Finding 6

Oil spill risk assessment and response planning for offshore installations

FINAL REPORT

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The assistance of Petronia Consulting and DNV GL in the compilation of this report is greatly appreciated.

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About this report

This report provides guidance for offshore installations, concerning the process of oil spill risk assessment (OSRA) and establishing or identifying suitable resources to enable an effective and efficient response to potential oil spill incidents. The process and methods in the report describe how information from an OSRA can be used as a logical and transparent basis for oil spill response planning.

Whilst the oil industry's primary focus remains the prevention of incidents leading to oil spills, it is recognized that preparedness and response to spills is an essential part of risk management. The guidance in this report aims to assist operators of offshore installations to develop and implement risk-based planning for oil spill incidents. Furthermore, it is anticipated that authorities involved in offshore regulation, and stakeholders with wider interests, will find this guidance a useful reference and tool to develop a shared understanding and approach to this important issue.

Section 1: Introduction

Background

The oil and gas industry recognizes the importance of assessing the oil spill risks associated with its operations and implementing measures to manage these risks. The primary focus and priority is the reduction of risk by the prevention of incidents which may lead to oil spills. However, additional risk reduction can be achieved by ensuring effective response in case of incidents, through the establishment of source control (e.g. well capping and containment solutions) and oil spill preparedness measures. This guidance document addresses oil spill risk assessment in general, but places emphasis on risk assessment in the context of planning and establishing appropriate oil spill preparedness and response.

This document's primary purpose is to provide guidance for operators of offshore installations. However it also aims to assist regulators and key stakeholders in understanding how the offshore industry addresses the determination of oil spill response capacity within a risk-based context.

The oil and shipping industries, working in partnership with governments and international organizations over a period of decades, have used structured research and experience of actual spills to gain a detailed understanding of effective oil spill preparedness and response. Much of that research and understanding is incorporated in the oil spill response 'good practice guidance' series of publications produced by IPIECA-OGP based on input from the oil industry.

Traditionally, the focus has been on the risks posed by tankers and other shipping, in response to the historic pattern of major spills resulting primarily from ship-source incidents. Improvements in prevention and preparedness have resulted in a significant decline in major oil spills from tankers. This is reflected in global data published by the International Tanker Owners Pollution Federation Limited (ITOPF), which indicate that the annual average number of spills greater than 700 tonnes was 24.5 per year during 1970–79, 3.3 per year during 2000–09 and 1.7 spills per year during 2010–12.

Following a number of high-profile incidents leading to major spills from offshore installations, the oil industry recognized the need to enhance the focus on already-existing offshore oil spill prevention and preparedness efforts. As the offshore exploration and production industry moves into more challenging environments the sector's risk profile is changing, warranting additional prevention and preparedness measures including specific guidance for offshore oil spill risk assessment and response planning. In addition, there is an increasing global environmental awareness and focus among the public, authorities and other stakeholders concerning offshore exploration and production, indicating the need for improved explanations and consensus regarding the industry's efforts to improve oil spill preparedness. OGP and IPIECA have developed and published this guidance as a tool to enhance the industry's offshore oil spill prevention and preparedness efforts and to better communicate those efforts to the various stakeholders.

Purpose of this document

The purpose of this document is to provide guidance and establish recommendations for effective execution of oil spill risk assessment (OSRA) and associated response planning for offshore oil and gas facilities and operations. This forms a fundamental part of the oil spill contingency planning process.

Scope

The first part of this guidance describes OSRA for offshore oil and gas activities. Oil spill risk assessment refers to the likelihood of liquid hydrocarbon releases to the sea and their potential for ecological and socio-economic consequences. This guidance covers the process of planning and executing the oil spill risk assessment, and includes recommendations on how to establish and evaluate the risk. Guidance is provided but no single method is outlined. The guidance emphasizes the application of risk assessment for oil spill response planning purposes. Other elements of risk management are not addressed in this guidance.

The second part of the guidance describes how outputs from the OSRA may be used to determine and plan for appropriate oil spill response resources to mitigate the risk. The tiered preparedness and response approach is used in conjunction with scenario-based planning, as the underlying basis for determining oil spill response resources. This approach is fully compatible with the International Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC Convention) and thereby acknowledges the importance of cooperation between the operators of offshore units and the relevant authorities in developing oil spill preparedness, particularly for major incidents.

The document follows the process outlined in Figure 1.

Area of application

This document applies to all offshore units, meaning any fixed or floating offshore installation or structure engaged in gas or oil exploration or production activities, loading or unloading of oil including FPSOs (floating production, storage and offloading units) and marine export pipelines. Shipping spills (except where tankers may be in very close proximity to operations, such as during loading of shuttle tankers) and consented releases of liquid hydrocarbons are not covered by the guidance.

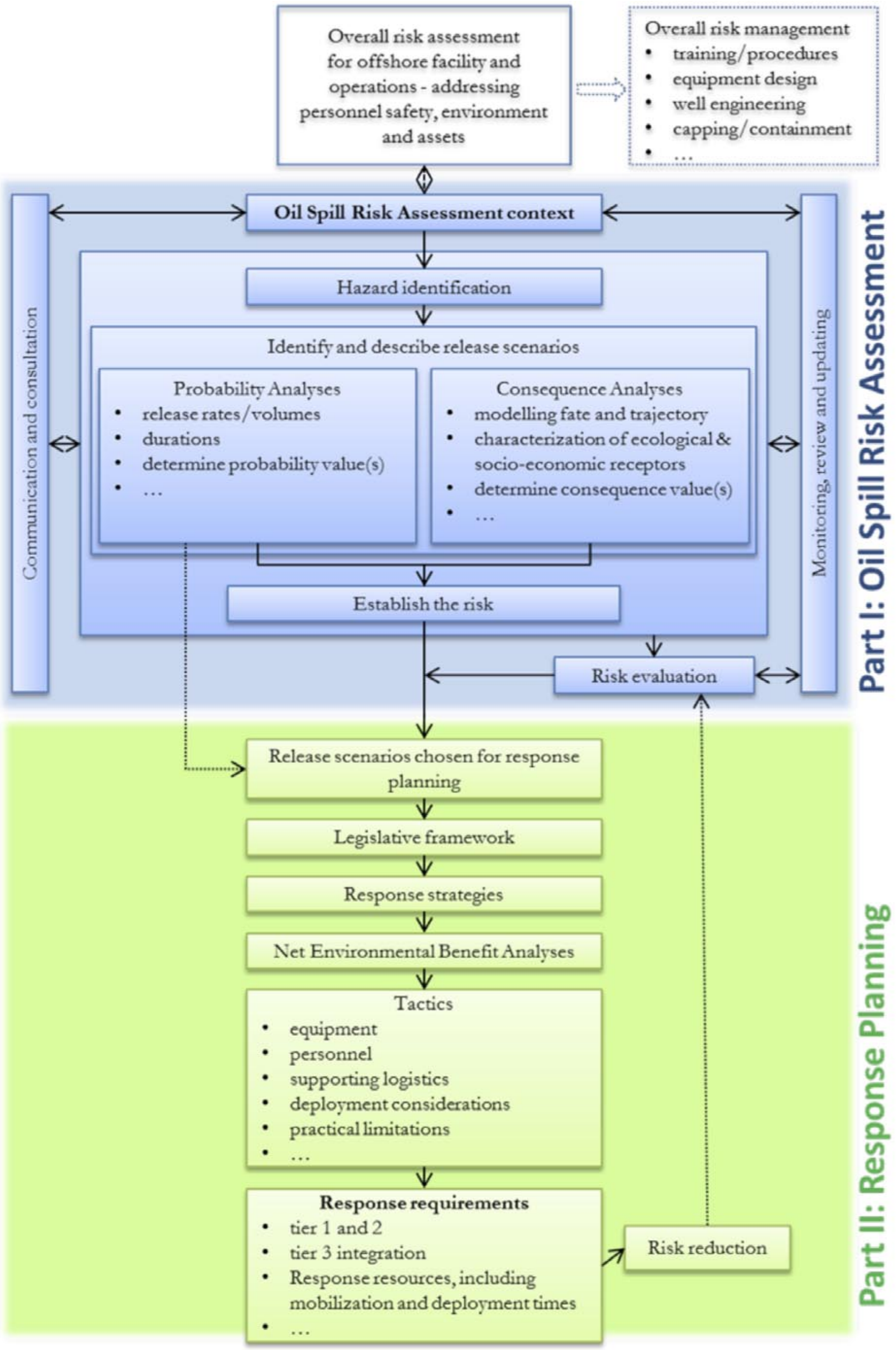
Terms, definitions and abbreviations

Terms and definitions provided in this document have been aligned to the extent possible with ISO 17776:2000[1] and ISO 73:2009[2]. See Appendix A for definitions of key terms and a list of acronyms and abbreviations used in the document.

[1] ISO 17776:2000. *Petroleum and natural gas industries—Offshore production installations—Guidelines on tools and techniques for hazard identification and risk assessment*.

[2] ISO GUIDE 73:2009. *Risk management—Vocabulary*.

