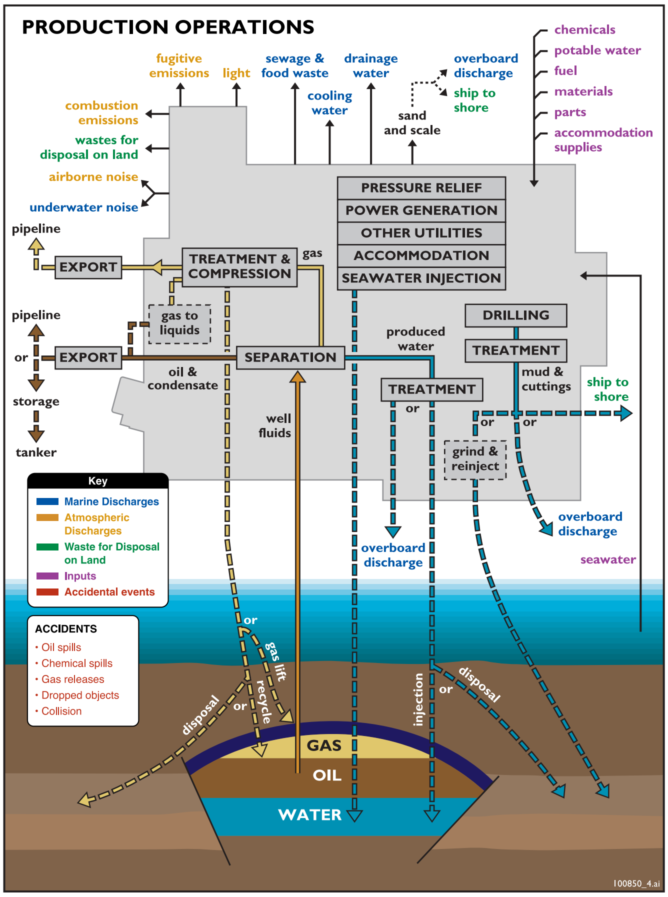
Department of Trade and Industry

Department of Trade and Industry

AN OVERVIEW OF OFFSHORE OIL AND GAS EXPLORATION AND PRODUCTION ACTIVITIES

AUGUST 2001



Hartley Anderson Limited

hartleyanderson@ha-an.demon.co.uk

CONTENTS

1 INTRODUCTION

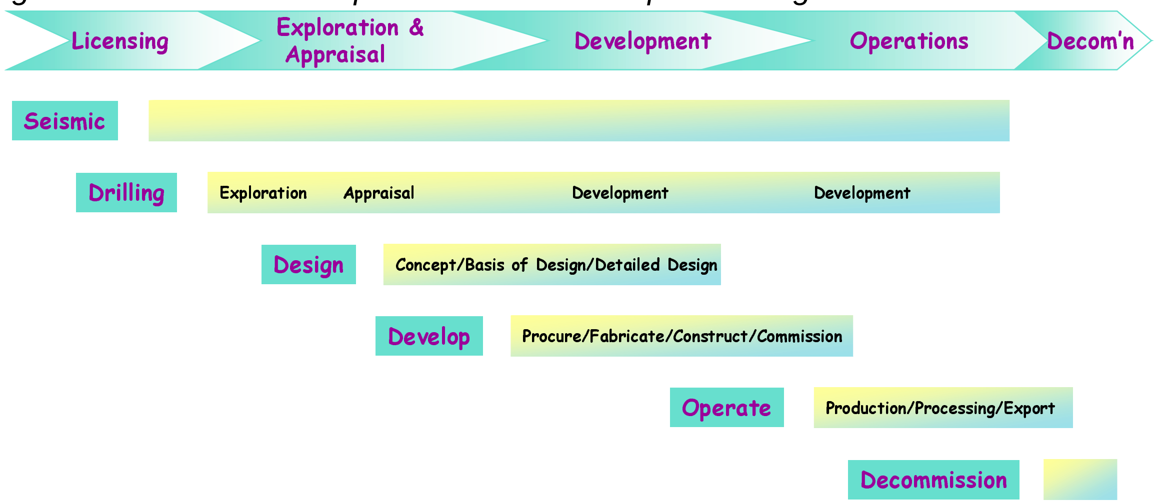
1.1 Purpose

This document is intended to provide an introduction for non-specialists to the key activities and potential sources of environmental effects associated with oil and gas exploration and production. It forms part of the information base for the DTI's Strategic Environmental Assessment process which aims to facilitate public and other consultation on the potential implications of future licensing of offshore areas of the United Kingdom Continental Shelf.

1.2 Scope and Structure of the Document

The main stages and activities associated with the exploration, development and production of offshore oil and gas resources are summarised in Figure 1 below.

Figure 1 – Oil and Gas Exploration and Development Stages and Activities



The document is structured so that each major stage is summarised in a separate section along with its associated activities and potential sources of environmental effects. In common with other specialist areas, there are a number of terms and acronyms peculiar to the oil and gas industry – to aid understanding a combined glossary and abbreviations list is provided at the end of the document. While the summary is a stand alone document, for the curious, some suggestions for further reading are included.

2 AN OVERVIEW OF OFFSHORE LICENSING

Exploration and production in the oil and gas industry is regulated primarily through a licensing system managed by the DTI Oil and Gas Directorate's Exploration and Licensing Branch. A brief overview of the offshore or "Seaward" licensing process is given below, more detail can be found on the DTI's website at www.og.dti.gov.uk/upstream/licensing.

The first offshore licensing round took place in 1964 and the first significant discovery of gas was made in the southern North Sea in 1965 and oil was discovered four years later in the central North Sea. Seaward licensing rounds have been held roughly every two years since 1964 with the last, the nineteenth being held in 2000/2001. In January 2000, there were 109 oil fields, 87 gas fields and 16 condensate fields in production offshore.

The *Petroleum Act 1998*, entered into force in 1999 and consolidated a number of provisions previously contained in five earlier pieces of primary legislation. The Act vests ownership of oil and gas within Great Britain and its territorial sea in the Crown, and gives Government rights to grant licences to explore for and exploit these resources and those on the UK Continental Shelf (UKCS). Regulations set out how applications for licences may be made, and specify the Model Clauses to be incorporated into the licences.

There are two types of Seaward Licences:

- **Exploration Licences** which are non-exclusive, permit the holder to conduct non-intrusive surveys, such as seismic or gravity and magnetic data acquisition, *over any part of the UKCS* that is not held under a Production Licence. Wells may be drilled under these licences, but must not exceed 350 metres in depth without the approval of the Secretary of State. These licences may be applied for at any time and are granted to applicants who have the technical and financial resources to undertake such work. Each licence is valid for three years, renewable at the Secretary of State's discretion for one further term of three years. Exploration licence holders may be commercial geophysical survey contractors or licence Operators. A commercial contractor acquiring data over unlicensed acreage may market such data.

- **Production Licences** grant exclusive rights to holders "to search and bore for, and get, petroleum", in the area of the licence covering a specified block or blocks. For licensing purposes the UKCS is divided into quadrants of 1° of latitude by 1° of longitude (except where the coastline, "bay closing line" or a boundary line intervenes). Each quadrant is further partitioned into 30 blocks each of 10 x 12 minutes. The average block size is about 250 square km (roughly 100 square miles). Relinquishment requirements on successive licences have created blocks subdivided into as many as six part blocks in some mature areas. Production Licences are usually issued in periodic "Licensing Rounds", when the Secretary of State for Trade and Industry invites applications in respect of a number of specified blocks or other areas.

Most activities carried out under a Exploration or Production Licence require the consent of the Secretary of State and may require compliance with other legislative provisions and specific conditions attached to the consent.

3 EXPLORATION AND APPRAISAL

3.1 Introduction

The purpose of exploration activity is to identify commercially viable reserves of oil and gas. The conditions necessary for such reserves to have accumulated are complex and largely dependent on past geological history and present geological formations and structures. For the deposits to occur, particular combinations of potential source and reservoir rocks together with migration pathways and trap structures are needed. Finding such reservoirs and estimating the likelihood of them containing oil and gas is a technically complex process requiring the use of a range of techniques. Such techniques include deep and shallow geophysical (seismic) surveys, shallow drilling and coring, aero-magnetic/gravity surveys and exploration and appraisal drilling.

