate the system, remove cuttings and control pressure.

drilling rig
The complete machinery and structures needed for drilling a well (the most visible component being the mast or derrick).

dry hole
A well drilled without finding gas or oil in commercial quantities.

E&P Forum
The Oil Industry International Exploration and Production Forum, an international industry trade association.

effluents
Liquid waste materials discharged from the operations.

exploration
The search for reservoirs of oil and gas, which includes aerial and geophysical surveys, geological studies, core testing, and drilling of wells.

exploration drilling
Drilling carried out to determine whether hydrocarbons are present in a particular area or geological structure or to learn more about subsurface structures.

field
Geographical area in which a number of oil or gas wells produce from a continuous reservoir.

flaring
Controlled disposal of surplus combustible vapours by igniting them in the atmosphere.

flowline
The surface pipe through which oil travels from the well to processing equipment or to storage.

formation
A bed or deposit composed throughout of substantially the same type of rock; a lithological unit; each different formation is given a name.

gas processing
The separation of constituents from natural gas for the purpose of making saleable products and also for treating the residue gas.

geophones
The detectors used in seismic surveys to pick up acoustic waves reflected from sub-surface strata.

grey water
Waste water from washing operations (e.g. from showers, laundry, kitchen, handbasins etc).

injection well
A well used to inject gas or water into an oil/gas reservoir rock to maintain reservoir pressure during the secondary recovery process. Also a well used to inject treated wastes into selected formations for disposal.

IPIECA
International Petroleum Industry Environmental Conservation Association: an international industry trade association.

jack-up drilling rig
An offshore drilling structure with tubular or derrick legs that support the deck and hull. When positioned over the drilling site, the bottom of the legs rest on the sea floor. The rig is propelled or towed to location with its legs up, on arrival the legs are 'jacked' down to the seabed and the hull 'jacked' up above the sea surface.

OBM
Oil-based mud.

oil field
A productive oil or gas formation comprising one or more reservoirs, usually related to the same geological features.

primary recovery
The first stage of oil production in which natural reservoir pressure is used to recover oil.

produced water
Water originating from the natural oil reservoir, that is separated from the oil and gas in the production facility.

production
That phase of petroleum activities that deals with bringing the well fluids to the surface and separating them, and with storing, gauging, and otherwise preparing the product for the pipeline.

recoverable reserves
That proportion of the oil/gas in a reservoir that can be removed using currently available techniques.

recovery
The total volume of hydrocarbons that has been or is anticipated to be produced from a well or field.

reservoir rock
Porous and permeable rock, such as sandstone, limestone, or dolomite, containing petroleum within the small spaces in the rock.

secondary
Recovery of oil or gas from a reservoir by artificially maintaining or enhancing the reservoir pressure by injecting gas, water or other substances into the reservoir rock.

semi-submersible
A floating offshore drilling structure that has hulls submerged in the water but not resting on the seafloor.

shot hole
A bore hole in which an explosive is placed for blasting in use as the energy source for seismic survey.

sour crude or gas
Oil or gas which has a high sulphur content.

strata
Distinct, usually parallel beds of rock.

tertiary recovery
Recovery of oil or gas from a reservoir over and above that which can be obtained by primary and secondary recovery—generally involves sophisticated techniques such as heating the reservoir to reduce the viscosity of the oil.

UNEP
United Nations Environment Programme.

vibroseis
A seismic survey technique which uses a large vehicle fitted with vibrating plates to produce shockwaves.

well completion
The activities and methods used to prepare a well for the production of oil and gas, may include establishment of a flow between reservoir and surface.

wellbore
The wellbore, the hole made by drilling or boring; it may be open, or a portion may be cased.

workover
A process by which a completed production well is subsequently re-entered and any necessary cleaning, repair and maintenance work done.

References

(1) OLF Environmental Programme, Report Phase 1, Part A—Emissions to Air. OLF. December 1991.

(2) *Chemical Treatments and Usage in Offshore Oil and Gas Production Systems*. API, Offshore Effluent Guidelines Steering Committee. October 1989. Ed. C.M. Hudgins.