Figure 1 Overview of the oil spill risk assessment and response planning process



Part 1

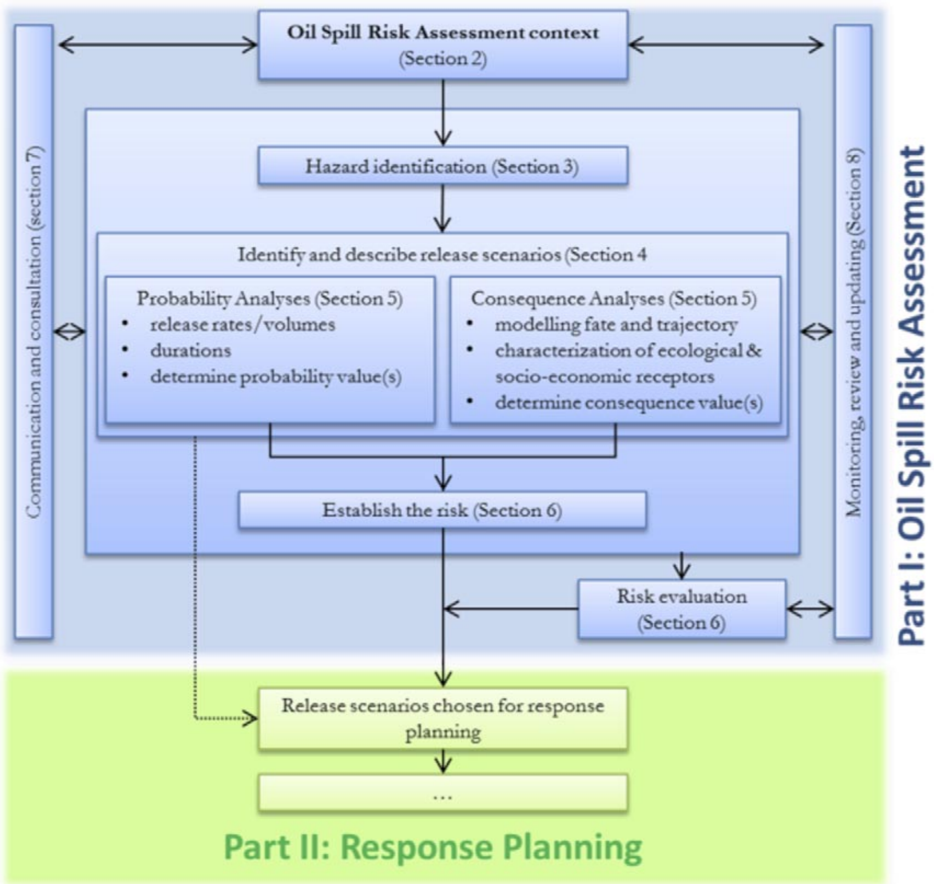
Oil spill risk assessment

Section 2: Establishing the oil spill risk assessment context

Oil spill risk assessment: an element in risk management

Oil spill risk assessment, in terms of establishing, analysing and evaluating the risk, is a key element in a risk management process. The outputs of the OSRA link directly to oil spill response planning, which is integral to risk reduction. The OSRA will often be part of an overall risk assessment process for safety, environment and assets. ISO 31000[3] concerns risk management and emphasizes the importance of establishing the context prior to starting or executing any of the elements included in the risk assessment process, and the importance of updating the context throughout the process. It also emphasizes the importance of communication, consultation, monitoring and review throughout the entire process. The elements of the OSRA process are illustrated in Figure 2. The section numbers in the figure indicate the sections in this guidance document which describe and give recommendations for each part of the process.

Figure 2 Elements in the OSRA process—with reference to relevant sections of this document



[3] ISO 31000:2009. *Risk management—Principles and guidelines*

The oil spill risk assessment process starts by defining the context of the assessment such as objective, scope, methods, boundaries, risk tolerance criteria, etc. and describing the activity to be assessed (see *Risk assessment context* on pages 9–11). Thereafter the process is designed to address a series of key questions:

What can go wrong and lead to the potential release of oil?
Hazards related to the activity are identified. The hazardous events are analysed, allowing the identification and description of oil spill release scenarios.

How likely are the identified scenarios?
The likelihood of each potential release scenario is determined using either qualitative or quantitative methods, depending on the risk assessment context and the availability of data. A likelihood value is derived for each scenario, which enables the various scenarios to be ranked for comparative purposes, when establishing the risk. A likelihood value may have been established as part of the identification of hazards (i.e. the previous step).

What happens to the spilled oil?
The oil spill scenarios are modelled to understand the potential fate and trajectory of the spilled oil, as well as to establish an 'influence area' of the activity, i.e. the area(s) with a reasonable likelihood of being oiled.

What are the key environmental (both ecological and socio-economic) receptors?
Environmental receptors within the influence area are mapped, and impact indicators identified within the mapped resources. An environmental consequence value(s) is derived for each scenario.

What is the risk for environmental damage?
Combining the likelihood values for the oil spill scenarios (worst credible case discharge, WCCD) with the potential environmental consequence values of the same scenarios establishes their risk. Based on the risk of each scenario, the risk level of the operation can be established. Higher risk activities will be identified and risk reducing measures can be developed.

How is the established risk utilized in oil spill response planning?
The resulting risk level can be compared against oil spill risk tolerance criteria or environmental goals to evaluate the risk level of the operation. The ALARP (as low as reasonably practicable) principle may be used for evaluating risk reducing measures. The results of the risk evaluation provide input to oil spill response planning at Tiers 1, 2 and 3. The consequence evaluations performed during the risk assessment process will also provide useful input to a net environmental benefit analysis (NEBA) when considering response strategy choices. Part 2 of this document provides guidance on how response planning uses oil spill scenarios from the OSRA to determine appropriate response resources.

During and/or after the risk assessment process there should be communication and consultation with internal stakeholders and possibly also with external stakeholders, depending on the complexity of the activity. For projects in the design, construction or expansion phase, the risk assessment (scope/inputs/methods, etc.) should be monitored to ensure that the assessment is still relevant as the project evolves. If the risk assessment is no longer valid for the activity, it needs to be reviewed and updated.

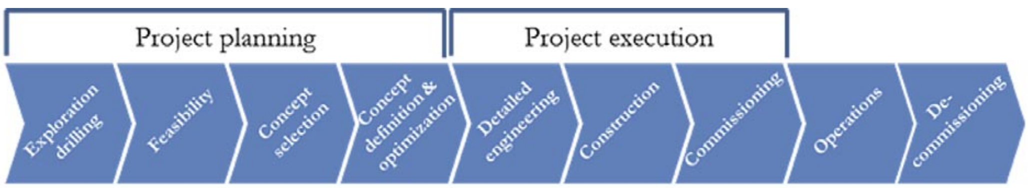
Level of detail

The level of detail to be implemented and achieved for the OSRA should be established prior to conducting the study. The selected level of detail should be suited to the purpose of the OSRA and the type of decisions to be made.

The life cycle phase of the project is an important factor in the selection of the level of detail (Figure 3). In the early phases of a project, i.e. during feasibility or concept phases, the uncertainty related to the information available will typically be high. In these phases, a qualitative OSRA may be suitable. Additionally, qualitative results may be sufficient for decision making during these early phases. For the later phases of a project, such as detailed engineering and Engineering, Procurement and Construction (EPC) for operations, more reliable information will typically be available. During these phases, conducting a quantitative OSRA may be more appropriate. Similarly, quantitative and more detailed results would typically be more suitable for decision making at this stage.

For mobile facilities or those that are already in place, an OSRA may be conducted to confirm that adequate risk mitigation measures, preparedness planning and response resources are in place. Similar to above, the required level of detail and quantitative or qualitative nature of the OSRA will depend on the purpose and type of decisions to be made.

Figure 3 Typical offshore oil and gas project life cycle phases



Risk assessment context

Establishing the context for the risk assessment process should involve, but not be limited to, the topics addressed in the following sections.

Establish objectives, scope and responsibilities

The main objective of conducting an OSRA is to determine that the offshore activity is in line with corporate risk tolerance. This is achieved by identifying, characterizing, evaluating and presenting the risk. The evaluation should include consideration of risk mitigation measures, incorporating oil spill prevention, preparedness and response. Oil spill response planning is a tool to reduce potential consequence of an incident, forming an integral part of the risk mitigation.

Conducting an OSRA may have other objectives; for example, it may provide:
- support for decision making related to different development concepts or design/decommissioning options;
- a basis for approval by regulatory authorities; and
- a basis for stakeholder communication.

The normal scope of the OSRA is to identify and evaluate the risk to the environment from accidental oil spills from offshore units. The environment should include both ecological and socio-economic factors. It can be beneficial to communicate with relevant stakeholders to ensure that the scope of the assessment meets the needs of both the operator and the relevant stakeholders (see Section 7 on *Communication and consultation*).

Responsibilities related to planning and execution of the OSRA process, the associated elements and the various activities included, should be defined. This is typically related to approval of assumptions, definition of objectives, provision of study basis, time schedule for required information and definition of risk tolerance criteria.

The established objectives, scope and responsibilities for the OSRA process should be documented.

Establish methods, models and tools to be used in the process

The following should be considered when defining the methods, models and tools to be used in the process:

- Best practice and industry practice in the geographical region and regulatory regime.
- Suitability for the defined objective(s) and scope of the OSRA. Choices might need to be reconsidered based on the results of the hazard identification.
- Availability of relevant and/or required input data and models.

A description of the method, model or tool used, including a justification of its use in the analyses, should be documented. Uncertainties related to the use of methods, models and tools should also be documented.

Boundaries and basis for the OSRA

The facilities and operations that are to be subjected to the risk assessed should be defined and described in a suitable manner. The boundaries, i.e. what should and what should not be subjected to the assessment, should be defined for the following main aspects, at a minimum:

- installations and technical system(s), for example topside drilling or production facilities, subsea facilities, FSOs (floating storage and offloading units), FPSOs (floating production, storage and offloading units), flow lines, export pipelines, wells, well servicing/interventions, storage tanks, process system(s), utility system(s) etc.; and
- period(s), phase(s) and/or activities.

The inputs used as the basis for the OSRA process should be documented.

Risk tolerance criteria

The risk level should be measured against ecological and socio-economic risk tolerance criteria (RTC), other decision criteria/goals and the ALARP principle. RTC is defined by the maximum likelihood of a certain consequence which is tolerable for the operating company. If RTC or other environmental decision criteria are used, these should be established prior to the OSRA as they constitute a reference for the evaluation of the results from the risk assessment (see Section 6 on *Establishing and evaluating the risk* for recommendations on RTC and risk evaluation).

The environmental RTC should, as far as possible, be:

- suitable for evaluation of the activity/activities and/or system(s) in question;
- suitable for comparison with the results of the analysis to be performed;
- suitable for decisions regarding risk reducing measures;
- suitable for communication;
- unambiguous in their formulation (such that they do not require extensive interpretation or adaptation for a specific application);
- unbiased with respect to any particular concept solution, either explicitly or implicitly through the way in which risk is expressed.

The environmental RTC or other environmental decision criteria to be used in the risk assessment process should be documented. They are often established as part of a companies' overall risk management system and will therefore be in place in advance of an OSRA.

Execution plan for the process

The OSRA will provide relevant information for decision making, and should therefore be carried out either prior to making decisions or to confirm previous decisions affecting/concerning the risks/activities being analysed. In some cases, change management or an incident may trigger the OSRA; in these cases previous decisions may be challenged and amended.

Planning an OSRA for a standard or existing operation/activity will normally be straightforward and closely follow the steps in Figure 1. However, during the feasibility, conceptual and/or engineering phases of a project (e.g. for a new facility), or during the planning of a larger operation, several decisions, which could have a minor or major effect on the risk, are typically made. It is therefore important that the OSRA provides necessary decision support throughout the development of the project, at the right time and with the appropriate level of detail, and not only at the end of the assessment process. In such cases, a plan for the execution of the risk assessment process, which ensures that the objectives are met and that the outputs are available at the right time, should be established and documented.