Based on a general geological understanding, broad areas of the earth have been identified as prospective, with the potential to contain reserves of oil and gas. Prospective areas are further defined using surface/shallow mapping techniques and geophysical (seismic) surveys to aid understanding of deeper, subsurface geology. Aero-magnetic and gravity surveys are useful in defining general structure such as sedimentary basins but not for pinpointing areas with potential oil and gas. Areas of potential interest are subjected to further geophysical study, which may involve reinterpreting existing seismic data or conducting new surveys. The only reliable way to determine whether the identified formations contain hydrocarbons is to drill into them. However, the decision to drill is not taken solely on geological grounds. Government requirements, economic factors (drilling costs, transport costs, market opportunities, relative merit/financial risk) and technical feasibility (including safety and environmental considerations) are all factored into the decision.

3.2 Geophysical surveys

Surface techniques do not allow reliable extrapolation as to the subsurface geology. Although other methods may be used for reconnaissance, seismic survey techniques remain the most effective method of developing an understanding of the deep geology of an area. Seismic surveys are based on the same principles used to record data on subsurface geology during earthquakes but utilise a much smaller man-made energy source to generate energy waves which are directed into the earth's crust. Some of these energy waves are reflected or refracted back from geological structures deep beneath the surface and picked-up by sensitive detectors (geo- or hydrophones). Geophones are deployed at the ground or sediment surface and detect surface particle velocity whilst hydrophones are used principally in marine seismic and detect pressure (sound) waves in water. The strength and speed with which the waves return is affected by the nature of the formations and other media through which they have travelled. The data are recorded and interpreted using a combination of computer software and experienced judgment to produce geological maps.

Marine seismic surveys are conducted from survey vessels which deploy a seismic source, normally an array of air guns, beneath the sea surface to generate pressure (sound) waves which transmit through the sea, sediment and the subsurface geological structures. Pressure waves reflected from subsurface structures are recorded by a series of hydrophones, typically arranged at intervals along buoyant streamers towed just beneath the sea surface behind the vessel (Figure 2). Where floating streamers are used, corrections have to be calculated to compensate for the drift induced by currents (feathering effect).

One or more guard vessels normally accompany marine seismic survey vessels, to liase with fishermen and other small vessels and prevent collisions with the streamers etc.

On occasion, a multi-component system involving a combination of geophones and hydrophones may be deployed on the surface of the seabed. These are arranged along cables which may be towed along behind the vessel (dragged array) or lifted and replaced in a new location as the survey progresses. Such surveys normally involve two vessels, one attached to and processing the data from the sensors and one from which the source is deployed. Multi component systems are considered to be better at penetrating through some structures which are opaque to traditional towed seismic survey techniques. This method of hydrophone deployment is not usually used in initial seismic survey. There are two types, a dragged array involving up to 750m of cable which can be used down to water depths of 2000m, or a dual sensor ocean bottom cable where up to 72km of cable is laid on the seabed but only in waters of less than 200m. The deployment and retrieval of the cables is intended to be along straight lines, and without lateral dragging although tidal and other currents can cause this to occur.

Seismic surveys mainly use 2-dimensional or 3-dimensional methodologies:

- **2-D seismic** utilises a single hydrophone streamer towed behind the survey vessel together with a single source. The reflected pressure waves are assumed to lie directly beneath the streamer and hence the nomenclature of 2-D. Repeated parallel lines are typically run at intervals of several kilometres (minimum *ca.* 0.5km) and a second set of lines at right angles to the first to form a grid pattern. 2-D seismic provides a broad understanding of the geology of the area, however, its weakness lies in the interpretation of what is between the grid lines.
- **3-D seismic** utilises one or more hydrophone streamers towed behind a vessel. A series of closely spaced (some 25 or 30 metres apart) parallel lines are run in a “race track” pattern to allow adjacent lines to be run in the same direction. Unlike 2-D no cross over lines are run. In simple terms, 3-D seismic collects a series of 2-D slices at very close intervals which can be interpreted to produce a 3-D understanding of the geology of the surveyed area.

2-D seismic surveys can be conducted relatively quickly and inexpensively but the data produced, though valuable, does not give as accurate an understanding as 3-D surveys. As a result, the majority of marine seismic surveys now conducted to identify oil and gas reserves are 3-D.

Data from seismic surveys may be reinterpreted as the result of information from other sources including exploration drilling. Seismic survey should not be viewed only as an exploration tool. Surveys are periodically conducted in areas with developed fields to provide new information on the reservoir(s) and input to decisions on development drilling and reservoir management programmes.

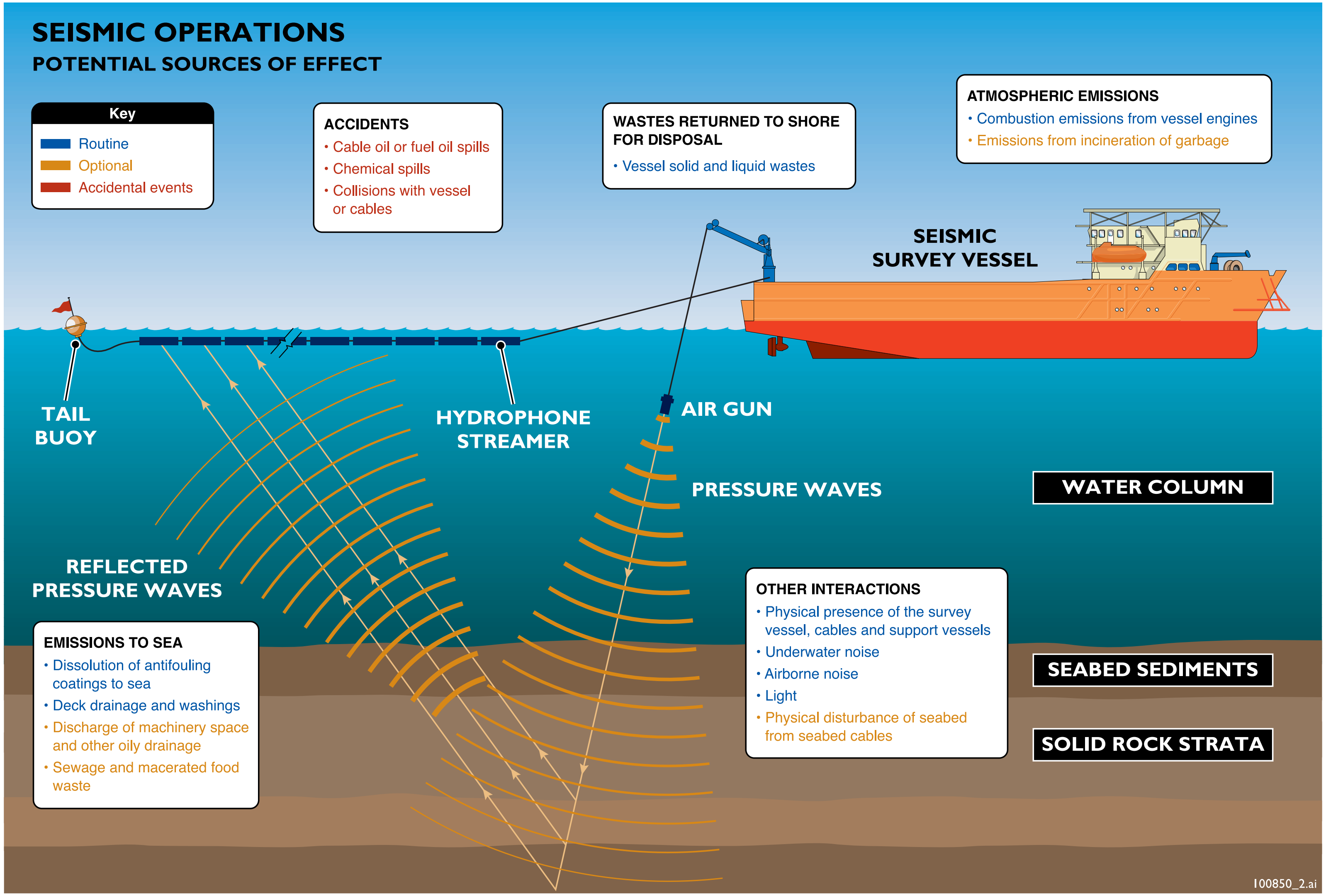
In some developed areas, fixed arrays of seismic receivers (multi-component system) have been deployed on the seabed connected by a series of parallel cables to allow repeated surveys to be conducted over precisely the same area. This method provides as detailed data as 3-D seismic but in addition, shows the temporal changes as oil is produced. Such surveys are therefore referred to as 4-D seismic.

On occasion, vertical seismic profiles (VSP) may be generated through the deployment into a well of a number of geophones spaced on a cable. The seismic source is deployed in the water column either suspended from the rig or platform (zero offset VSP) or from a source vessel at some distance from the well (offset VSP). VSP allows data from the rocks/structures encountered during drilling to be correlated with seismic data. Such surveys are usually of short duration (1-2 days) and utilise sources with volumes intermediate between those used in typical seismic and rig site surveys (see Section 3.3.1). 3-D VSP may, uncommonly be generated by making multiple passes with the source vessel.