(3) *Chemical Usage in North Sea Oil and Gas Production and Exploration Operations*. OLF. (February 1991)

(4) Exploration and Production (E&P) *Waste Management Guidelines*. E&P Forum. September 1993. Report No. 2.58/196.

(5) *The Impact of Water-Based Drilling Mud Discharges on the Environment.* Industry and Environment Overview Series. UNEP Paris (1985).

(6) *The Physical and Biological Effects of Processed Oily Drill Cuttings* (Summary Report). E&P Forum. April 1996. Report No. 2.61/202.

(7) *North Sea Produced Water: Fate and Effects in the Marine Environment.* E&P Forum. May 1994. Report No. 2. 62/204.

(8) *APELL Awareness and Preparedness for Emergencies at Local Level*. A Process for Responding to Technological Accidents. UNEP/IE. Paris. (1988).

(9) *Hazard Identification and Evaluation in a Local Community.* UNEP/IE Technical Report No. 12. Paris. (1992).

(10) *A Guide to Risk Assessment and Risk Management for Environmental Protection.* HMSO. London. (1995).

(11) *A Guide to Contingency Planning for Oil Spills on Water*. IPIECA 1991.

(12) *Sensitivity Mapping for Oil Spill Response.* IMO/IPIECA. 1996.

(13) *Guidelines on Biological Impacts of Oil Pollution.* IPIECA 1991.

(14) *Biological Impacts of Oil Pollution: Coral Reefs.* IPIECA 1992.

(15) *Biological Impacts of Oil Pollution: Mangroves.* IPIECA 1993.

(16) *Biological Impacts of Oil Pollution: Rocky Shores.* IPIECA 1995.

(17) *Environmental Principles.* EUROPIA/E&P Forum (1991).

(18) *Environmental Guidelines.* UKOOA (1991).

(19) *The Oil Industry Experience. Technology Cooperation and Capacity Building.* Contribution to Agenda 21. UNEP/IPIECA. London. (1995).

(20) *Partnerships for Sustainable Development. The Role of Business and Industry.* UNEP/PWBLF/Tufts University. London. (1994).

(21) *Oil and Gas Exploration and Production in Arctic and sub-Arctic Regions.* IUCN/E&P Forum (1993). Report No. 2. 55/184.

(22) *Oil and Gas Exploration and Production in Mangrove Areas* (IUCN/E&P Forum 1993). Report No. 2. 54/184.

(23) *Guidelines for the Development and Application of Health, Safety and Environmental Management Systems.* E&P Forum (1994). Report No. 6. 36/210.

(24) American Petroleum Institute. *Safety and Environmental Management Programs (SEMP) in the offshore oil industry.* RP75.

(25) *Oil Exploration in the Tropics: Guidelines for Environmental Protection.* IUCN (1991).

(26) *Oil Industry Operating Guideline for Tropical Rainforests.* E&P Forum (1991). Report No. 2. 49/170.

(27) International Association of Geophysical Contractors, (1992). *Environmental Guidelines for World-wide Geophysical Operations*. IAGC, Houston, USA.

(28) *Oil Exploration, Development and Production in Coastal Waters: Best Environmental Practice. Countryside Council for Wales* (January 1994). FSCRC Report No. FSC/RC/19/93.

(29) Environmental Management Tools—Sustainable Industrial Development. *Industry and Environment.* UNEP IE. Paris. Volume 18, No 2–3. April–September 1995

(30) *Oil and Gas Exploration and Production in Arctic and sub-Arctic Offshore Regions.* E&P Forum. In preparation.

(31) *Environmental Assessment. A Guide to the Procedures.* HMSO. London. (1989).

(32) *Environmental Source Book Volume III: Guidelines for Environmental Assessment of Energy and Industry Projects.* World Bank Technical Paper Number 154. 1991. ISSN 0153-7494.

(33) International Tanker Owners Pollution Federation Technical Papers 1–12 (1981–86).