Section 3: Hazard identification

Objective

Hazard identification should be carried out in a comprehensive manner. The objectives of hazard identification are to:

- identify hazards associated with the facilities and operations being studied, the threats, and the circumstances which may trigger hazardous events (i.e. incidents when a hazard is realized);
- identify the potential characteristics of hazardous events; and
- identify potential preventive measures.

For the purposes of this document, the focus will be on hazardous events related to potential releases of liquid hydrocarbons (i.e. oil spills) to the surrounding environment.

Process

The hazard identification process should be as comprehensive as reasonably practicable; events which are identified as hazardous will form the basis for subsequent analyses and the selection of oil spill scenarios. Hazardous events that are not identified at this stage will be excluded from further assessment. Hazards should be identified whether or not they are considered under control by the organization. Sources of hazardous events, and sets of circumstances which may trigger the events, should be identified whether they are temporary or permanent.

Appropriate hazard identification tools and methods should be applied. Selected tools should be suited to the objectives of the hazard identification and to the type of hazardous events to be identified. A list of potential hazard identification tools which can be applied is provided under the subsection on *Tools*, below.

The basis for the OSRA (see the subsection on *Boundaries and basis for the OSRA*, on page 10) should be established prior to the hazard identification. It is important to ensure that personnel involved in the hazard identification process are aware of and understand the basis.

The hazard identification process should be documented with, as a minimum, a record of the:

- basis for the OSRA;
- information used as a basis for the identification process;
- methodology applied;
- resources involved, including personnel;
- criteria used for the screening of hazardous events; and
- identified hazardous events, their causes and characteristics.

Tools

A list of the main techniques for hazard identification applicable for offshore units is presented below. The list is based on information provided by the Center for Chemical Process Safety[4] (cited by the Centre for Maritime and Petroleum Technology[5]), and on ISO 17776[6]. These references should be consulted for further details concerning their use.

Tools recommended for use in the hazard identification process include the following:

- **Hazard review:** a mainly intuitive, qualitative review of the installation to identify the hazards that are present.
- **Hazard checklist:** a review of the installation against a list of hazards that have been identified in previous hazard assessments.
- **What-if analysis:** a flexible review technique, which can be applied by experienced individuals to any installation, operation or process, to identify hazards.
- **Hazard identification/Environmental issues identification (HAZID/ENVID):** a structured approach to the identification of the possible causes and consequences of hazardous events.
- **Preliminary hazard analysis (PHA):** an analytical technique used to identify hazards which, without adequate precautions, will give rise to a hazardous event.
- **Hazard and operability analysis (HAZOP):** a systematic approach to identifying hazards and operability problems occurring as a result of deviations from the intended range of process conditions.
- **Procedural HAZOP:** a version of HAZOP applied to safety-critical operations such as drilling, rig-moves, heavy lifts etc.
- **Failure modes, effects and criticality analysis (FMECA):** a systematic review of facility equipment items, their potential failure modes and the effects of these failures on the equipment or facilities.
- **Inspections and audits:** visual examinations of an existing installation and its operating procedures to identify potential hazards.

4 CCPS, 1992. *Guidelines for Hazard Evaluation Procedure*. 2nd edition. Center for Chemical Process Safety. American Institute of Chemical Engineers, New York.

5 CMPT, 1999. *A Guide to Quantitative Risk Assessment for Offshore Installations*. Centre for Maritime and Petroleum Technology, London. ISBN 1 870553 365.

6 ISO 17776:2000. *Petroleum and natural gas industries—Offshore production installations—Guidelines on tools and techniques for hazard identification and risk assessment*.

Examples of hazardous events

Depending on the scope of the study, and on the basis of the OSRA, hazardous events to be identified may include, but are not limited to:

- loss of well control (blowout) from drilling, completion, producing wells, well intervention or work-over;
- spill from ruptured or leaking flow-lines, pipelines, risers and/or subsea equipment;
- loss of containment, such as spill from storage facilities or offloading/transfer (e.g. from FPSOs);
- spill due to ship collision or collapse of the installation;
- spill from topside or subsea processing systems;
- spill from utilities;
- spill during bunkering or fuelling.

Section 4: Likelihood analyses

Objective

The objective of the likelihood analysis is to characterize the identified hazardous events, in terms of likelihood, the event duration and location, potential volumes of hydrocarbons discharged, and the type of hydrocarbon released. This establishes an overview of all events that could lead to ecological and/or socio-economic consequences.

Analyses of hazardous events

The degree of detail to be achieved for the likelihood analyses will depend on the type of OSRA to be carried out: a high degree of detail and use of data on oil spill statistics would typically be required for a quantitative analysis, while less detail would be required for a qualitative analysis.

For quantitative approaches, modelling tools may be applied for the evaluation of the characteristics of the hazardous event (e.g. flow modelling for leaks). The selected tools should be suited to the objectives of the evaluation, to the capabilities of the organization, and to the type of events being analysed.

Experience from relevant historical events may also be applied for this purpose. In particular, failure and accident data may be applied to establish the likelihood of hazardous events. Failure and accident data that are applied should be suitable in relation to the context of the study and the method, model(s) and tool(s) used. It should also be ensured that the data is representative for the events being analysed.

It may be appropriate to adjust statistics and historical data to reflect project- or event-specific characteristics. Such adjusted data will then form the basis for establishing the likelihood of hazardous events. Adjustment can be made based on significant trends in the historical data, or on documented changes in the robustness of the oil spill barrier. Changes in barrier robustness can lead to a reduced or increased likelihood for a hazardous event. For example, a reduction in the likelihood of a hazardous event may be due to documented improvements in equipment reliability; conversely, operational aspects such as high pore pressure and low fraction pressure may reduce the barrier robustness. The basis for the adjustment and the methodology applied should be documented if these statistics are adjusted.

Recognized sources of data should be used wherever possible. Data should be adapted to the objectives of the analysis, and to the events being analysed. When no data are available, or where the data are uncertain, assumptions may be applied. In this case, conservative values should be applied (i.e. leading to higher level of risk). A list of recognized data sources may be found in an annex of NORSOK Z-013[7].

[7] Standards Norway, 2010. NORSOK STANDARD Z-013: *Risk and emergency preparedness assessment*. Edition 3, October 2010.

The analyses of events should be documented. As a minimum, the documentation should include:

- all identified hazardous events, and their likelihood and characteristics in terms of flow, location, quantity and composition of hydrocarbons released;
- a record of the methodology applied;
- the tools used;
- resources involved, including personnel; and
- assumptions taken and sources of data used, as well as the uncertainties related to these elements.

Whichever method is used to analyse the likelihood of hazardous events, the outcome should be an ascribed likelihood value which may be used in the establishment of risk.

Selection of oil spill scenarios

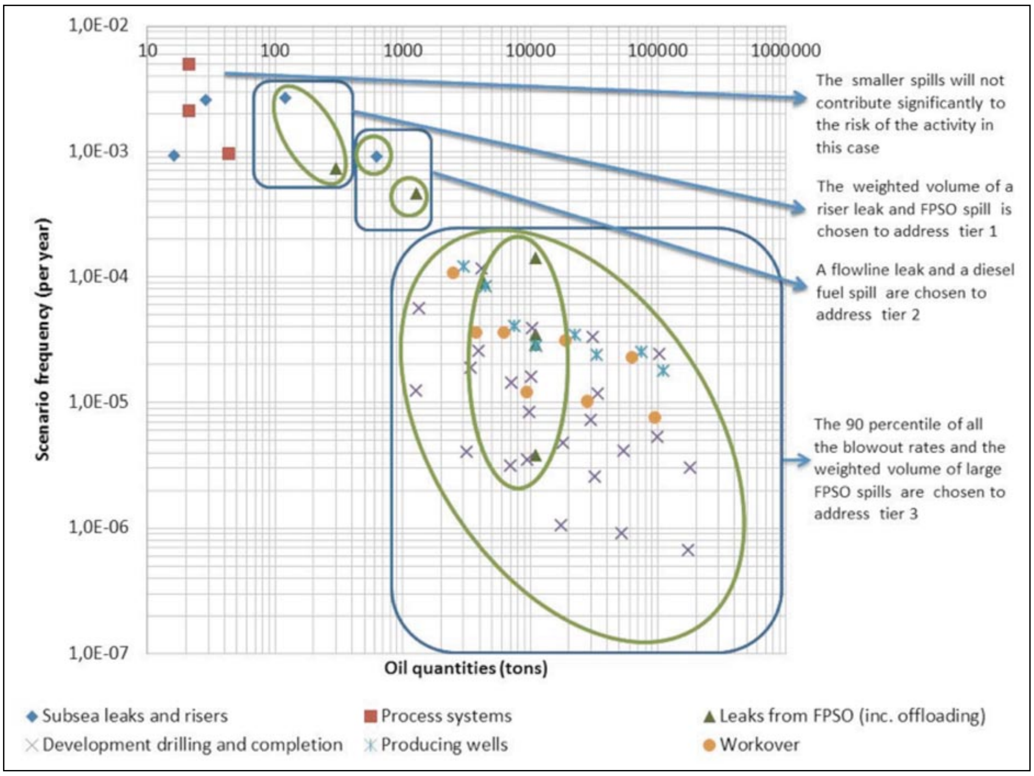
When all hazardous events have been identified, an assessment should be undertaken to select those events to be taken forward in the OSRA and to define the oil spill scenarios to be modelled. These oil spill scenarios are analysed through fate/trajectory modelling and determination of potential consequences, which are combined with the event's likelihood to establish the risk.

The identified hazardous events may be considered for further analysis and, as a minimum, all events that potentially have a significant contribution to the risk should be considered (Figure 4). The likelihood of an event, and the potential quantity of discharged hydrocarbons, are the two main parameters contributing to the risk from an event. Hazardous events with higher likelihood and higher potential quantity of discharged hydrocarbons (i.e. combination of flow rate and duration) have higher risk potential given the same release location and the same hydrocarbon type. Nevertheless, hazardous events that have a low likelihood but which may have a high severity should also be selected (see also the subsection on *Tier 3 planning,* on page 32).

At this stage in the OSRA there is no detailed information concerning the possible environmental consequences of the identified hazardous events. However, experienced risk assessors or local environmental specialists will be able to make an initial estimation of those events which may have the potential for high consequences. As a general rule, the closer the release location to sensitive resources and the greater the persistence of the oil, the higher the potential contribution to the risk from releases.