3.2.1 Potential sources of effect

Potential sources of effect from seismic survey are shown on Figure 2.

Figure 2 – Sources of potential environmental effects from seismic operations



3.3 Exploration and appraisal drilling

3.3.1 Well objectives and planning

As described above, the target structures to be drilled (bottom hole location) are identified principally from the interpretation of seismic survey information. Specific objectives are defined early in the planning cycle for the well and in many respects define the nature and cost of the well to be drilled. The simplest objective for a first exploration well in an area (a “wildcat well”) may be to determine whether the structure identified contains oil and/or gas. The more complex the objectives, the longer the well may take and the greater the range of tests to be conducted. Objectives will define the information to be gathered during the drilling including well logs and possible well test, and whether the well would be plugged and abandoned on completion of the programme or suspended for re-entry at a later date. On occasion, the well objectives may include provision for a sidetrack to the main well bore in the event that hydrocarbons are encountered. The majority of hydrocarbon reserves on the UKCS lie between 2000 and 4500m below seabed although there are shallower and deeper reservoirs.

Surface hole locations (and therefore rig position) are normally chosen to achieve the shortest well consistent with avoiding surface hazards and sensitivities. Before a well is drilled from a mobile drilling unit, information on the stability of surface sediments and potential subsurface hazards (e.g. shallow gas formations) must be gathered to ensure that the rig will not encounter problems when positioning or drilling the surface hole. Rig site surveys utilise a range of techniques, including 2-D seismic survey, although for rig site surveys a much smaller energy source and shorter hydrophone streamer is used. The survey typically covers a relatively small area of seabed, in the order of 2km or 3km square. The rig site survey vessel may also be used to gather baseline information on the seabed sediment, fauna and background contamination.

In scheduling a drilling operation the following are taken into account:

- the weather and current conditions
- seasonal environmental conditions and licence conditions
- availability of rigs
- commitments made to government
- other company internal constraints and objectives

The well design, including the length and diameter of the various hole sections and casings, mud types (see Section 3.3.3) to be used, and contingencies allowed for, is dependent on the nature of the rock formations to be drilled, the length of the well and the well objectives. The well design and plan is subject to external review and approval.

3.3.2 Drilling rigs

Exploration wells are almost invariably drilled from mobile drilling rigs. Rigs are basically of three types:

- **Jack-up rigs** which are based on a buoyant steel hull with 3 or more lattice legs up and down which the hull can be “jacked”. The rig is towed to location by 2 or more tugs with the legs jacked up so the hull floats. On reaching the drilling location the rig jacks its hull up the legs until the base of the legs are firmly in contact with the sea floor and its deck positioned above wave height. The rig's position is maintained by the legs which are in firm contact with the sea floor. No anchors are deployed, although in areas of strong seabed currents where sediment scour may be expected, gravel or rock may be dumped around the base of the legs to stabilise the sediments. Jack-up rigs are depth limited and can only operate in water depths of around 100m or less. These are the rigs which are most often used in the shallower waters of the southern North Sea.

- **Semi-submersible rigs** which float at all times on pontoons are the most likely rig type to be used in the deeper waters of the North Sea. The rig is towed to location by two or more tugs. The pontoons contain ballast tanks, and the height of the deck above the sea surface can be altered by pumping ballast (sea) water in or out of the pontoons. During drilling operations, the deck is lowered but still kept above wave height. Rigs used in deep water, harsh environments maintain position over the drilling location either by anchors (and where fitted, with rig thruster assistance as necessary) or by dynamic positioning using a series of computer controller thrusters. Rig anchoring typically involves the deployment by anchor handler vessel, of eight or more 12 tonne high efficiency seabed penetrating anchors. The anchors are attached to the rig by cable and near the anchor by chain, of which a proportion (a minimum of 100m) lies on the seabed (the catenary contact). Hauling in of the cables by the rig "sets" the anchors in the seabed after which minor adjustments to the rig position can be made by hauling or paying out cable. The precise arrangement of anchors around a rig is defined by a mooring analysis which takes account of factors including water depth, tidal and other currents, winds and seabed features. The relationship between water depth and lateral extent of the anchor pattern is not linear and typical radius of an anchor patterns for a semi-submersible drilling rig operating in a water depth of 100m is 1300 - 1400m. Anchors are retrieved by anchor handler vessels by means of pennant wires which slide down the cable towards the anchor allowing a more or less vertical retrieval, facilitating anchor breakout from the seabed.

- **Drill-ships** are based on a conventional ship's hull adapted with a moon pool to allow the deployment of the drill though the hull. They typically have their own motive power and are not dependent on tugs, maintaining position with DP and/or anchors. Drill-ships can operate in deep water and are the platform from which the academic Ocean Drilling Programme is conducted. However because of the hull shape, they are more affected by wind and wave movement than semi-submersible rigs, and as a consequence would be more likely to suffer from weather down time.

Exploration rigs are self-contained with their own power generation, utilities and accommodation facilities. Supplies are brought to the rig and wastes returned to shore by supply boat. Crew are transferred on and off the rig by helicopter. For safety reasons, a stand by vessel is deployed in the field for the duration of the drilling programme. A drilling derrick above the drill floor bears the weight of the drillstring, which is a series of 9m long sections of hollow drill pipe, screwed together and to the bottom of which the drill bit is attached. Additional sections of drill pipe are added to the drill string as the well is drilled deeper. The lower part of the drill string, adjacent to the drill bit, is comprised of a series of heavy drill collars to give added weight to the drill bit. The drill bit is rotated either by rotating the whole drill string by means of a rotary table on the drill floor/topdrive system or by a downhole turbine powered by the flow of mud pumped down the hollow drill pipe.

3.3.3 Drilling operations

Once the rig is fixed in position, the well is commenced. A wide conductor (typically 30" or 36") is installed (spudded) into the surface of the seabed either by piling or using a water jet. The well is drilled in a series of steps with the hole sizes and casing getting progressively smaller. The upper section(s) of oil and gas wells is normally drilled "open" without a riser so that displaced sediments and rock are discharged directly around the wellbore. The uppermost section of the well is sometimes made by water jetting rather than drilling, and can result in a plume of sediment in the water column. The methods used and the depths to which a surface hole is drilled are dependant on several factors, particularly well design and intended function and the nature of surface sediment/rock types. Side scan sonar and ROV inspection around exploration wells indicate that surface hole cuttings form a low mound with a radius of 5 to 10m around the wellhead.

A blow out preventer (BOP), comprising a series of hydraulic rams which can close off the well in an emergency, is installed at the seabed. A riser (pipe) is deployed from the rig and connected via the wellhead so that drill mud and cuttings from lower hole sections can be returned to the rig for separation and treatment. The riser is fitted with devices to maintain it under tension whilst compensating for heave.

Drilling muds are a combination of a weighting agent and other materials suspended in a fluid (the base fluid). The choice of mud weight (specific gravity) and base fluid type (water, synthetic "oil" or low-toxicity oil) is dependent on the nature of the formations to be drilled. The weighting agent most commonly used is the dense mineral barites (barium sulphate). However in certain circumstances, including where local environmental sensitivities require this (e.g. where scallop beds are present), alternatives such as calcium carbonate may be used. The function of the mud is to provide:

- a circulation to remove cuttings from the hole
- to cool the drill bit
- and to provide a hydrostatic head to maintain well control by exerting a greater pressure than that present in the well

Other chemicals are included in the mud formulation to aid its performance. Muds may be premixed onshore and transported in the mud tanks of the rig, or via supply vessel, or alternatively they can be made on the rig.

The contaminant composition of drilling wastes has changed significantly over the last few decades, in response to technical and regulatory developments. Previous widespread and substantial discharges of oil-based muds, and later synthetic oil muds, have been superseded by alternative disposal methods (either containment and onshore treatment, or reinjection) or by water-based muds. The major environmental effects of development of the North Sea in the 1980s and early to mid 1990s, i.e. the formation of cuttings piles beneath platforms and zones of benthic effects surrounding the platforms, are therefore unlikely to be repeated in future UKCS developments.

Base fluids are chosen on the basis of the formations to be drilled since certain rock types, such as shales, absorb water and expand, thereby potentially causing the drill pipe to stick and disrupting the drilling operation. If formations such as these are expected, then a non-water based fluid, either a synthetic or low-toxicity oil, may need to be used in those sections of the well.