(34) *A Field Guide to Coastal Oil Spill Control and Clean-up Techniques.* CONCAWE (1981). Report No. 9/81.

(35) *A Field Guide to Inland Oil Spill Clean-up Techniques.* CONCAWE (1983). Report No. 10/83.

(36) *Dispersants and their Role in Oil Spill Response.* IPIECA 1993.

(37) *The removal of offshore installations: a compilation of International Rules, Guidelines and Standards.* E&P Forum. Report No. 10.11/193. June 1993.

(38) *Decommissioning Offshore Oil and Gas Installations: Finding the Right Balance.* A discussion paper. E&P Forum. 1995

(39) *Quantitative Risk Assessment.* A Position Paper issued by the E&P Forum May 1989. Report 11.2/150.

(40) *Recommended Measurements to Improve the Availability and Quality of High Priority Quantitative Risk Assessment Data.* E&P Forum. April 1991. Report No 11.3/174.

(41) E&P Forum Workshop on Data in Oil and Gas Quantitative Risk Assessments, 15 December 1993. Report No 11.7/205. January 1994.

(42) *Environmental Auditing.* International Chamber of Commerce Paris. June 1989.

(43) *Environmental Auditing.* UNEP/IEO Technical Report No 2. 1990.

(44) *Treatment of Production Water—A Review of Current Performance.* E&P Forum (July 1989). Report No. 2. 29/111.

(45) *Technologies for Handling Produced Water in the Offshore Environment.* E&P Forum (Sept 1996). Report No. 2. 71/247.

(46) *Atmospheric Emissions from the Offshore Oil and Gas Industry in Western Europe.* E&P Forum (December 1994). Report No. 2. 66/216.

(47) *Oil-based Drilling Muds.* Status Report. E&P Forum (November 1985). Report No. 2.37/124.

(48) *Oil-based Muds—Some Developments Influencing Cuttings Discharges and their Environmental Implications—a progress report.* E&P Forum (1985). Report No. 2.41/136.

(49) *E&P Forum Guidelines for the Planning of Downhole Injection Programmes for Oil-Based Mud Wastes and Associated Cuttings from Offshore Wells.* E&P Forum (October 1993). Report No. 2. 56/87.

(50) *Government Strategies and Policies for Cleaner Production.* UNEP/IE. Paris. (1994).

(51) *Eco-efficiency and Cleaner Production—Charting the Course to Sustainability.* UNEP—Paris, World Business Council for Sustainable Development—Geneva. 1996.

(52) *Decommissioning, Remediation and Reclamation Guidelines for Onshore E&P Sites.* E&P Forum (October 1996). Report No. 2.70/242.

(53) *Environmental Problems of Petroleum Production in the Amazon Lowlands of Ecuador.* Hettler, J; Lehmann, B; Le Marie, L. (1996). Berliner geowiss.Abh. (A). 183. 71pp. Berlin 1996.

(54) *Quantitative Risk Assessment Data Directory.* E&P Forum. (October 1996). Report No. 11.8/250.

(55) *Overview of Rules Regulations and Recommended Practice for Operational Discharges from Offshore Oil and Gas Exploration and Exploitation Activities.* Petroconsultants (UK) Ltd. Report for Netherlands government. Society of Petroleum Engineers Conference, New Orleans, June 1996.

Short bibliography on environment

Global Environment Outlook. UNEP, 1997.

Encyclopaedia of the Environment. R. Eblen & W.R. Eblen eds., Rene Dubois Center for Human Environments, Houghton Kifflin, 1994.

The World Environment 1972–1992—two decades of challenge. UNEP, M.K. Tolba & O. El-Kholy eds., Chapman & Hall, London, 1992.

Environmental Data Report, 1993–1994. UNEP, Blackwell Publ.

State of the World 1995. L.R. Brown, Worldwatch Institute. Earthscan Publ. 1995

Vital Signs 1994—the trends that are shaping our future. L.R. Brown, H.Kane, D.M. Roodman, Worldwatch Institute, 1994.

Chemical Pollution, a global overview. UNEP, 1992

Our Common Future. Report by the UN Commission on Environment and Development, 1987.