Hazardous events may be aggregated to define the oil spill scenarios. The aggregation process can be necessary to reduce the number of scenarios to be modelled, due to modelling capacity and time restraints. Events that are aggregated should have identical, or very similar, characteristics in terms of: the release location and duration; the quantity of oil released; and the weathering characteristics of the oil. The likelihood of the resulting scenario should be equal to the sum of the likelihoods of the aggregated hazardous events, given that the events are independent. The duration of the release and the quantity of hydrocarbons released should be equal to the average durations and quantities, weighted on likelihood. A more conservative

Figure 4 Example of the selection of release scenarios based on likelihood and quantity



Left: The blue rectangles illustrate groups of events that illustrate Tiers 1–3 spills. The green borders indicate events that can be selected and combined as spill scenarios. The axes in the figure use logarithmic scales.

approach may be to utilize the maximum release duration and quantity as representative for the aggregated events. Another option in the case of a qualitative risk assessment could be to use the highest likelihood of the hazardous events representing the single scenario with the highest risk.

The aim of the selection process is ultimately to provide a risk basis for oil spill response planning. This planning is typically structured as a tiered response (see Section 10, *Tiered preparedness and response resources*). It is recommended that, in selecting oil spill scenarios, consideration is given to ensuring that all three of the response tiers are covered. Typically this may involve one or two scenarios commensurate with each of the three tiers.

Figure 4 provides an example of how release scenarios are selected from hazardous events, presented in terms of their likelihood and quantity of oil spilled. This example considers an FPSO with subsea production wells and export through offloading. Sixty-four hazardous events have been identified (combination of a source, quantity and a release location). The purpose of this example is to illustrate the principles; note that a real operation of this nature may have more or less hazardous events.

In Figure 4, the hazardous events are plotted on the chart for visualization and selection purposes. The chart axes represent the oil quantity and the event's likelihood. For this case, all scenarios except the diesel fuel release have the same type of oil and the same geographical location. It is therefore deemed appropriate to select the scenarios for the OSRA based only on their likelihood and the quantity of oil.

The selection process should be documented, including as a minimum the method and criteria applied for the selection of scenarios, and any hazardous events that are not selected, together with the justification for this decision. Box 1 (opposite) provides an example of an analysis of release scenarios following a blowout, represented by likelihood, flow rate and duration.

International subsea capping and containment capability may be a relevant risk reducing measure in case of a loss of well control (blowouts) on subsea wells. Capping can be planned for, and will have an effect on, the duration probabilities of blowouts on subsea wells. Box 2 provides an event tree analysis of probabilities for spill durations in the case of capping of a subsea blowout. An example of planning and evaluation of risk reduction of capping is given in Box A1 in Appendix 2; example 2.

The Ixtoc I *oil well blowout in the Bay of Campeche, Mexico, 1979.*

Source: Wkimedia Commons/NOAA

Box 1 Example of release scenarios from a blowout based on likelihood, flow rates and duration

This example describes a blowout event analysis for the drilling of an exploration well. Blowout flow rates may vary depending on: the penetration depth into the formation (full penetration or entering the formation); the flow path in the well (through annulus, open hole or drill pipe); the opening status of the blowout preventer (BOP), i.e. whether fully open or partially closed; and the release location (at the sea surface or subsea). The event tree analysis (ETA) on the right (Figure A) illustrates how alternative potential scenarios arising from the blowout can be determined.

Each combination of these parameters (blowout scenario) is studied through flow modelling. One example of a blowout scenario is a blowout that occurs when entering the formation, and which flows through the well annulus and onwards through a BOP which is fully open to the sea. In this case, a proprietary simulation model is used. This leads to a wide range of potential hydrocarbon flow rates from the well.

Each blowout scenario is then given a likelihood based on statistics and assumptions. The overall likelihood for a blowout from this well is extracted from relevant statistics, in this case the Scandpower[8] statistics applicable for operations in the North Sea. Figure B illustrates the range of flow rates and associated frequencies.

The potential blowout durations are assumed independently of the flow rates, and in this case are based on the Scandpower statistics. For this well, it has been determined that the maximum duration of a blowout is 68 days (Figure C), which corresponds to the time required to mobilize a rig, drill a relief well, and successfully kill the well. The durations are then divided into categories.

The result of this blowout event analysis is a list of flow rates, their associated likelihood and potential duration, as well as location.

Figure A: Event tree analysis (ETA)

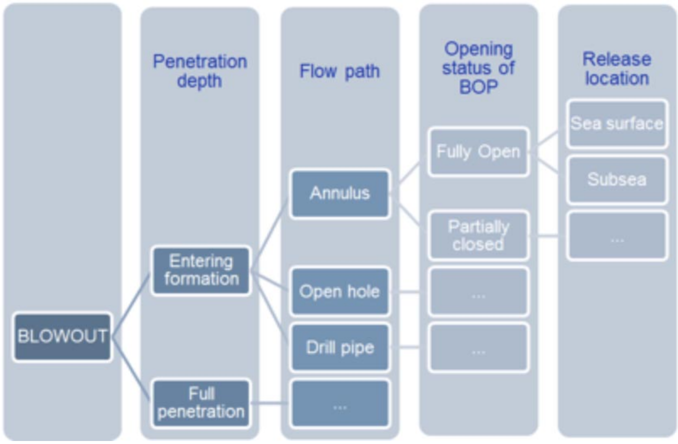


Figure B: The range of flow rates and associated frequencies

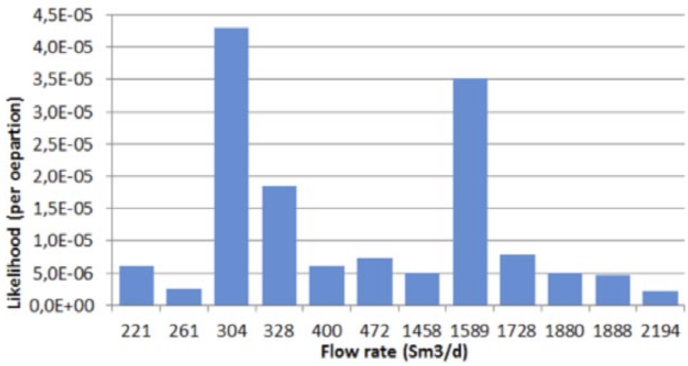
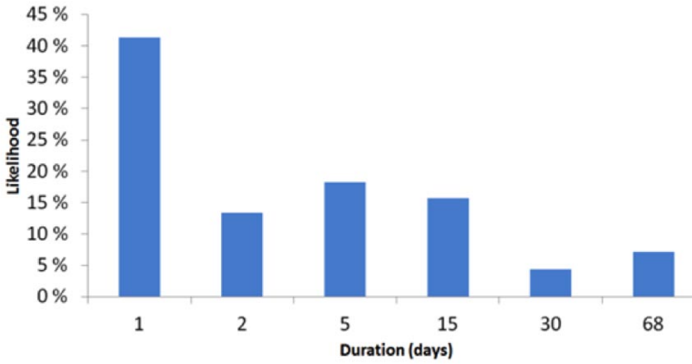


Figure C: The likelihood of the event duration (max. duration 68 days)



[8] Scandpower, 2012. *Blowout and well release frequencies based on SINTEF offshore blowout database 2011.* (The document is updated annually).

Box 2 Example of planning for capping of subsea blowout

This example describes a blowout event tree analysis for capping as a risk reducing measure for subsea blowouts. Capping will have an effect on the duration probabilities of subsea blowouts. In most cases capping will significantly reduce the duration of a blowout, if drilling of a relief well is the alternative consequence reducing measure.

In some situations, a topside blowout from a floating installation may be converted into a subsea blowout if the floater is disconnected. This should be addressed in the topside versus subsea blowout frequency distribution in the likelihood analysis.

Figure D shows that in the case where capping is a possible risk reducing measure, there are two alternative situations; the capping stack may be installed without further delay, or the seabed must be cleared from debris before installing the capping stack. The latter will cause a delay and increase the time for successful capping. In both cases, there is a minor possibility that the capping stack is not successful in well shut-in and that other risk reducing measures such as containment and/or relief well drilling is required in order to stop hydrocarbon from flowing into the environment.

In the case of a subsea blowout, the time to cap a well would be equal to the time to mobilize the capping equipment, install it at the well, and successfully cap the well and stop the well from flowing into environment. In mature areas with highly developed infrastructure and access to appropriate vessels and trained crew for transporting and deploying the capping stack, there is a high probability that successful capping can be achieved within 3–7 days. If there is a need to clear the seafloor from debris before installing the capping stack, the time to achieve successful capping could increase to 10–15 days. In developing areas, the time to achieve successful capping is expected to be longer.

Detailed planning is needed to establish capping as a risk reducing measure for specific wells, and this is also recommended to be able to evaluate the probability of success and the time to mobilize, install and successfully cap the well. In some cases capping may need to be complemented with a containments system (not shown here) that brings hydrocarbons from a subsea wellhead to the surface in a safe and controlled way, ready for storage and disposal.

Figure D: Event tree analysis for capping

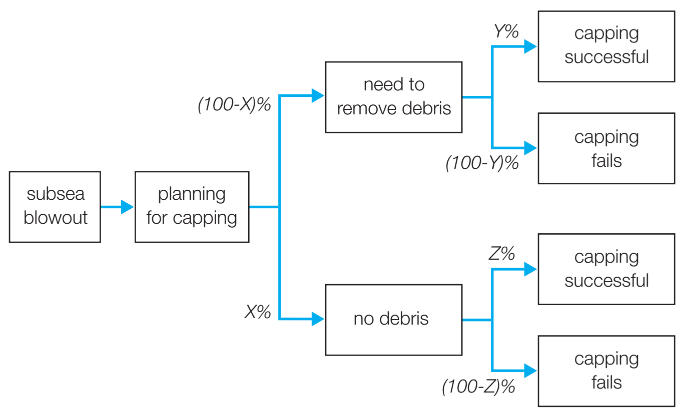


Figure E: Capping stack

Section 5: Consequence analyses

Introduction

For each of the selected release scenarios, the potential environmental consequence is combined with the likelihood of oil pollution to establish the risk, as outlined in Figure 1. In this context, environment refers to both ecological and socio-economic resources. A consequence value is required to allow its combination with the likelihood; this may be derived using qualitative or quantitative methods. The determination of a consequence value requires:

- estimation of the likely fate and trajectory of spilled oil through modelling, to identify possible oil pollution in marine and coastal areas (see *Modelling of oil spill fate and trajectory*, below);
- identification and characterization of potential environmental receptors at sea and on shorelines (see *Characterization of ecological and socio-economic resources* on page 25);
- evaluation of the sensitivity of the environmental receptors, and identification of those to be used as impact indicators for the determination of consequence values (see *Assessing environmental consequences* on page 27); and
- estimation of environmental impact as a function of oil exposure and environmental sensitivity.