Muds and cuttings are returned via the riser to the rig for treatment. Firstly cuttings and muds are separated on shale shakers (vibrating screens) and the mud returned to the mud tanks for re-use. Cuttings from the shale shakers are normally either discharged, when drilled with water based muds or in the case of synthetic or low toxicity oil based muds, contained for shipment to shore for further treatment and disposal. The opportunity to re-inject cuttings is not normally available for exploration and appraisal wells. The cuttings are monitored for evidence of hydrocarbons by the mudlogger.

3.3.4 Cementing

As each section of the well is drilled, the drill string is removed from the well and steel casing lowered into the well and cemented into place to prevent the well from caving in. A measured amount of quick drying cement slurry is pumped into the casing and a plug inserted above it. The cement is forced down to the bottom of the casing and then up the annulus (i.e. the space between the outside of the casing and the wall of the well) by pumping mud on top of the cementing plug. Pumping ceases once some cement is observed returning with the mud returns indicating that all the mud in the annulus has been replaced with cement. Drilling activity is suspended, until the cement has set, the actual time being dependent on the cement additives used.

3.3.5 Logging and coring

Dependent on the original objectives, readings and sampling may be conducted in the lower sections of the well, particularly in potential reservoir rocks. Cores are taken by replacing the drillbit with a core barrel which can cut rock cores several metres long. Other measurements, including porosity/permeability, electrical resistivity and formation density may be made using electronic/radiographic instruments lowered into the uncased, lower sections of the well using a wireline unit (wireline logging). If hydrocarbons are found, then a downhole tester is lowered into the well by wireline. This instrument measures fluid pressures and takes samples of the fluids.

3.3.6 Well testing

Where significant hydrocarbons are encountered, the well may be tested by installing a section of production liner in the lower hole and flowing the well to the surface for a short period to measure pressures and flow rates and take samples of well fluids (well test or drill stem test). Prior to a well test, the well is cleaned up using a combination of high-density brines and clean-up chemicals to remove all traces of mud and cuttings debris from the bore. The brines are circulated to the rig via the riser and may be contained for reuse/disposal or discharged overboard. The liner is then perforated in the reservoir section allowing reservoir fluids to flow into the liner bore and up to the rig. A gravel pack may be installed to prevent production of unconsolidated sand from the reservoir with the fluids. The well fluids are processed on the rig, through a surge tank and a test separator, to provide information on the relative proportions of gas, oil and water. The hydrocarbons produced during a well test are either burned in a high efficiency burner or in the case of oil produced during extended well tests, contained typically in a specialist storage vessel for transport to shore for treatment.

3.3.7 Well suspension and abandonment

Following completion of the drilling programme the well is either abandoned or suspended. When being abandoned, the well is plugged with cement and the casing cut below the surface of the seabed, (using a circular metal cutting tool attached to the bottom of the drill string, or explosive charges). Suspending a well allows re-entry and involves plugging it with cement and capping the top hole casing. Following suspension or abandonment, a video debris survey is conducted using a remotely operated vehicle (ROV) and any dropped objects recovered.

3.3.8 Abnormal operations

On occasion a mechanical failure of the tools down the hole may occur, for example a fracture of the drill pipe. A range of “fishing” techniques and tools may be used to recover the equipment to the surface so that drilling can recommence. Should this be unsuccessful then the well may be plugged with cement and a (mechanical) sidetrack well drilled from just above the plug and down to the target location.

The drill pipe may become stuck in some formations. The first approach is to attempt to carefully jolt the pipe free. If this approach fails then a small amount (a "pill") of synthetic or oil base fluid may be used to help free the pipe, with the fluid recovered for disposal when circulated to the rig.

Whilst drilling through porous formations, the drill mud may be lost into the pore spaces in the rock resulting in a dramatic reduction in the amount of mud returned to the rig. Mud returns are constantly monitored to aid early identification of such lost circulation. Lost circulation is remedied by loading the mud with various materials to plug the porous rock e.g. cellulose strips, ground walnut shells.

In the event that gas, oil or water pressures exceed the hydrostatic head and invade the well (known as “a kick”) the back pressure is detected on the rig. Normally, the mud weight is increased through the addition of weighting material to the point where downhole pressures are balanced and contained. In extreme circumstances the blow-out preventer (a series of hydraulic rams which can close off the well) is operated.

3.3.9 Appraisal wells

If a hydrocarbon bearing reservoir is discovered during exploration drilling, one or more appraisal wells may be drilled. Appraisal wells are used to delineate the physical dimensions of the field and calculate its development potential. Such information is important in determining:

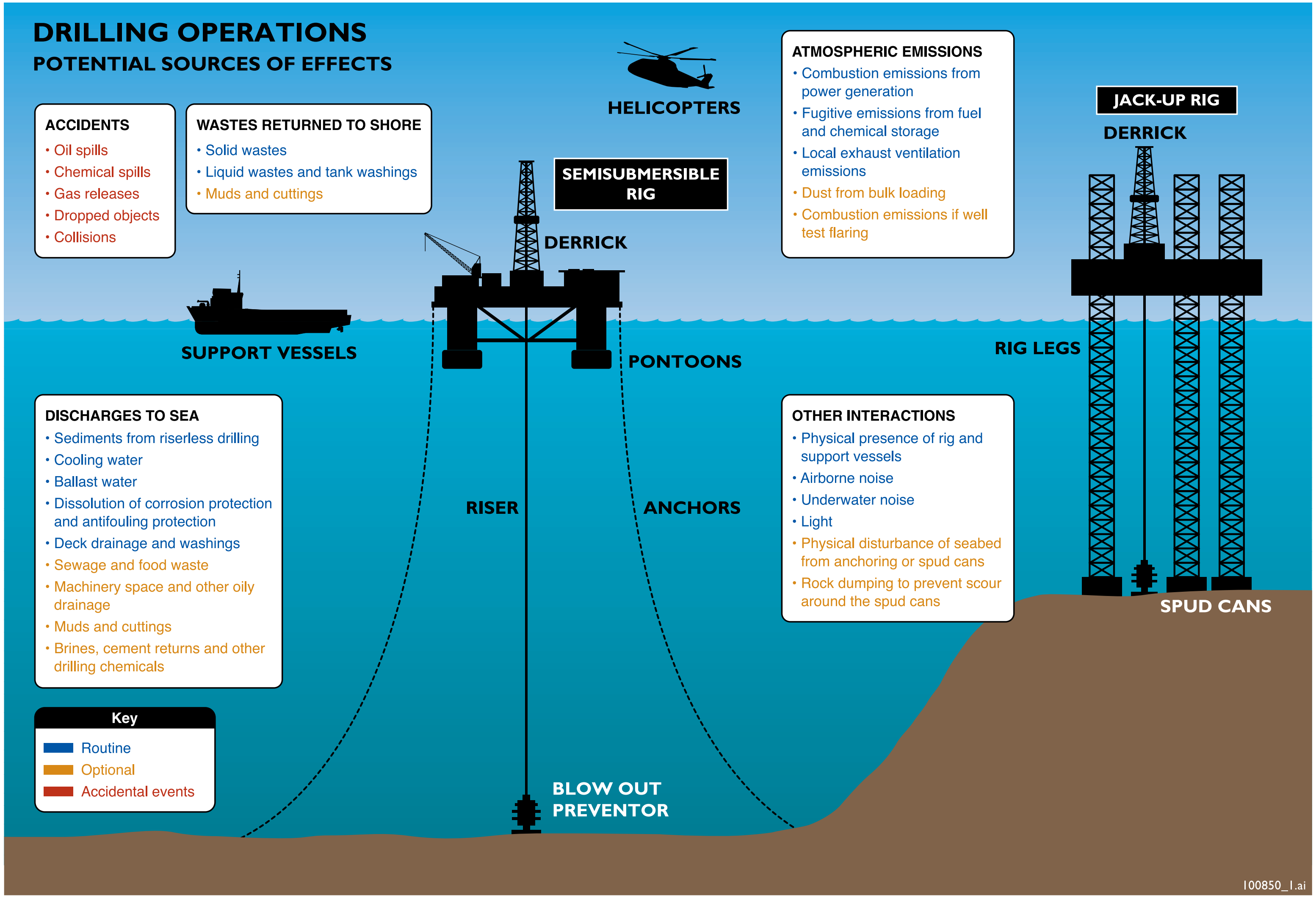
- whether it would be economically viable to develop the field
- likely hydrocarbon production rates
- appropriate process and export facilities

Most appraisal wells would normally include extensive logging and involve a well test. Because of the cost, as few appraisal wells as possible would be drilled, the actual number being dependent on the particular circumstances of the field. Some appraisal wells are drilled as future potential production wells and suspended following completion for future re-entry.

3.3.10 Potential sources of effect

Potential sources of effect from exploration and appraisal drilling are shown on Figure 3.