Agenda 21. Conference document from the UN Conference on Environment and Development, Rio de Janero, 1992.

Industrial Ecology. T.E. Graedel and B.R. Allenby, AT&T, Prentice Hall Publ. 1995.

Changing Course—a Global Business Perspective on Development and the Environment. S. Schmidheiny, MIT Press, 1992.

Blueprint for Green Management—creating your company's own environmental action plan G. Winter, McGraw-Hill, 1995.

Environmental Business Management—an introduction. Klaus North, ILO, 1992.

Environmental Guidelines for World Industry, International Chamber of Commerce, Paris, 1990.

Some UNEP IE publications

Environmental Management Practices in Oil Refineries and Terminals—An Overview. 1988, 103 pp.

The Impact of Water-Based Drilling Mud Discharges on the Environment—An Overview. 1985, 50 pp.

UNEP/ICC/FIDIC Environmental Management System Training Resource Kit. UNEP/ICC/FIDIC, 1995, 400 pp.

Company Environmental Reporting: A Measure of the Progress of Business and Industry Towards Sustainable Development (TR 24). 1994, 118 pp.

From Regulations to Industry Compliance: Building Institutional Capabilities (TR 11). 1992, 62 pp.

The Oil Industry Experience: Technology Cooperation and Capacity Building. Contribution to Agenda 21, UNEP/IPIECA, 1995, 65 pp.

Storage of Hazardous Materials: A Technical Guide for Safe Warehousing of Hazardous Materials (TR 3). 1990, 80 pp.

Hazard Identification and Evaluation in a Local Community (TR 12). 1992, 86 pp.

APELL—Awareness and Preparedness for Emergencies at Local Level: a Process for Responding to Technological Accidents. 1988, 63 pp.

Management of Industrial Accident Prevention and Preparedness. Training Resource Package, 1996, 110 pp.

Risk Management of Contaminated Industrial Land. Training Resource Package, 1996, 110 pp.

Government Strategies and Policies for Cleaner Production. 1994, 32 pp.

Climate Change and Energy Efficiency in Industry. UNEP IE/IPIECA, 1991, 64 pp.

Audit and Reduction Manual for Industrial Emissions and Wastes (TR 7). UNEP/UNIDO, 1991, 127 pp.

Monitoring Industrial Emissions and Wastes (TR 27). UNEP/UNIDO, 1996, 131 pp.

Environmental Aspects of Selected Non-Ferrous Metals (Cu, Ni, Pb, Zn, Au) Ore Mining (TR 5). UNEP/ILO, 1992, 116 pp.

Environmental and Safety Incidents Concerning Tailings Dams at Mines. UNEP/DHA, 1996, 129 pp. 20

Case Studies Illustrating Environmental Practices in Mining and Metallurgical Processes. UNEP/ICME, 1996, 61 pp.

Environmental Management of Mine Sites—A Training Manual (TR 30), UNDDSMS/UNEP, 1994, 311 pp.

Landfill of Hazardous Industrial Wastes—A Training Manual (TR 17). 1994, 315 pp.

Anticipating the Environmental Effects of Technology—A Primer and Workbook. 1996, 216 pp.

Industry Environmental Compliance (TR 36). 1996, 158 pp.

Partnerships for Sustainable Development: the Role of Business and Industry. a joint Prince of Wales Business Leaders Forum. Tufts University/UNEP publication, 1994, 100 pp.

(TR = Technical Report)

Annex 1

Multi-stakeholder partnership

In the Introduction to this document, reference was made to partnership and stakeholders, and the purpose and scope outlines the audience as being key 'stakeholders'. The figure below attempts to illustrate the wide variety of people and organizations—government, academia, business, industry and civil—who may have an interest in various aspects of development. It is obvious that there is an enormous range and complexity with a wide variety of geographies, issues, interests and agendas. One of the underlying tenets of Agenda 21 is the commitment and genuine involvement of all social groups[20], and the oil and gas industry has demonstrated its commitment[17,18,19] to this concept. The aim of partnership is to move from positions of confrontation, dependence or isolation, to positions of mutually agreed and understood interdependence.