Modelling of oil spill fate and trajectory

Objective and introduction

The objective of computer simulation of oil spill fate and trajectory is to estimate the physical changes which spilled oil undergoes (i.e. the so-called 'weathering' processes including evaporation, spreading, natural dispersion, emulsification and shoreline stranding) and its potential pathways, travel times, areal distribution and associated volumes under the prevailing climate.

There are two general types of trajectory models: stochastic/probabilistic and deterministic. Stochastic models apply historical wind and current conditions to simulate multiple oil spill trajectories that together give a statistical output. Deterministic models utilize a single set of wind and current conditions (for example the most probable) to simulate a single oil spill trajectory.

The following approach is recommended for oil spill fate and trajectory modelling for use in the OSRA and in oil spill response planning. Oil spill modelling should be performed for release scenarios that have been selected and defined through the processes described under *Selection of oil spill scenarios* on page 16. It is recommended that the scenarios include at least one or two from each of the three response tiers. Some spill models can be used to analyse and simulate various risk mitigation measures (e.g. spill response options). Models can provide information on the effectiveness of the response planning and the cost-benefit solutions for response options. In such cases, the modelling assumptions, such as assumed effectiveness of response options, should be clearly stated.

Selection of oil type and characteristics

The oil type to be used in the modelling should be selected specifically for the activity to be analysed. If the oil type is unknown (e.g. in the case of exploration drilling) a representative oil type may be selected based on best available data, or a range of oils may be used to bracket the type of oil that is anticipated. It may be justifiable to carry out representative modelling for a group of facilities, taking into consideration similarities in oil types and volumes, geographic proximity and geological similarity.

The oil type should be characterized by its physical and chemical properties, including the weathering profile. The characteristics are based on results from laboratory analyses and weathering tests. Alternatively, oil weathering models can be used if sufficient oil properties are known.

Near-field modelling and far-field oil fate and trajectory modelling

The applied oil spill model should be relevant for the spill scenarios and be able to cover both a subsea and a topside oil release. A near-field model should be capable of modelling the dynamics and fate of subsea oil and gas as it rises through the water column, if appropriate to the operation, and it should take into consideration the total well stream composition of oil, gas and water. The model should also be capable of modelling flow variation due to other well parameters such as pressure and temperature.

The drift and fate of the oil at the sea surface should be modelled with a far-field trajectory model. The far field model should be able to utilize inputs from the near-field model to enable modelling of the oil's fate and trajectory when the oil reaches the sea surface. The subsea component of the oil spill could also be modelled in the far-field model to take into account the fate of hydrocarbons mixed in the water column during the rise of the oil/gas plume and during dispersion and dilution of oil from a surface oil slick.

It is recommended that subsurface modelling be performed with three-dimensional (3D) models that can be initialized with the droplet size distribution data that are the product of the near-field modelling. Only 3D models can simulate the subsurface fate parameters that are likely to result from such a release. 3D models should preferably use 3D current (subsurface current) data as input (see below).

Oceanographic and meteorological data

An oil spill trajectory model should use wind and current data based on in-situ monitoring and/or modelled oceanographic or meteorological data fields. The current data are ideally three dimensional, and the wind data should reflect the wind to be experienced by oil slicks at the sea surface. For near-field modelling, the density profile (salinity and temperature) in the water column may also be required.

The oceanographic and meteorological data should include information on wind/current direction and speed, sea and air temperature, and possibly sea ice. The data should cover all seasons or yearly quarters relevant for the purpose of the risk assessment, and be specific for the region where the offshore activity will take place. Sufficient data should be included to capture the variation in surface wind and sea currents in the area, meaning a period of time sufficiently long that stochastic modelling can give representative values for the area.

In cases where modelled wind and/or current data are used as the basis for the fate and trajectory modelling, the data should be validated by either *in-situ* data or remote sensing observations. The resolution of the modelled data should reflect the complexity of the systems (water body and topography) and the purpose of the risk assessment.

Modelling resolution in time and space

The modelling should at least include the periods for the planned activity and the subsequent months, but it is recommended that all seasons or yearly quarters are covered in the simulations, with the possible exception of time-limited operations, to establish a better overall risk characterization.

The oil spill modelling should be stochastic, allowing for a large number of simulations based on variations in historical wind and current data. This should be performed for each spill scenario to generate a statistical output covering the potential geographical distribution of oil with mass balance and related travel times. The modelling should ensure sufficient spill simulations to reflect the variations in the metocean input data. The stochastic analyses should be paired with a most probable deterministic case that can be utilized to support response planning.

The model area should be sufficient to cover the influence area of the potential oil spills, i.e. sea and coastal areas that can reasonably be expected to be directly affected by an oil spill. It is recommended that the influence area be defined as the area with more than a 5% probability of oil presence for a modelled scenario.

The resolution of the model output should be aligned with the resolution of the input data (see *Near-field modelling and far-field oil fate and trajectory modelling*, above) and should reflect the purpose of the risk assessment.

Output parameters

The oil spill model should generate the following output parameters:

- Mass balance: percentage of oil evaporated, naturally dispersed, dissolved, emulsified, remaining on the sea surface and stranded on the shoreline over time.
- Probability and distribution of oil mass/volumes at the sea surface and at the shoreline if appropriate.
- Concentration of oil in the water column.
- Drift time to shore, if appropriate, or to areas of particular concern.

It is useful if the model has the capability to reflect predefined threshold limits for oil volumes/concentration that can be reported in the output parameters.

The quality of the output from oil spill models reflects the standard/quality of the model and the quality of the input data. The limitations and resolution of the modelling should be understood, and care should be taken to ensure that a model's results are not used out of the context of the OSRA. It is important to document the quality of input data to provide an understanding of this context and the reliability of output.

Result presentation

The modelled fate and trajectory of the spilled oil may be presented as maps (either static or interactive GIS-based) and tables showing the probability of the distribution of oil both at sea and on shorelines if applicable. Single (deterministic) simulations may be presented in maps with oil movement over time. Figure 5 provides examples of modelling outputs as maps. The results presented should provide relevant information on environmental exposure that can be directly utilized for the consequence analyses. This may be surface and shoreline volumes of oil, water-column concentrations, and/or time to reach the shoreline, etc.

Clear explanation and labelling of maps, particularly maps of stochastic results, are required to avoid misinterpretation which can lead to misconceptions among stakeholders and the wider community. Juxtaposing results from deterministic modelling runs can help to avoid confusion, as shown in Figure 5.

Reporting should be on a monthly, seasonal/quarterly or yearly basis as relevant. In addition to statistical parameters, visualization of actual trajectory and fate simulations (spread of oil and mass balance over time) is useful for risk communication.

Figure 5 Example of oil spill model output

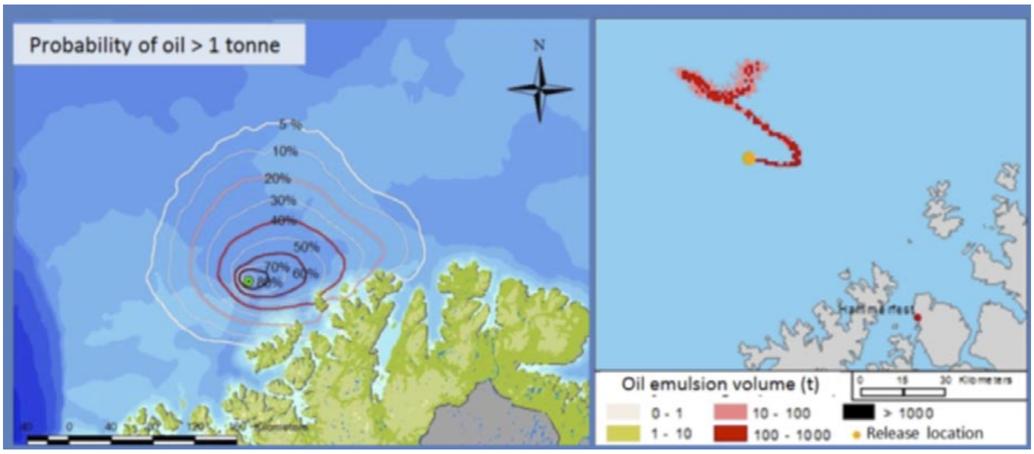


Figure 5 illustrates the results of a single deterministic simulation and a wind and current pattern: the left panel shows the stochastically-modelled influence area (probability of more than 1 tonne of oil in a 10 x 10 km grid cell) from subsea blowout; while the right panel shows the location and volume of emulsion at the sea surface five days into a blowout.

Characterization of ecological and socio-economic resources

Objective

The objective of environmental characterization is to determine the spatial and temporal distribution of relevant ecological and socio-economic resources (i.e. environmental receptors) and their sensitivity, within the influence area from the potential oil spills. These environmental receptors are typically categorized into three types:

- **Biological features:** living resources and their habitats including marine life, birds and mammals, which may include endangered or protected species.
- **Shoreline type:** generally described in terms of their substrate, sediment size and wave exposure.
- **Sensitive socio-economic features:** these represent human use resources and can include fisheries (subsistence, artisanal and commercial fishing/harvesting, and fishing villages), aquaculture, and tourism/recreation areas and activity.

Mapping of environmental receptors

Mapping of ecological and socio-economic resources allows the identification of those which may be exposed to oil. Mapping should be performed within the influence area of the potential spills (see *Oceanographic and meteorological data* (page 22) for recommendations on how to define influence area). The IPIECA/IMO/OGP good practice guidance on *Sensitivity mapping for oil spill response*[9] provides examples of mapping both ecological and socio-economic resources. Environmental impact assessments and monitoring data can provide valuable input to the mapping of resources. Operators within the same area are encouraged to share information on ecological and socio-economic resources to secure efficient mapping and consistent input.

The identification and mapping of ecological and socio-economic resources should include spatial and temporal distribution and sensitivity of these resources at a relevant scale (see *Evaluating the sensitivity of environmental receptors* (below) for a discussion of sensitivity). The temporal resolution (e.g. by month, season/quarters or year) of the mapping depends on the distribution, abundance and sensitivity of the environmental resources to oil throughout the year. Some resources are more sensitive at specific times of the year or at a specific life stage, for example when a population is clustered due to mating, or during the egg and larva life stage of fish or freshly hatched sea turtles. The sensitivity of such resources will therefore vary, with some resources having large monthly variations while others have seasonal variations. Other resources will have the same sensitivity throughout the year. Temporal factors associated with socio-economic resources such as commercial and recreational fishing or tourism should also be identified. The final objective is to capture significant temporal or spatial variations in the consequence values as inputs into the risk assessment and oil spill response planning.