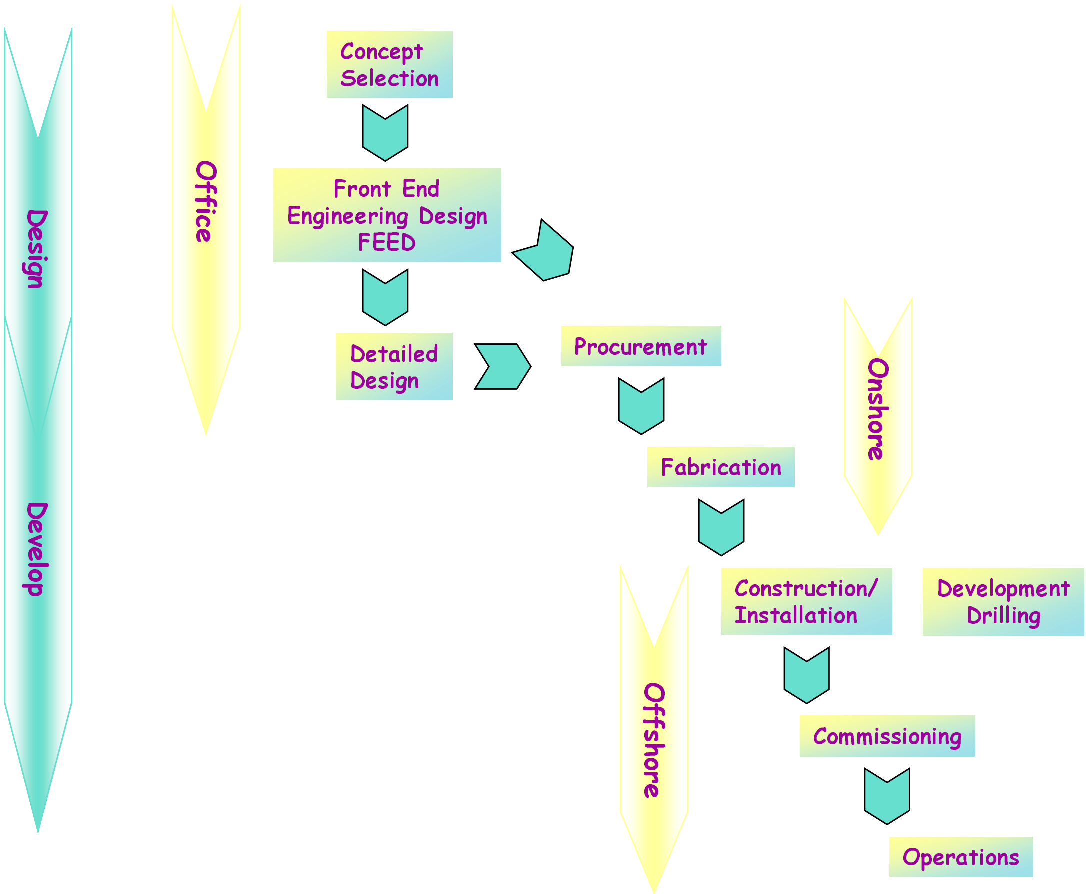
Figure 3 – Sources of potential environmental effect from semi-submersible drilling operations



4 FIELD DEVELOPMENT

A number of factors including field economics, availability of export routes, technical feasibility and environmental sensitivities are brought to bear on the decisions as to whether, when and how to develop a field for production. The development of a field is a staged process (see Figure 4 below) with a great deal of activity taking place prior to the commencement of construction work offshore. Environmental Impact Assessment is an integral part of the selection of options, design, planning and execution processes.

Figure 4 – Offshore Design and Development Process



The summary description below focuses on the nature of the key potential field activities:

- Drilling of development wells
- Construction and installation of production and export facilities
- Commissioning of the systems

4.1 Development drilling

The objective of a development drilling programme is to access as efficiently as possible the recoverable reserves from the field. The number of wells and locations from which they are drilled are dependent on the size and nature of the reservoir. Development wells are often drilled over a period of time and both the temporal and areal spacing of the wells are dependent on the reservoir properties and field economics. The function of the wells that may be drilled during the life of a field would fall into the three broad categories:

- Production wells
- Injection wells (water or gas)
- Disposal wells (cuttings, produced water or gas)

although it is sometimes possible to convert wells from one function to another.

In terms of operations and activities, development drilling is similar to exploration and appraisal drilling. The surface locations of development wells are normally centred at the main production facility and directional drilling techniques are used to access the different parts of the reservoir. The drill string incorporates assemblies to weight and deflect the drill bit to the desired angle from vertical. Electronic/radiographic instruments are incorporated in the string to relay to the surface information on location and angle of deviation of the drill bit and porosity and density of the formations. Because the frictional coefficient increases with the angle of deviation, turbo drills or jet bit drills are used rather than rotary drills. Particularly where shales may be expected, the rheological properties of an oil based or similar mud may be required to prevent stuck pipe in these sections of the well. The reservoir section of the well may be drilled more or less horizontal. In such cases one or more horizontal sidetracks may be drilled from the same well to maximise access to the reservoir.

Where it is not technically feasible to drill to the target location from the main facility then development wells may be drilled at one or more satellite locations. However, to minimise footprint and maximise use of infrastructure deviated drilling techniques are also used.

To reduce delay between the installation of the main facility and commencement of production, some development wells may be predrilled from a mobile rig and temporarily suspended. Where a number of wells are to be drilled from the same surface location a steel template may be deployed on the seabed rather than a series of individual guide bases. Templates are normally fixed on the seabed with two or more piles and also provide for accurate subsequent positioning of the jacket relative to the template. Cuttings reinjection facilities are often not available at this stage and cuttings contaminated with synthetic or low-toxicity oil based muds are contained and would be shipped to shore for treatment.

Subsequent development wells at the main facility are either drilled from a drill rig permanently installed on the facility or from a mobile drilling rig adjacent to a floating installation or cantilevered over a fixed platform. The conductors for wells drilled from a fixed platform extend from the seabed through slots on the facility with the wellhead and blow out preventer located on deck. With floating facilities, the wellheads and blow out preventers are on the seabed and connected to the installation by flexible risers (see Figure 5). Following completion of a production well, a valve assembly (Christmas tree) is installed on the wellhead, and production tubing installed in the well. The well is cleaned up using a combination of heavy brines and clean-up chemicals which are either discharged or contained and shipped to shore for reuse/disposal dependent on type. Once all debris and mud has been cleaned from the well, well fluids will be flowed for a short period. Where clean-up operations are being conducted on the platform, the well fluids will normally be processed. Satellite wells may be cleaned-up via a mobile rig and in these cases, the well fluids may be disposed of via a high efficiency burner. Subsea wellheads are typically fitted with various trawl protection structures to avoid snagging.

Past development drilling using oil based muds has resulted in significant accumulations of contaminated cuttings under some platforms in the central and northern North Sea. Since only cuttings from the surface hole and sections drilled with water based muds would be discharged, significant accumulations of contaminated cuttings would not be expected from future development drilling in the North Sea.

4.2 Construction and installation

4.2.1 Possible types of production facility

A range of different structures have been used to support offshore oil and gas production on the UKCS including fixed, floating and subsea facilities, see Figure 5.

Fixed

Fixed steel jackets are normally 4 or 6 leg structures, constructed of a welded steel tubular framework. The jackets are normally towed out to the development location and manipulated into position by a heavy lift barge. Piles are driven into the seabed at each leg to fix the jacket into place and the topsides lifted into place by in one or more lifts. Fixed steel jackets are deployed in water depths of up to 450m. In some instances, to achieve separation of accommodation and hydrocarbon processing, 2 or more platforms may be installed in proximity and bridge linked.

Concrete gravity base platforms are constructed out of concrete reinforced with steel and have been used in locations where the seabed is too hard to permit piling. The platform is supported on concrete legs, at the base of which are ballast and storage tanks. Having been towed out to the development location, the ballast tanks are flooded and the structure settled on the seabed. Concrete structures have been used in water depths of up to 350m.

Floating

Tension Leg Platforms (TLP) are floating structures, ballasted and anchored by tensioned steel tendons to templates piled to the seabed. TLPs are relatively stable and can operate in a wide depth range (up to *ca.* 2,100m).