Roles within the partnership have been summarized within the text of Agenda 21 as follows:

'Agenda 21 addresses the pressing problems of today and also aims at preparing the world for the challenges of the next century. It reflects a global consensus on development and environment cooperation. Its successful implementation is first and foremost the responsibility of governments.'

Chapter 1

Civil society

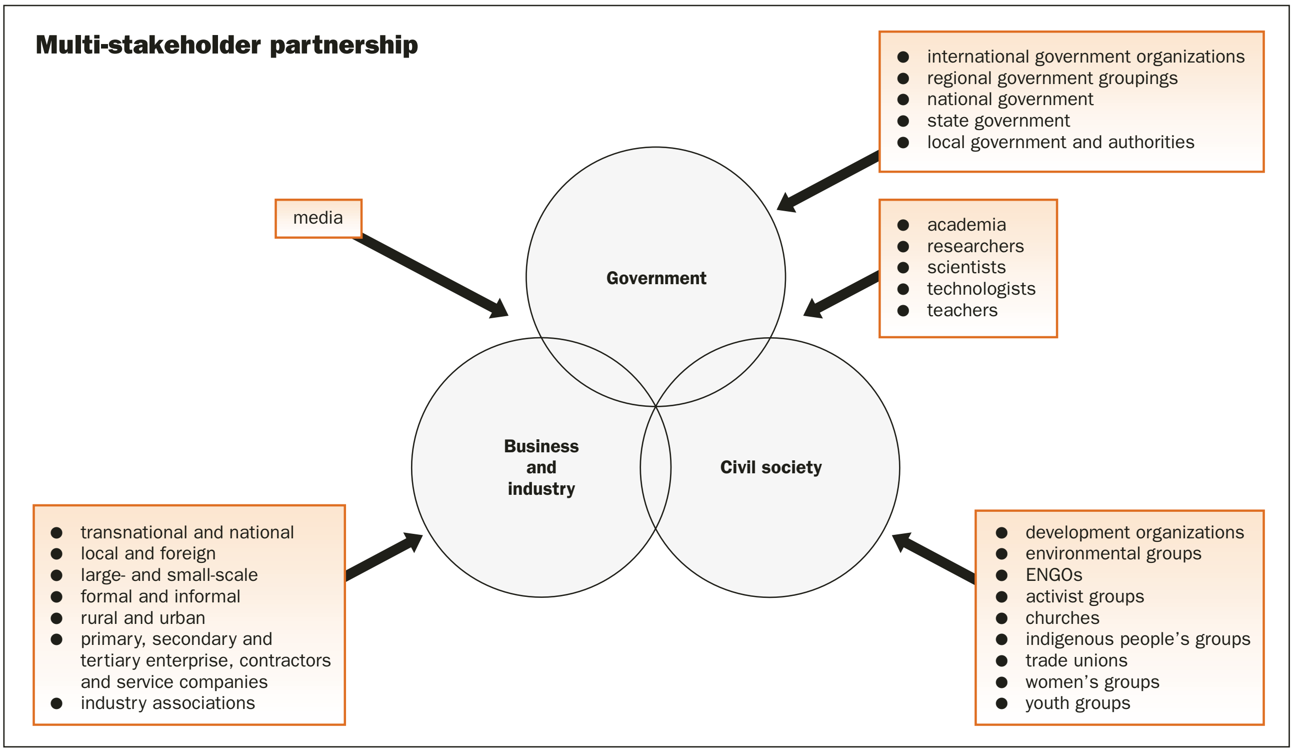
'… play a vital role in the shaping and implementation of participatory democracy. Their credibility lies in the responsible and constructive role they play in society. Formal and informal organizations, as well as grass roots movements, should be recognized as partners in the implementation of Agenda 21.'

Chapter 27

Business and industry

'… including transnational corporations, and their representative organizations should be full participants in the implementation and evaluation of activities related to Agenda 21.'