[9] IPIECA/IMO/OGP, 2011. *Sensitivity mapping for oil spill response*. www.ipieca.org/publication/sensitivity-mapping-oil-spill-response-0

The distribution of environmental receptors should also be described/mapped for open sea, and not only for the coastline. Sea mammals, seabirds, fish/shellfish, deep water corals or other similar habitats are all important ecological and/or socio-economic resources that are found in or at open sea.

In some areas, information about the distribution and abundance of ecological and socio-economic resources may be scarce. In most cases it is still possible to gather sufficient information to perform an OSRA. However, this increases the uncertainty of the results of the assessment, and a conservative approach should therefore be taken when assessing sensitivity.

Evaluating the sensitivity of environmental receptors

In principle, the evaluation and ranking of the sensitivity of environmental receptors aims to address their ability to tolerate and recover from acute exposure to oil during a spill. There are three main elements to consider when ranking the sensitivity of the environment to oil:

1. Sensitivity of biological features

This is a species-specific sensitivity that is a combination of individual sensitivity to oil pollution (e.g. toxicity, smothering effects, behavioural pattern that affects the likelihood to be exposed to the oil pollution) and the population's sensitivity to disturbance. It includes the resilience to oil pollution and the ability to recover after oil pollution.

2. Shoreline sensitivity

This describes a shoreline's holding capacity for oil, and how effectively it is cleaned by natural mechanisms. The IPIECA/IMO/OGP guideline *Sensitivity mapping for oil spill response* gives a good description and ranking of substrate sensitivity. As an example, oil persistence on exposed, high-energy rocky shorelines will be substantially less than on a protected mud flat or marsh/wetland.

3. Socio-economic sensitivity

Socio-economic sensitivity is derived from the economic importance of the resource and the likelihood that oil pollution will have an impact on the socio-economic activity in the event of a spill. Economic sensitivity may be viewed in a wide perspective and includes subsistence utilization of resources for local food without realizing the monetary value of the resource.

The above three elements should all be taken into consideration when ranking the sensitivity of the environment in the influence area.

Based on the sensitivity evaluation and ranking, the impact indicators can be defined. This means that a limited number of ecological and socio-economic receptors are selected among the most sensitive receptors in the influence area, and used to categorize or quantify the consequences. Impact indicators should be selected from both ecological and socio-economic resources.

Assessing environmental consequences

The risk evaluation requires direct input on potential oil spill consequences; it is therefore necessary to assess the potential consequences for the selected sensitive ecological and socio-economic resources (impact indicators) under threat of oiling. Assessment of the potential consequences may be qualitative or quantitative, depending on the availability of information.

Assessment of environmental consequences should, as a minimum, be based on the sensitivity of the resource and the potential exposure to oil pollution. To make a good assessment of potential consequences from various oil spill scenarios, relevant and valid relations between the extent of the oil exposure and the environmental impact should be established for the impact indicators.

A qualitative consequences assessment can be expressed as a relative ranking of consequences; for example as a relation between the Environmental Sensitivity Index (ESI) and the estimated oil amount or oil concentration that pollutes the area. A more detailed assessment of consequences can be performed based on established relations between oil exposure volumes or concentrations and the impact on sensitive receptors such as shoreline habitat, seabird populations, sea turtle populations or fisheries. Such quantitative relations can be expressed as a relation between the extent of oil exposure (volume/concentration), the effects of the oil in terms of ecological damage or economic loss, and the potential duration of the environmental impact.

Section 6: Establishing and evaluating the risk

Objective

Risk is established by combining the likelihood value and the potential consequence of each scenario. Once the risk has been established, the primary objectives are to evaluate and communicate the risk of an activity or scenario to stakeholders and decision makers in a logical and understandable way such that 1) the risk level can be evaluated against risk tolerance criteria (RTC), and 2) properly informed decisions (e.g. using the ALARP principle) can be made regarding the implementation of risk reducing measures to achieve a tolerable risk level.

Presenting the risk

The establishment of risk brings together the information from the previous stages. A clear and balanced picture of the risk exposure should be presented by giving the likelihood for different consequences or consequence categories resulting from the oil spill scenarios and activities. If the consequences are expressed in categories in the quantitative analysis, the risk should also be expressed as the cumulative likelihood for all consequence categories.

The overall risk level and the main factors contributing to the risk should be identified and presented. The overall risk level incorporates the risk from many activities and operations and their relevant oil spill scenarios.

The risk may be presented for different environmental compartments (e.g. sea surface, water column, shoreline etc.) and for the various socio-economic resources or activities. The main focus should be on the impact indicator(s) with the highest risk level.

A presentation of the sensitivity in the results with respect to variations in the input data is recommended. This will provide information on whether changes in the input data will have strong, moderate or limited influence on the results of the assessment. If the sensitivity of the assessment is high for certain input data, the precision and quality of these data need to be carefully addressed in the assessment.

Figure 6 presents an example of a risk matrix which may be a suitable expression of risk for early project phases where limited information is available, and for assessment of single operations, tasks or scenarios. More complex methods may be used which will provide additional information concerning the risk; examples are given in Appendix 2.

A clear description should be given of the methodology, models and/or tools used in the risk assessment, including a justification of their use. Results, premises and assumptions should be documented in a manner which enables easy use as input to the response planning. A focus on areas with the greatest risk-reducing potential, and on those with high-risk activities, should be part of the documentation.

Figure 6 Example of a risk matrix

	Consequence				
Likelihood (per year)	Insignificant impact	Small impact	Moderate impact	Large impact	Very large impact
≥ 10^{-1}					Very high risk
≥ 10^{-2}					
≥ 10^{-3}					
≥ 10^{-4}					
< 10^{-5}	Very low risk				

Risk tolerance criteria

The risk presented by the oil spill scenarios should be evaluated against risk tolerance criteria (RTC) or other environmental decision criteria/goals. Depending on the outcome of the risk level evaluations, it may be necessary to take measures to reduce the risk.

Risk tolerance criteria define the threshold for a tolerable likelihood of an environmental impact. The tolerable threshold varies with the severity of the environmental impact, where higher likelihood is tolerable (acceptable) for less severe impacts.

Different types of RTC may be appropriate depending on the purpose and level of detail of the analysis, for example:

- quantitative environmental RTC for quantitative studies;
- risk comparison criteria.

Quantitative RTC can be defined for various operations, such as drilling operations and the operation of installations and/or fields. More than one type of RTC, per operation, can be established to cover several analytical endpoints, for example the analytical endpoints could be the recovery time of ecological resources or loss of economic income for socio-economic resources. RTC should include frequencies of spills to the environment and a measure of potential consequences.

Risk reducing measures

Identification of possible risk reducing measures should be performed as a part of the risk assessment process, as well as throughout the preceding steps. The risk assessment should seek to identify measures that:

- reduce the possibility of accidental events occurring, i.e. preventive measures (e.g. more reliable BOP, corrosion protection on pipeline, additional barriers);
- reduce the potential size of spills from actual events, i.e. response/source control measures (e.g. subsea isolation valves, well capping and containment solutions); and
- reduce the consequences if accidental events should occur, i.e. mitigating measures (e.g. oil spill preparedness, plan for high-risk activities during seasons or yearly quarters with lower consequence potential).

Measures representing good practice should, as a minimum, be identified and implemented. The effect of the identified risk reducing measures should be evaluated. Depending on the residual risk level, additional risk reducing measures may be necessary. The ALARP principle may be used for evaluating those additional measures.

The ALARP principle

Use of the ALARP ('as low as reasonably practicable') principle is recommended for all activities/risks included in the oil spill risk assessment (see Figure 7, overleaf). The principle is that risks not meeting tolerability criteria shall be subject to risk reduction regardless of cost, and that the residual risk is tolerable provided that it is as low as reasonably practicable. This can be demonstrated through a process called ALARP demonstration.

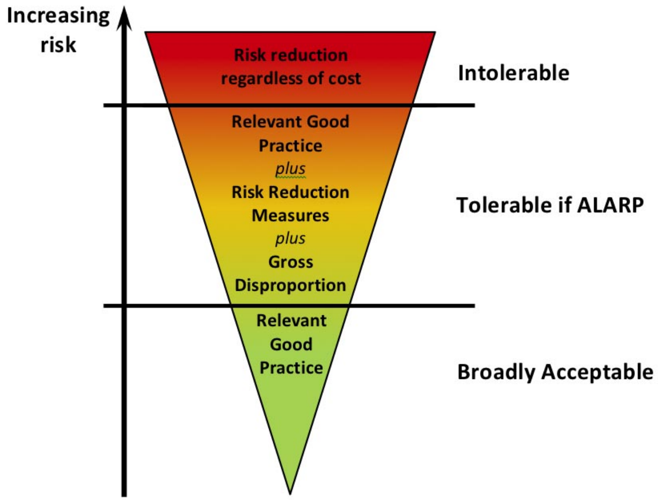
The zone between the 'intolerable' and 'broadly acceptable' regions in Figure 7 is the 'tolerable if ALARP' region. Risks in that region may be considered tolerable provided that:

- the nature and level of the risks are properly assessed and the results used properly to determine risk reducing measures;
- the residual risks are not disproportionately high, and are kept as low as reasonably practicable; and
- the risks are periodically reviewed to ensure that they continue to meet the ALARP criteria.

Evaluating whether the residual risk is tolerable or not calls for an ALARP demonstration. The tools used to demonstrate ALARP and the extent of the demonstration should be proportionate to the level of risk.

ALARP demonstration should be carried out with a 'reversed onus of proof' mindset, i.e. it is not necessary to 'prove' the merit of a proposed risk reduction measure, but rather to 'prove' why it is justifiable *not* to implement a proposed measure.

Figure 7 Illustration of the ALARP principle



The following questions should be answered as part of the ALARP demonstration:

- What more can be done to reduce the risks?
  Risks should be reviewed and a list of measures which could be implemented to reduce those risks should be drawn up, in a proportionate way. Identification of additional risk reducing measures is considered feasible in most cases.
- Are the associated costs significantly disproportionate to the risk reduction achieved?
  The answer to this question may be qualitative or quantitative depending on the predicted level of risk prior to the implementation of additional measures. If it cannot be shown that the cost of the measure is grossly disproportionate to the benefit to be gained, then the measure should be implemented.

Input to oil spill response planning

For the purposes of oil spill response planning and determining oil spill response capability, the results from the OSRA will provide important input related to the likelihood of different spill scenarios, the ecological and socio-economic consequences of the scenarios, and the likelihood of exposure and oil volumes in geographical areas. As discussed in Part 2 of this document, such information supports the strategic selection of key scenarios for further analysis in response planning, including NEBA, establishing response strategies and assessing resource needs across all response tiers.