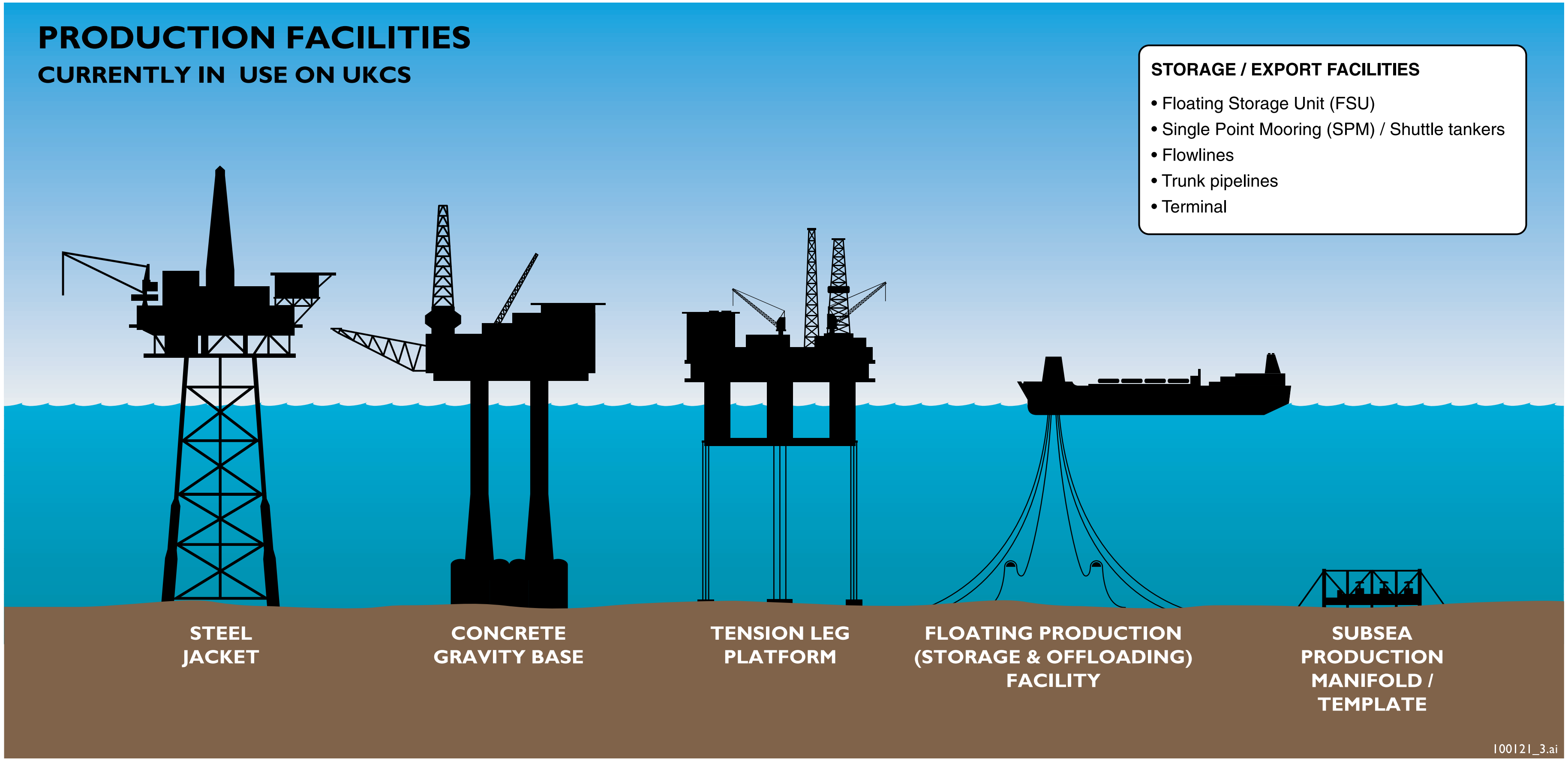
Floating Production Systems (FPS) and Floating Production, Storage and Offloading Systems (FPSO) are facilities based either on ships' hulls or semi-submersibles. They are ballasted and anchored to the seabed, can accommodate vertical movement and operate in a wide depth range. Wells are normally fitted with subsea completions and produced to the facility via flexible risers with built in compensation for vertical movement.

Both types of structures can operate in relatively deep water and are normally towed out to the development location with the topsides facilities already pre-commissioned onshore.

Subsea

Smaller fields or parts of the reservoir, which cannot be successfully accessed by directional drilling from the main facility location, are developed using a combination of subsea completions, manifolds and pipelines tying the development back to a surface facility for fluids processing and export (host facility). Umbilicals with multiple cores are used to inject chemicals at the wellhead/manifold as necessary (e.g. to prevent the formation of hydrates or protect the pipeline from corrosion) and to support electric and hydraulic control of the wellhead and/or manifold valves from the main facility.

Figure 5 – Types of offshore facility



It is not possible to be definitive as to which structures would be used for future developments in the North Sea, although it is likely that they would be based on a combination of floating and subsea structures and perhaps fixed platforms in the event of a very large discovery. A number of issues affect the selection of production facility including expected field life, reservoir fluid type and flow rates and location.

Offshore installations are self contained units with all the facilities needed to support the main processes and export including:

- power generation
- pressure relief
- water treatment
- utilities
- drains
- helideck
- cranes
- crew accommodation

Drilling facilities may or may not be permanently installed depending on the type of development. Structures are fitted with corrosion protection in the form of sacrificial anodes and/or impressed current systems.

4.2.2 Export facilities

The majority of oil production from the UKCS is exported to shore by pipeline with the remainder exported by tanker. Currently gas is only exported by pipeline, although technologies in development may allow the conversion of gas into liquids (gas to liquids) and therefore export via tanker or oil pipeline. In fields with no economically viable export route gas surplus to fuel gas requirements is either injected into the reservoir for future recovery or other rock formations via disposal wells. The disposal of surplus gas by routine flaring is unlikely to be approved for any developments on the UKCS.

There is a well developed export pipeline infrastructure in the North Sea and production from small new developments can be expected to be exported via existing facilities. The development of very large new reserves could justify the installation of new pipelines and terrestrial reception facilities.

Tanker offloading requires both oil storage and offloading facilities. These may be provided by the main facility as, for example, in the case of FPSOs. Where insufficient storage is available on the main facility, a separate storage facility may be permanently anchored in the field. Where the main or storage facility design does not permit safe approach by tanker then an alternative mooring, for example, a single point mooring, is located a safe distance (up to several kilometres) away. Oil is transported by short infield pipeline(s) from the host facility to the storage and/or offloading units.

Marine oil and gas pipelines are laid either by anchored or dynamically positioned pipelay barges, where sections of steel pipe are welded together to form the pipeline as the barge progresses along the pipeline route. Alternatively, a prefabricated pipeline is laid from a large reel mounted on a dynamically positioned ship, although this technique has limitations in terms of the size of pipeline that can be accommodated. Anchored pipelay barges usually have an array of 12 anchors which are redeployed in sequence during pipelaying. The anchor type is selected according to sediment and weather/current conditions of the area and are normally either 12 tonne high efficiency seabed penetrating anchors or 20 to 25 tonne stockless general marine anchors. The anchors are attached to the barge by steel cables (typically 75mm in diameter) of which about a third to a half forms a catenary contact on the seabed. The anchors are repositioned by anchor handler vessels and dropped in a corridor between 2 and 3km wide centred on the pipeline. Each anchor is advanced about 650m which results in a total of 24 anchor drops being made within the pipelay corridor for each 1300m advanced (24 drops in an area of 2.8km^2). Once dropped, the anchor cable is hauled in from the barge until a good hold is achieved. This normally drags the anchor along the seabed for between 5m and 50m depending on anchor type. The barge then uses the anchor spread to pull itself along as pipelaying progresses and during this process the catenary contact cable is dragged across the seabed surface, resulting in cable scrape. Mounds of sediment up to 2m high may be formed in clay and mud seabeds during the pulling against the anchors or when the anchors are retrieved for redeployment.

The degree and nature of seabed scarring or disturbance during pipelay barge operations is dependant on a range of factors including:

- Laybarge type
- The anchor type, size and weight
- The nature of the seabed sediments
- The load placed on the barge and hence the anchors by prevailing weather and current conditions
- Barge and anchor handler crew skill

Dynamically positioned (DP) vessels normally have no contact with the seabed other than the pipeline being laid. As a result of continuous thruster use to maintain station, DP vessels can generate more underwater noise than conventional barges.

Large diameter (greater than 16 inches) pipelines are typically laid directly onto the surface of the seabed while smaller ones are normally trenched into it to a depth of about 1m. The pipeline trench is either cut by plough where displaced sediment is sidecast or made by water jet which disperses the removed sediment more widely as a plume in the water column. Trenches are either backfilled with sidecast material or allowed to fill naturally over time with sediments transported by tidal and other currents. Umbilical cables for the control of subsea facilities are either placed alongside a buried pipeline in its trench or buried separately, normally using a marine version of the agricultural mole plough. The trenching is typically undertaken using equipment deployed from the laybarge or other support vessel.