Chapter 30



Annex 2
Some air quality/operational discharge standards

Table A-1: Selected World Health Organization air quality guidelines

Substances	Time-weighted	Averaging time
Lead	0.5–1.0 mg/m^3	1 year
Nitrogen dioxide	400 mg/m^3 150 mg/m^3	1 hour 24 hours
Ozone	150–200 mg/m^3 100–120 mg/m^3	1 hour 8 hours
Sulphur dioxide	500 mg/m^3 350 mg/m^3	10 minutes 1 hour
Total suspended particulates	120 mg/m^3	24 hours
Carbon monoxide*	60 mg/m^3 30 mg/m^3 10 mg/m^3	30 minutes 1 hour 8 hours
Polyaromatic hydrocarbons	**	**
Benzene (airborne)	**	**

* to prevent carboxyhaemoglobin levels exceeding 2.5–3 per cent in non-smoking population

** no safe level recommended, owing to carcinogenicity

Table A-2: Operational discharge standards prescribed by regional instruments

Convention	Legal basis	Produced water	Oily cuttings	Chemicals	Sewage/garbage
OSPAR Convention 1992	Recommendation 1986; Decision 92/2	Average 40 mg/l	Exploration–10 g/Kg Production–100 g/Kg*	Notification Scheme under development	N/A
Helsinki Convention 1992	Article 10, Annex IV; Recommendation 9/5	15 mg/l (40 mg/l if 15 cannot be met)	Not permitted in sensitive areas. Permitted elsewhere subject to a number of provisions	Defines handling and disposal requirements for different chemicals. All discharges must be authorized	Treated sewage discharge prohibited < 4 n.m. from the coast. Untreated discharge permitted > 12n.m. Disposal of garbage restricted
Barcelona Convention 1976	Mediterranean Seabed Protocol 1994 Articles 10,11,12	Average 40 mg/l (Max < 100 mg/l). 15 mg/l limit for machinery drainage	100 g/kg prohibited in specially protected areas	Chemical Use Plan required	Prohibited < 4 n.m. from the coast. Disposal of garbage restricted
Kuwait Convention 1978	Kuwait Protocol 1989 Articles IX, X, XI	Average 40 mg/l (Max < 100 mg/l). 15 mg/l limit for machinery drainage	Oil contamination minimization required	Chemical Use Plan required	Prohibited < 4 n.m. from the coast. Untreated discharge permitted > 12 n.m. Disposal of garbage restricted

* Until 31 December 1996 when the discharge standard of 10g of oil per Kg of dry rock is to apply to all wells. There is currently no available technology that can reduce the oil content to this level.

N/A Not applicable

Table A-3: Offshore discharge limits for oil in produced water—prescribed by national legislation
(based on Petroconsultants[55])

Country	Legal basis	Licensing/ monitoring authorities	Discharge limit oil in water	Comment
Canada	Act RSC 1987	Newfoundland Offshore Petroleum Board	40 ppm	Production activities have not yet commenced
United States	40 CFR 435	EPA; Minerals Management Service	29 mg/l monthly average	No visual sheen, max. discharge levels of 42 mg/l. Discharge is prohibited in near-shore areas
Netherlands	Regulation 687/1224, 1987	Min Economic Affairs; State Supervision of Mines	40 mg/l	For gas platforms, exemptions from 40 mg/l limit where best available technology already installed
Norway	PARCOM 10/10/1 of 1988	SFT	40 mg/l	Monthly average
United Kingdom	PARCOM 10/10/1 of 1988	Dept of Trade and Industry;	40 mg/l	Monthly average. Max. discharge 100 ppm
Egypt	Decree No 338/95	EGPC/EEAA	15 ppm	Special dispensations may be awarded by the EGPC
Italy	Dm of 28.7 1994	Ministry of Environment	40 ppm	More stringent standards may be applied
Tunisia	Order of 1989	ANPE	10 ppm	Zero discharge conditions have been imposed
Nigeria	Act No 34/68; Regs 1992	Min Petroleum Resources; (DPR) Environmental Protection Agency (FEPA)	48 mg/l monthly average offshore	Coastal estuary 10–20 mg/l
China	GB 4914-85	National Offshore Oil Corp; Environmental Protection Bureau	30–50 ppm	Standard dependent on location of drilling operations
Indonesia	MD KEP3/91	Min of Mining and Energy	25 ppm	To be changed to 75 ppm during 1997
Thailand	NEQA 1992; Gov. Reg. 20/90	Dept of Mineral Resources; Pollution Control Dept	100 ppm	The discharge limit has no legislative basis and is defined on a case-by-case basis
Vietnam	Decision No 333/ QB 1990	Petrovietnam, MOSTE	40 ppm	Revised regulations in preparation
Oman	Decree No 10/82	Min of Petroleum Resources; Min of Environment	40 mg/l	No offshore activity at present 5 mg/l limit on discharges from coastal facilities
Argentina	Resolution No 105/92	SRNAII	Case-by-case	No regulations for offshore legislation, onshore regulations applied in principle
Venezuela	Decree No 833/1995	MARNR	20 ppm	Special exemptions granted if environmental impact is not significant