General recommendations

During the selection of oil spill scenarios (see page 16) consideration is given to ensure that all three response tiers are covered. Typically this may involve one or two scenarios commensurate with each of the three tiers. As a minimum, the oil spill scenarios representing the highest risk to the environment should be included in the oil spill response planning.

If the risk level of the activity is high, more detailed oil spill response planning is warranted. The oil spill risk assessment will normally identify ecological or socio-economical resources/areas of higher risk for which further oil spill response planning may be appropriate. These resources/areas of higher risk may differ between seasons due to changes in wind and currents, or changes in the presence or sensitivity of the resources.

The OSRA can also provide useful input to NEBA (see Appendix 3) when choosing appropriate strategies as part of the oil spill response planning.

Tier 3 planning

Although hazardous events resulting in releases of large quantities of oil (e.g. thousands of tonnes per day) over extended periods (>weeks) are extremely rare, their potential consequences may be severe. Such events may not present the highest risk due to their very low likelihood but they should be considered in the response planning process. This is typically described as the worst credible case discharge (WCCD).

The WCCD case scenario sets the upper limit for a sustained Tier 3 response (see Section 10, *Tiered preparedness and response resources*). This scenario can be interpreted as the largest release that could reasonably be expected from a facility or operation. If no national/regional requirements provide definitions of the WCCD it is recommended that the WCCD is defined based on the worst credible consequence scenarios.

For offshore installations, the WCCD would most often stem from loss of well control (i.e. a blowout). However, depending on the well characteristics and other operational factors, the WCCD could originate from other hazardous events, for example a spill from an FPSO for an operation where the well characteristics (e.g. very low pressure) mean that uncontrolled well flows would be minimal. Assessment of the credibility of worst case discharges should be based on the likelihood for a large spill volume event to occur.

It is also important to consider the expected duration of an oil spill when identifying the WCCD. A WCCD resulting from loss of well control should correspond to a credible maximum time to regain well control (kill the well or a well bridge over). This has traditionally been viewed as being equal to the time to mobilize a rig, drill a relief well and successfully kill the well. However, the development of international subsea capping and containment capability drives industry towards a reconsideration of the requirements for establishing the credible longest spill duration as well as intervention handling. In this case, the time to cap a well would be equal to the time to mobilize the capping equipment, install it at the well, and successfully cap the well and contain the well flow. Containment complements capping capability, and is designed to support incident response in rare scenarios where well shut-in is not initially possible. A containment system brings leaking oil from a subsea wellhead to the surface in a safe and controlled way, ready for storage and disposal. Debris removal, BOP intervention and subsea dispersant hardware underpins the capping and containment capability.

The discharge flow rate from the WCCD is a primary factor that will define the capacity of the Tier 3 oil spill response. The discharge duration may cause additional challenges, for example the endurance capacity of the response operation and associated logistics in coping with a long-duration spill response.

Additionally, consideration should be given to the characteristics of the spill scenarios when identifying the WCCD. For example, a subsea spill versus a topside spill may present different challenges to the response operations, and the ecological and socio-economic consequences may also differ between these release points. In the case of significant differences in subsea and topside spill characteristics, both scenarios should be considered in the oil spill response planning process.

Similarly, a significant pipeline spill can present response challenges including single or multiple release points, proximity to environmental receptors and timely mobilization of spill response resources.

Sufficient information related to all of the above considerations for WCCD should be available throughout the OSRA, to support the Tier 3 oil spill response planning.

Tier 1 and 2 planning

The results from the modelling of smaller-scale discharges with potentially higher likelihood can be useful in refining the detail of Tier 1 and Tier 2 planning. Local or regional high risk areas are identified in the OSRA. The distance to the shoreline or other sensitive ecological or socio-economic resources is also mapped in the OSRA. The oil spill trajectory and fate modelling will normally provide input on drift time to shore for the oil in different seasons or yearly quarters. This information provides input to determine response times for oil spill combatting systems and personnel. The model results will also give valuable mass balance estimations, as oil volumes and oil-water emulsion volumes, for informing the selection of the most appropriate response strategies and protecting environmentally sensitive areas.

Section 7: Communication and consultation

The objective of communication and consultation is to involve relevant stakeholders, whether internal or external, as a measure to improve the quality of the OSRA process and its suitability for its intended purpose(s), at the right time or with the appropriate level of involvement throughout the entire process. There should be an emphasis on early interaction to maximize understanding of key stakeholder issues and minimize potential project delays. Communication and consultation ensure that those potentially affected by the hazardous events and those responsible for managing the risks understand the scope used as a basis for the calculation and evaluation of the results, the establishment of the risk, and the reasoning leading to risk management decisions.

Internal and/or external communication and consultation should be performed during the OSRA process. The type of communication used, and the content delivered, should be adapted to the target audience. For larger and more complex projects, a plan should be developed at an early stage in the process to communicate and consult with internal and external stakeholders.

This plan should address communication and consultation relating but not limited to:
- establishment of the context for the risk assessment;
- execution of the assessment;
- how the assessment and its results should be communicated to various stakeholders; and
- involvement of personnel with operational knowledge (e.g. exploration/production and oil spill response personnel).

Resources and responsibilities related to communication and consultation should be identified and included in the plan. The plan should describe the schedule and the manner for the communication to be performed (i.e. written and/or oral communication). It is important that those performing the assessment communicate clearly with those responsible for technical and operational solutions so that all parties are made aware of the assumptions and presuppositions used in the assessment.

A mechanism to capture and review feedback from communications with stakeholders should be established, including identification of those persons responsible for results and outcomes.

Section 8: Monitoring, review and updating the OSRA

Objective

The main objective of monitoring, review and updating the OSRA is to ensure that the risk assessment remains relevant as the project evolves. This is applicable to fields or facilities in operation over many years, and also to field development projects.

The following activities are recommended:
- Monitor the established context with respect to its validity.
- Update the context throughout the process, if and when required.
- Ensure that the risk assessment process and its various elements are carried out based on an updated context, if and when the context has been modified.

Monitoring and review of the OSRA

Monitoring and review should include analysing and capturing lessons learned from events, changes and trends, detecting deviations from assumptions and premises of the risk assessment, and/or detecting changes in the external and internal context, including changes to the risk itself. This should include a review of the underlying data used in the OSRA to ensure that it remains current, relevant and accurate.

Monitoring and review activities should be pre-planned and can involve regular checking or surveillance of what is already present, or ad hoc reviews based on new information. Responsibilities should be clearly established, and the results of such activities should be recorded and reported, internally or externally as appropriate. Personnel should be familiar with the oil spill risk assessment.

The monitoring and review activities should be followed up, and a plan should be prepared, containing an assessment of the conclusions and recommendations, as well as plans for implementation of potential risk reducing measures, including oil spill preparedness.

The need for updates

If the basis for the OSRA (e.g. its methods, models, input data, assumptions, limitations, etc.) has changed, the OSRA needs to be validated. For as long as the risk assessment may be relied upon (e.g. to be used for future decision making), any deviation from the basis for the assessment should be assessed with respect to its effects on the risk and/or validity of the assessment and its results. Examples of deviations include: changes in the project design or modification of existing facilities (e.g. drilling of new wells that are significantly different from wells already included in the risk assessment), or changes in data used as a basis for the risk assessment (e.g. new failure frequencies, updated data on distribution and abundance of environmental resources etc.).

The decision to update the OSRA, or to perform a new, one should take into consideration:

- the current project phase;
- the period for future use of the current risk assessment;
- changes to, or availability of, new information, e.g. probability or environmental data used in the OSRA;
- the type of decisions that the assessment is intended to support in the future; and
- the extent of work and time required to perform a new assessment versus the need for decision support at a given time.

When updating an assessment, the complete basis for the assessment should be reviewed. This review should be documented. Personnel resources in charge of this review should be familiar with the OSRA methodology involved, and the basis for the assessment.

Part 2

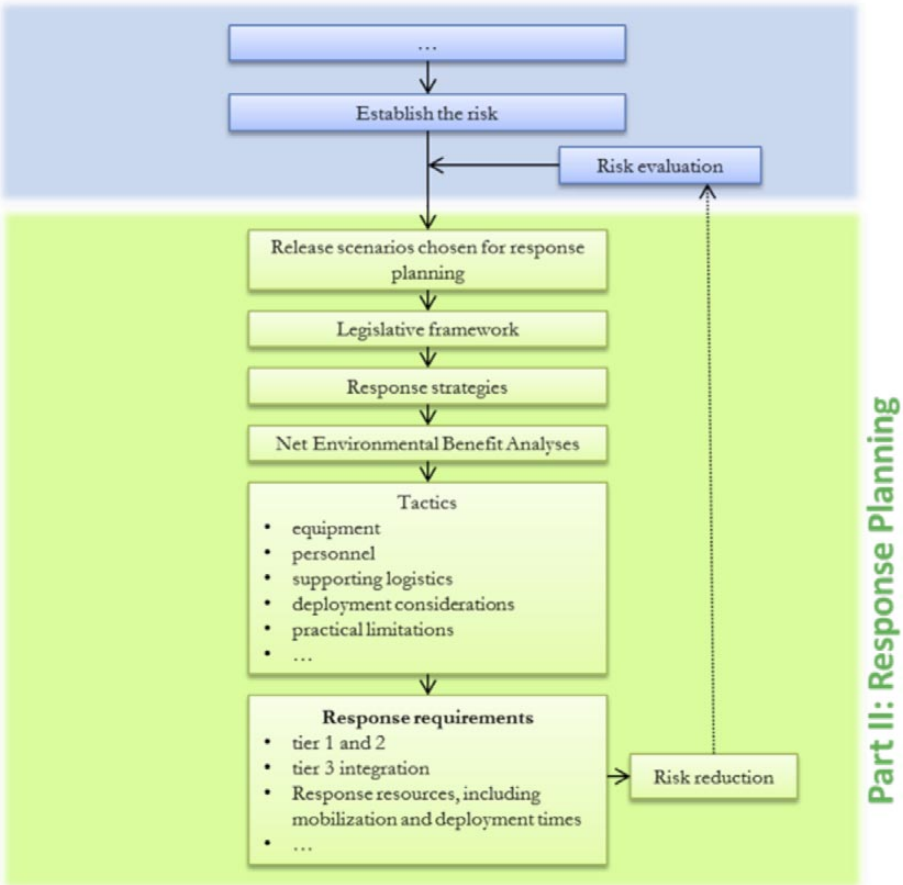
Oil spill response planning

Section 9: Response planning

Response planning considers, in tactical and logistical detail, the preferred and viable response strategies proposed to address the oil spill scenarios identified in the OSRA. It should be used as the basis for the determination of appropriate oil spill response resources at each tier (see Section 10, *Tiered preparedness and response resources*) and thereby demonstrate that preparedness is commensurate and balanced with the risk posed by an offshore installation. The response planning process is shown in Figure 8 and addresses the following questions:

- What oil spill scenarios are identified in the OSRA?
- Do all the scenarios warrant detailed analyses for the determination of oil spill response resources at each response tier?
- What are the viable strategies for delivering a response with the greatest net environment benefit, for the scenarios subjected to detailed analyses?
- What are the tactical measures required to implement the identified response strategies, considering technical, practical and safety factors?
- What tiered resources are required to mount the tactical measures and achieve an effective and realistic response?