In recent years, pipeline “bundles”, have been used for some developments. Pipeline bundles consist of a large diameter carrier pipe which contains a number of pipelines and often the umbilical. Bundles are normally surface laid. The bundle is manufactured onshore and towed out to the location in completed sections which are then filled with sea water (chemically treated to prevent corrosion of the bundle) and lowered to the sea floor.

Pipelines and subsea structures are fitted with corrosion protection in the form of sacrificial anodes, normally of aluminium.

Pressure testing (hydrotesting) of pipelines and subsea equipment with seawater is carried out to detect leaks prior to use. The seawater typically includes a small quantity of a dye and is normally. The treated seawater is normally discharged. The pipeline is dewatered/dried prior to use using a quantity of glycol and/or methanol or by using air drying or vacuum drying techniques.

4.2.3 Potential sources of effect

Potential sources of effect from the construction, installation and pre-commissioning of export facilities are:

Atmospheric Emissions

- Combustion emissions from vessel power generation
- Fugitive emissions from vessel fuel and chemical storage

Discharges to Sea

- Hydrotest water
- Machinery space and other oily drainage from construction vessels
- Deck drainage and washings from construction vessels
- Sewage and food waste from construction vessels
- Dissolution of corrosion and antifouling protection from construction vessels

Other Interactions

- Physical disturbance to seabed from pipelaying/trenching, rock dumping and anchoring
- Physical presence of vessels
- Physical presence of pipelines and facilities
- Airborne noise
- Underwater noise
- Light

Wastes to Shore

- Solid and liquid construction and commissioning wastes

Accidents

- Fuel and other oil spills
- Gas releases
- Chemical spills
- Dropped objects
- Collisions

4.3 Commissioning

Much of the topsides process and utility equipment may be pre-commissioned onshore. Once the well(s) are brought on stream, final commissioning will be completed. As systems are being fully commissioned and fine-tuned, some process “trips” normally occur, resulting in shut down of part or whole systems and sometimes necessitating the disposal of gas to flare for a period.

4.3.1 Potential sources of effect

Commissioning of facilities may result in short term changes in performance of the process systems resulting in following potential sources of effect:

Atmospheric Emissions

- Venting and flaring of gas
- Emissions from power generation

Discharges to water

- Discharges of injected chemicals
- Produced water quality

5 PRODUCTION OPERATIONS

5.1 Introduction

The main function of the process system is to separate well fluids into the oil and gas phases and condition them for transport by removing most of the water and solids.

The principal production systems and options for export and disposal of emissions and discharges are shown in Figure 6 overleaf.

5.1.1 Atmospheric emissions

The major sources of emissions to atmosphere are internal combustion for power generation by installations, terminals, vessels and aircraft, flaring for pressure relief and gas disposal, cold venting and fugitive emissions.

Power requirements for the offshore industry are dominated by production installations (typically >50MW per platform), with substantially smaller contributions from mobile drilling units (typically 10MW per unit) and vessels. The major energy requirement for production is compression for injection and export, with power generated by gas or dual-fuel turbine (gas/diesel). Fuel gas accounts for over 60% of total CO_2 emissions from the UKCS operations.

Flaring from UKCS installations has been substantially reduced relative to historic levels, largely through development of export infrastructure and reinjection. New developments will generally flare in substantial quantities only for pressure relief, with "zero routine flaring" now considered a realistic design target for planned developments.

5.1.2 Produced water and other aqueous discharges

Produced water is derived from reservoir ("fossil") water and from breakthrough of treated seawater injected to maintain reservoir pressure, and is generally the largest single wastewater stream in oil and gas production.

Other overboard discharges are generally of much lower volumes than produced water, and are unlikely to have significant effect, outside the immediate vicinity of fixed or mobile installations.

5.1.3 Process and utility chemicals

A range of process and utility chemicals are used in the offshore production of oil and gas. Chemicals may be contained in closed systems e.g. as heating medium or dependent on function, partition in whole or part with the oil or water phase. Examples of some of the key functions of chemicals used offshore are to:

- Aid separation of fluids
- Prevent foaming in process vessels and piping
- Prevent the formation of hydrates
- Inhibit corrosion of equipment and piping
- Inhibit the build up of scale in equipment and piping
- Treat and dry gas
- Treat seawater

5.1.4 Logistics and support

Supplies to the facility (chemicals, diesel, parts, consumables, food and other supplies) and returns from the facility (wastes, unused parts and chemicals etc) are transported to and from land by supply boat. Personnel are carried by helicopter.

A stand-by vessel is normally located in the vicinity of the main facility to provide safety cover and for oil spill response.

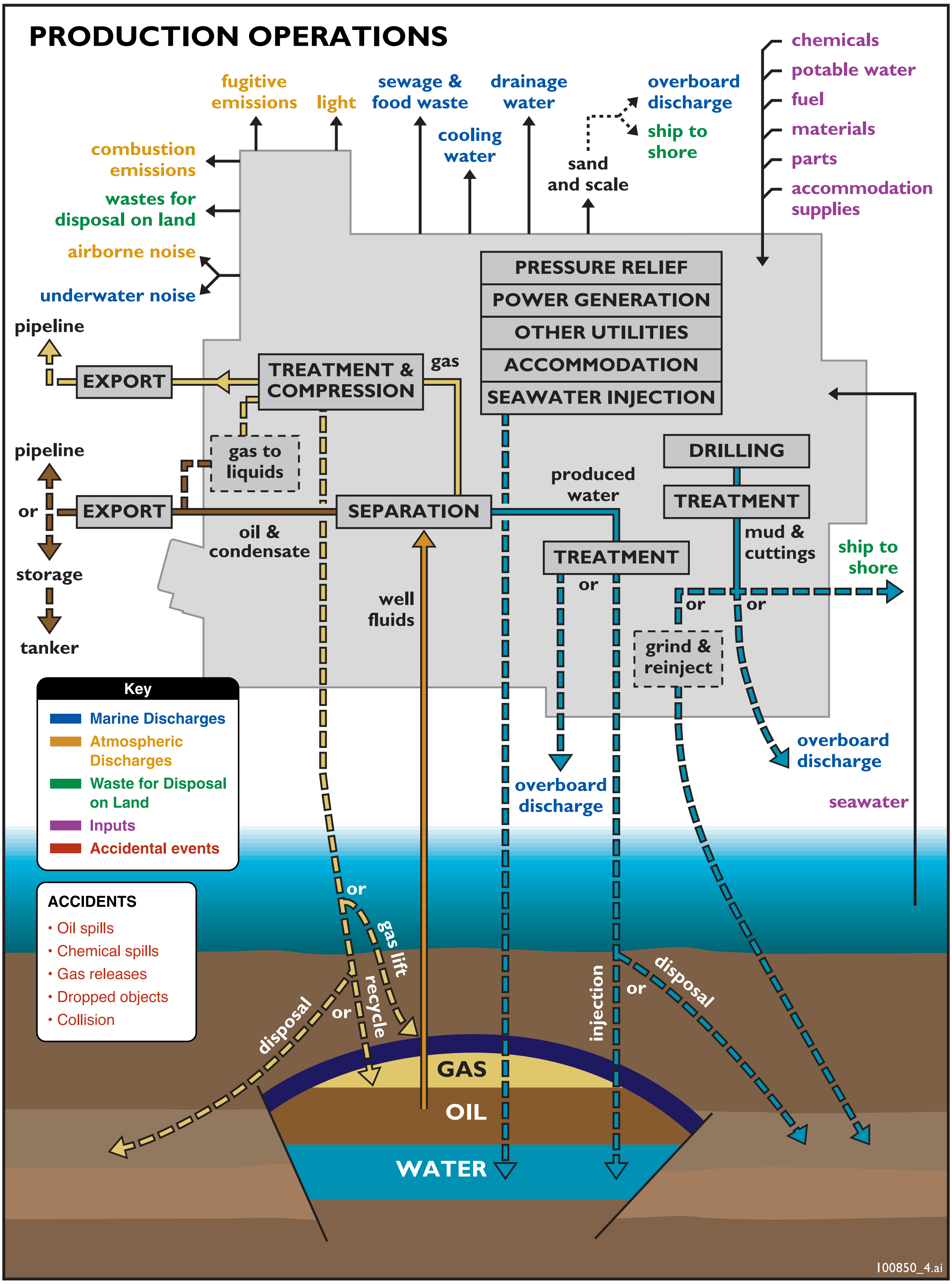
5.1.5 Well workover

During the life of a field, wells may be worked over to remedy faults or to improve performance. Workovers are conducted either from the main facility, if a drilling rig is permanently installed, or from a mobile rig brought into the field. The term workover covers a range of well intervention techniques including wireline and coiled tubing operations and often involves the use of chemicals.