Annex 3

Management practices for pollution prevention corresponding to EUROPIA/E&P Forum Guiding Principles[17]

Strategic element	Management practices
• Develop programmes to reduce overall emissions and waste generation. • Work with others to resolve problems arising out of the handling and disposal of hazardous substances from members operations. • Conduct operations and handle raw materials and products in a manner that protects the environment and the health and safety of employees and the public, while conserving natural resources and using energy efficiently. • Promote among employees an individual and collective sense of responsibility for the preservation of the environment and protection of health and safety of individuals. • Promote these principles and practices by sharing experiences and offering technical assistance to others who deal with similar raw materials, petroleum products and waste.	• Provide management support for ongoing pollution prevention activities through appropriate policies, actions, communications, and resource commitments. • Develop and implement a programme to improve prevention and early detection and reduce impacts of spills and other accidental releases from operations. • Develop an inventory of significant releases to air, water and land; identify their sources; and evaluate their impact on human health and the environment. • Periodically review and identify pollution prevention options and opportunities, develop approaches for reducing releases, and set goals and timing for reducing releases considering community concerns, technology and economics, and impact on human health and the environment. In reducing releases, give preference first to source reduction; second to recycling and reuse; and third to treatment. Measure progress. • Include pollution prevention objectives in research efforts and in the design of new or modified operations and processes. • Support a communication programme to promote pollution prevention opportunities within the industry, including sharing of industry experiences and accomplishments.

Annex 4
International agreements

The following conventions and agreements may include provisions relevant to oil and gas exploration and production operations. Note that this is not a comprehensive list and does not include conventions covering such subject areas as: maritime and shipping regulations, road traffic, vehicle noise, nuclear testing, animal health and welfare, whaling, sealing, fishing, conservation of fish stocks, exploration and exploitation of the deep seabed, exploration and exploitation of outer space and atomic energy.

This annex should, therefore, be taken as a guide to the international regulatory provisions which might prevail.

Convention for the Protection of Birds Useful to Agriculture. 1902.

Convention Relative to the Preservation of Fauna and Flora in their Natural State. 1933.

Convention on Nature Protection and Wild Life Preservation in the Western Hemisphere. 1940.

International Convention for the Protection of Birds. 1950.

International Plant Protection Convention. 1951. Amended 1979, 1983.

Statutes of the International Centre for the Study of the Preservation and Restoration of Cultural Property. 1956. Amended 1963, 1969.

African Convention on the Conservation of Nature and Natural Resources. 1968.

Convention on Wetlands of International Importance especially as Waterfowl Habitat. 1971. Amended 1982, 1987.

Convention Concerning the Protection of the World Cultural and Natural Heritage. 1972.

Agreement on Conservation of Polar Bears. 1973.

International Convention for the Prevention of Pollution from Ships 1973 (MARPOL).

Convention on International Trade in Endangered Species of Wild Fauna and Flora. 1973. Amended 1979, 1983.