5.1.6 Potential sources of effect

Potential sources of effect (in addition to the physical presence of the installation and associated facilities) from production operations are shown in Figure 6.

Figure 6 – Sources of potential environmental effects from production operations



6 DECOMMISSIONING

At the end of field life (less than 10 to more than 25 years) production and export facilities will be decommissioned.

Facilities will be decommissioned according to the requirements of UK, EU, OSPAR and other international regulations and agreements in force at the time. The methods used to decommission individual facilities would be selected on a case-by-case basis. Wells will be plugged with concrete and the conductors cut off below seabed level. Floating installations would be towed away, potentially to a new location for reuse and associated risers and seabed anchor points removed. Similarly subsea manifolds will be removed. Pipelines would be considered for removal on a case-by-case basis.

It should be noted that for a few decommissioned fields there may be the potential for redevelopment (re-commissioning) in response to technological advances and improved economic conditions. Such redevelopments, would require the consent of the Secretary of State and compliance with legislation in force.

7 GLOSSARY & ABBREVIATIONS

Term	Definition
2D	2 Dimensional
3D	3 Dimensional
4D	4 Dimensional
Annulus	The space between the drill string and well bore
Aqueous discharges	Watery discharges to the sea
Barite	Barium sulphate – a heavy mineral added to drilling mud as a weighting agent to increase its specific gravity and thus the hydrostatic head of the mud column
Base fluid	The liquid component of drilling mud
Bathymetry	Measurement and study of ocean depth and floor
BOP (Blow-out preventor)	Hydraulically operated device used to prevent uncontrolled releases of oil or gas from a well
Christmas tree (xmas tree)	Valve assembly at the top of a well used to control flow of oil or gas
Combustion emissions	Emissions of gases including carbon dioxide and oxides of nitrogen and sulphur, from the burning of fossil fuels such as oil or gas
Condensate	Liquid hydrocarbons, sometimes produced along with natural gas
Contaminants	Substances which may cause impurity or pollution
Corrosion protection	Use of chemicals or sacrificial anodes to protect a structure from progressive breakdown by chemical attack (or rusting)
Cuttings pile	Pile of mainly rock chips deposited on the seabed as a result of drilling
DP	Dynamic Positioning
Drill bit	A drilling tool used to cut through rock
Drill casing	Steel pipe cemented into a well to prevent cave-in and stop fluids from leaking to or from surrounding rock into the hole
Drill cuttings	Rock chips produced as a result of drilling

Term	Definition
Drill string	Lengths of steel tubing roughly 10m long screwed together to form a pipe connecting the drill bit to the drilling rig. It is rotated to drill the hole and delivers drilling fluids to the bit
Drilling mud	Mixture of clays, water and chemicals used to lubricate the drill bit and return rock cuttings to the surface; also used to maintain required pressure
DTI	Department of Trade and Industry
Dynamic Positioning	Use of thrusters instead of anchors to maintain the position of a vessel
EC	European Community
EEC	European Economic Community
Environmental Impact Assessment	Systematic review of the environmental effects a proposed project may have on its surrounding environment
EU	European Union
Flare	Controlled burning of gas for pressure relief (or during well testing to disposal of excess gas)
Formation	An assemblage of rocks or strata
FPS	Floating Production System
FPSO	Floating, Production, Storage and Offloading Facility
Fugitive emissions	Very small chronic escape of gas and volatile liquids from equipment and pipework
Geology	Physical structure and substance of the earth
GOR	Gas Oil Ratio (ratio of gas to oil in produced hydrocarbons - expressed by volume)
Global Warming	Rise in the earth's temperature due to infra-red radiation being trapped in the atmosphere by water vapour, carbon dioxide and other gases
Greenhouse gases	Gases believed to contribute to the greenhouse effect, including carbon dioxide, water vapour and methane
Hydrocarbon	Compounds containing only the elements carbon and hydrogen, including oil and natural gas
Licence block	Area of the sea which has been sub-divided and licensed to a company or group of companies for exploration and production of hydrocarbons
Licensing round	An allocation of licences made to oil companies

Term	**Definition**
Liner	Small diameter casing placed within a well to carry hydrocarbons back to the surface
Manifold	Assembly of pipes, valves and fittings which allows fluids from more than one source to be directed to various alternative routes
Mattresses	Concrete structures used to protect pipelines or other subsea structures
Organic compounds	Materials containing carbon combined with hydrogen, often with other elements
OSPAR	Oslo and Paris Commission
Permeability	Degree to which a solid allows the passage of fluid through it
PON	Petroleum Operations Notice
Porosity	Degree to which a substance allows movement of fluids through its pores
Produced water	Water removed from the reservoir along with oil and natural gas
Rheological	Relating to flow or current
Riser	Pipe connecting a rig or platform to a wellhead or pipeline
ROV	Remotely Operated Vehicle
Sacrificial anodes	Metal plates placed on underwater structures to prevent corrosion. The seawater attacks the anodes rather than the structure
Satellite wells	Wells a considerable distance from the main development, connected via pipelines
Scale	Minerals deposited on the inside of pipework and equipment. Some scales may contain low dose, naturally occurring radiation.
SEA (Strategic Environmental Assessment)	An appraisal process through which environmental protection and sustainable development is considered in decisions on policy, plans and programmes
Sediments	Loose material, such as sand and mud, laid down at the bottom of the sea, river or lake
Seismic	Survey technique used to determine the structure of underlying rocks by passing acoustic shock waves into the strata and detecting and measuring the reflected signals. Depending on the spacing of survey lines, the seismic is referred to as either 2 or 3-D.

Term	**Definition**
Shale	Mud or claystone rocks
Shallow gas	Gas accumulation present near the surface of the seabed
Sidetrack well	Creation of a new section of well to detour around an area or to reach another area
Tank washings	Effluent as a result of cleaning tanks from rigs or vessels
Target location	Position within a reservoir which is the target of the drilling
TLP	Tension Leg Platform
Trenching	Excavation of a trench into the seabed in which a pipeline or umbilical can be laid
UK	United Kingdom
UKCS	United Kingdom Continental Shelf
UKOOA	United Kingdom Offshore Operators Association
Umbilical	Flexible pipeline containing several different cores, which are used to carry electrical power, chemicals and control fluids to the wellhead or other equipment
VOC (Volatile organic compounds)	Organic compounds such as ethylene and benzene which evaporate readily and contribute to air pollution directly or indirectly
VSP	Vertical Seismic Profile
Wellhead	Control equipment fitted at the top of a well
Wildcat well	Exploration well in an area not previously drilled

8 SOME FURTHER READING

Boesch DF and Rabelais NN (1987). Long-term environmental effects of oil and gas development. Elsevier Applied Science, London.

Cairns WJ (1992). North Sea oil and the environment: developing oil and gas resources, environmental impacts and responses. Elsevier, Cambridge

DTI (2001). Development of UK Oil and Gas Resources 2001. The Stationery Office.

Engelhardt FR, Ray JP and Gillam AH (eds) (1989). *Drilling Wastes*. Elsevier Applied Science, London. 867pp.

Environment Agency (1998). Oil and gas in the environment. Environmental Issues Series, The Stationery Office, 104pp.

Gallaway BJ, Senner RGB, Fechhelm RB and Hubbard GF (1997). Environmental trends in the Gulf of Mexico in the twentieth century: The role of offshore oil and gas industry. Report to the American Petroleum Institute, 110pp. Available at www.api.com

Gulland J and Walker C (1998). Marine seismic overview. In, Seismic and Marine Mammals Workshop, 23-25 June 1998 (sponsored by AMJIG and IAGC).

Middleditch BS (ed) (1981). Environmental effects of offshore oil production, the Buccaneer gas and oil field study. Plenum Press. 446pp.

Reed M and Johnsen S (eds) (1996). *Produced Water 2: Environmental Issues and Mitigation Technologies*. Plenum Press.

Richardson WJ, Greene CR Jr, Malme CI and Thomson DH (1995). *Marine Mammals and Noise*. Academic Press.

Stockil P (Ed.) (1977). Our Industry Petroleum. The British Petroleum Company Limited, London. 600pp

Swan JM, Neff JM and Young PC (1994). Environmental implications of offshore oil and gas development in Australia - the findings of an independent scientific review. Australian Petroleum Exploration Association, Sydney, 695 pp.

UK Offshore Operators Association and the Natural History Museum. Britain's Oil and Gas. Second Edition. 55pp.

UKOOA (2000). Balancing Needs 2000 Environmental Performance Report. http://www.oilandgas.org.uk