Convention for the Prevention of Marine Pollution from Land-based Sources. (Paris Convention) 1974. Amended 1986.

Helsinki Convention on the Protection of the Marine Environment of the Baltic Sea Area, 1974.

Nordic Environmental Protection Convention. 1974.

Convention on Conservation of Nature in the South Pacific. 1976.

Kuwait Regional Convention for Cooperation on the Protection of the Marine Environment from Pollution, 1978 (Kuwait Convention).

Protocol of 1978 relating to the International Convention for the Prevention of Pollution from Ships, 1973 (MARPOL Protocol).

Convention on Long-range Transboundary Air Pollution. 1979.

Convention on the Conservation of Migratory Species of Wild Animals. 1979. Amended 1985, 1988.

Convention on the Conservation of European Wildlife and Natural Habitats. 1979. Amended 1987, 1991.

United Nations Convention on the Law of the Sea (UNCLOS) 1982.

Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region. 1983.

Protocol to the 1979 Convention on Long-range Transboundary Air Pollution on Long-term Financing of Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP). 1984.

Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern African Region. 1985.

Protocol Concerning Protected Areas and Wild Fauna and Flora in the Eastern African Region. 1985.

ASEAN Agreement on the Conservation of Nature and Natural Resources. 1985.

Protocol to the 1979 Convention on Long-range Transboundary Air Pollution on the Reduction of Sulphur Emissions or their Transboundary Fluxes by at least 30 per cent. 1985.

Protocol on Substances that Deplete the Ozone Layer. 1987. (Montreal Protocol).

Protocol to the 1979 Convention on Long-range Transboundary Air Pollution Concerning the Control of Emissions of Nitrogen Oxides or their Transboundary Fluxes. 1988.

Protocol Concerning Conservation and Management of Protected Marine and Coastal Areas of the South-East Pacific. 1989.

Protocol to the Kuwait Convention concerning Marine Pollution resulting from Exploration and Exploitation of the Continental Shelf, 1989.

Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal. 1989. (Basel Convention).

Agreement on transboundary cooperation with a view to preventing or limiting harmful effects for human beings, property or the environment in the event of accidents. 1989.

Protocol Concerning Specially Protected Areas and Wildlife to the Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region. 1990.

Amendment to the Montreal Protocol on Substances that deplete the Ozone Layer. 1990.

International Convention on Oil Pollution Preparedness, Response and Cooperation. 1990.

Protocol to the 1979 Convention on Long-range Transboundary Air Pollution Concerning the Control of Emissions of Volatile Organic Compounds or their Transboundary Fluxes. 1991.

Convention on Environmental Impact Assessment in a Transboundary Context. 1991.

Convention on the Protection and Use of Transboundary Watercourses and International Lakes. 1992.

Convention on Biological Diversity. 1992.

Convention for the Protection of the Marine Environment of the N.E. Atlantic, 1992 (the OSPAR Convention).

Convention on Transboundary Effects of Industrial Accidents. 1992.

Convention Concerning the Conservation of the Biodiversity and the Protection of Priority Forestry Areas of Central America. 1992.

Protocol for the Protection of the Mediterranean Sea against Pollution Resulting from Exploration and Exploitation of the Continental Shelf and the Sea-bed and its Sub-soil, 1994.

Copies of the texts of many of the above treaties can be found in the 1991 UNEP publication:

Selected Multilateral Treaties in the Field of the Environment Vol. 2 (Edited by Rummel-Bulska, I and Osafo, S) Grotius Publications Ltd, Cambridge 1991.

E&P Forum, 25–28 Old Burlington Street, London W1X 1LB, UK
Tel: +44 (0)171 437 6291   Fax: +44 (0)171 434 3721
http://www.eandpforum.co.uk

UNEP

UNEP Industry and Environment, Tour Mirabeau,
39–43 quai André Citroën, 75739 Paris Cedex 15, France
Tel: +33 1 44 37 14 50   Fax: +33 1 44 37 14 74
e-mail: unepie@unep.fr   http://www.unepie.org