Figure 8 The response planning process



Scenario response planning team

A dedicated team should undertake the response planning process. This response planning team should include a person (or persons) with knowledge and experience of:

- the technical and operational scope of the offshore installation;
- the risk assessment undertaken for the offshore installation, including the ecological and socio-economic setting;
- oil spill contingency planning, including the capability and limitations of response options and equipment, procedures for mobilization, cascade and integration of tiered response, and the incident management systems used by the operator and any relevant authorities;
- logistical and support capacity covering the geographic area which may be threatened by oil spills;
- legislative frameworks applicable to oil spill contingency planning; and
- stakeholder/public factors that may affect response options.

Choosing the scenarios to be analysed

The OSRA should identify the scenarios which require analyses (see also the subsections on *Selection of oil spill scenarios* (page 16) and *Input to oil spill response planning* (page 31)). Relatively few scenarios may warrant detailed analyses to determine the extent of required response resources at each of the three tiers; typically one or two scenarios from each tier will be sufficient. In some cases, it may be adequate to consider a single scenario covering the WCCD, as this will involve the escalation of a response through all three tiers.

The response planning team is responsible for ensuring that the scenario(s) identified by the OSRA covers the potential range of realistic oil spill challenges posed by the offshore installation throughout the period of operation, up to the WCCD. Any deviations from the scenarios used for response planning compared to those identified by the OSRA should be explained and documented.

An oil spill incident is unlikely to follow a planning scenario precisely. However, the tiered response approach, strategic options and resource escalation processes can be applied to any incident. The response planning should be realistic and thorough enough to determine, demonstrate and verify that overall oil spill preparedness is commensurate with the risk. The detailed analyses of chosen scenarios described in the following section are designed to achieve this requirement.

Analysis of scenarios

The chosen scenario(s) should be analysed by the response planning team through detailed consideration of anticipated response actions, incorporating the following elements:

- The normal operational, including monitoring and shutdown, characteristics and supporting documentation; in addition, any monitoring and assessments characterizing operational integrity, such as a corrosion monitoring programme, should be incorporated.
- The predicted trajectory and fate of oil spills as modelled in the OSRA; these may be presented as maps and tables showing the probability of the distribution of oil both at sea and on shorelines, if applicable, with associated contours of oil movement over time.
- Information concerning the distribution and sensitivity of ecological and socio-economic resources, focused on those which have special value and high vulnerability, as identified in the OSRA.
- A statement of the overall response objectives.
- The legislative frameworks, which may dictate, preclude or prefer certain response strategies.
- Stakeholder/public factors, which may dictate, preclude or prefer certain response strategies.
- The response strategies proposed; it is recommended that all viable response options are considered, within the legislative/stakeholder context.
- Inclusion of the NEBA principle in the process of choosing the response strategy (see Appendix 3 for further discussion concerning the application of NEBA).
- A capability assessment, including response resources such as teams, personnel and resources, incorporating differing environmental conditions which may be encountered and their potential to limit the performance of the response strategies.
- The proposed tactical plan for the chosen strategies in open sea and in nearshore and shoreline zones; the plan should include the equipment, personnel and logistics required for implementation.
- In scenarios with ongoing oil discharges over an extended period, the need for sustained oil spill response activities should be considered, including the availability of personnel and procurement of supplies and consumables.

The response planning should be documented to demonstrate that thorough consideration has been given to the oil spill scenarios. Table 1 provides guidance on the information typically included in the documentation.

Table 1 Elements typically documented during response planning

Scenario element	Notes
Response objectives	Several response objectives can be identified for most oil spills but the two that are generally universal include: • protecting the health and safety of responders and the public (the first priority with all response actions); and • minimizing damage to ecological and socio-economic resources, and reducing the time for resource recovery. Oil spill response actions can be effective, however it is generally unrealistic to indicate that avoidance of all impacts is an achievable objective in the event of a major oil spill. The aim of oil spill response actions is therefore to minimize ecological and socio-economic damages in a NEBA context. This is important in relation to (a) stakeholder/public expectations, (b) setting response objectives during an incident and (c) developing realistic measures for an effective response. A specific scenario will allow overarching aims to be refined into more specific objectives. These may include consideration of the value and priority placed on protecting particular ecological and socio-economic resources under threat, and whether an area contains particularly vulnerable habitats (e.g. coastal wetlands or sites used by endangered species) or critical socio-economic features (e.g. major seawater intakes or high value tourism locations).
Response strategies	In principle the full range of response options should be considered; see Appendix 4 for further information. The legislative framework, national response policy and/or stakeholder needs may either dictate or influence which options are allowed or preferred. However, if response options, such as dispersants, are not considered or if their use is postponed in favour of other options, the overall effectiveness of the response may be greatly reduced and lead to higher impacts. Different strategic options may be proposed at the three tiers; this may stem from the determination of response objectives (see above). It is also feasible to consider using multiple strategies simultaneously during an incident, although they may be deployed in different operating environments and/or discrete geographic zones.
Choosing strategies to minimize damage (i.e. NEBA)	The principle of NEBA should be integral to strategic decision making with respect to selecting the most applicable response strategies for each scenario to achieve the identified objectives. NEBA provides a tool to ensure that strategies are chosen to minimize the potential ecological and socio-economic damages associated with each scenario. The OSRA should provide adequate ecological and socio-economic data to enable the analyses to be undertaken.
Tactical plan	The tactical plan details how the chosen strategies will be implemented and usually forms the most substantial part of the action planning process. It addresses, but is not limited to, the following: • The proposed location of equipment deployments relative to the spill source and the associated operating environment(s) for the three tiers, such as open waters close to the source, open waters beyond the vicinity of the source, and nearshore sheltered waters and shorelines. • The likely effectiveness and limitations of tactical deployments. • Recommended or required response times for deployments (e.g. can protection booms be deployed around a sensitive area prior to oil contact?). *continued …*

Table 1 Elements typically documented during response planning (continued)

<table>
<tr><th>Scenario element</th><th>Notes</th></tr>
<tr><td>Tactical plan (continued)</td><td>

Deployment considerations, including safety and recommended configurations for equipment.
The quantities of equipment and personnel needed to implement the tactical plan.

The use of the potential spill volume as the only means to define the scale and extent of tactical deployments is not recommended:

The planning should incorporate consideration of spill volume but also take into account other fundamental factors having a significant influence on the amount, suitability and capability of resources needed for response to a specific operation such as oil type, prevailing climate and weather, proximity and type of ecological and socio-economic resources at risk, safety factors and mobilization of available infrastructure to support a response.
Potential spill volumes can provide useful guidance on certain aspects of oil spill response resources such as the volumes of dispersants to be held in stockpiles or potential volumes of waste which may be generated. However, the use of formulaic or mathematical models, solely based on spill volume, to calculate equipment requirements will most likely result in inappropriate and unsuitable resources being established.

Substantial oil spill response resources are available from the oil industry's global stockpiles and commercial service providers, and through regional and international agreements. Planning for Tier 3 incidents should take these into account and focus on ensuring the procedural and logistical means to access, mobilize and integrate suitable resources into the theatre of operations. The availability of Tier 3 resources for a WCCD scenario can assist the determination of the upper threshold for Tier 2 resources, although other scenarios may also be used to refine the Tier 2 resources.
Any innovative developments or specialized features that may improve either the efficiency or effectiveness of tactical deployments should be documented.
</td></tr>
<tr><td>Sustaining the response</td><td>For scenarios entailing a prolonged response, possibly extending for periods of months, an outline description of how the response can be sustained should be included. This should incorporate the establishment of a project management approach including data management, such as incident action planning and a Common Operating Picture, and the maintenance of supply lines for ongoing response actions.</td></tr>
</table>

Section 10: Tiered preparedness and response resources

The tiered preparedness and response approach is recommended as the underlying basis for oil spill contingency planning with respect to offshore installations. The planning approach categorizes potential oil spill incidents in terms of their potential severity and the associated scale of required response capabilities. However, in an actual spill the tiered categorizations are less of a consideration as industry will mobilize whatever resources are required to respond effectively along with additional resources as a contingency.

Three tiers are identified during planning, with response resources able to be escalated and cascaded into the theatre of operations in proportion to the requirements of an incident and regardless of the tier designation.

- Tier 1 scenarios are likely to be relatively small and/or affect a localized area. They may be dealt with using local resources, often pre-positioned close by and managed by the operator.
- Tier 2 scenarios are more diverse in their scale and by their nature involve a potentially broad range of impacts and stakeholders. Correspondingly, Tier 2 response resources are also varied in their provision and application, and may come from a number of sources. Examples include: mutual aid agreements between industry operators; industry funded oil spill response cooperatives; specialized Tier 2 services; or cooperation at the local/provincial government level. Management responsibilities are usually shared in a collaborative approach, and a critical feature is the integration of all resources and stakeholders in the response efforts.
- Tier 3 scenarios are rare but have the potential to cause widespread impacts, affecting many people and overwhelming the capabilities of local, regional and even national resources. Tier 3 response resources are concentrated in a small number of locations, held in readiness to be transported to the respective country when needed. Examples of such resources include Tier 3 Response Centres, stockpiles in high risk areas and neighbouring governments' capabilities. Such significant events usually call for the mobilization of substantial resources for which the critical requirements are rapid movement across international borders and the integration of all resources into a well-organized and coordinated response.

Many factors may influence the response resources needed and how the boundaries between tiers are defined in the planning process. Influencing factors will vary between different locations and operations, and their importance may be perceived differently by operators, governmental authorities and other stakeholders. As a result, it is entirely feasible that contrasting tier definitions could be established for different operations in the same locality as well as for the same type of operation in different localities. Table 2 provides examples of factors influencing the response resources at each tier.

The resources identified to meet the needs of the oil spill scenarios may be sourced from a mix of in-house, contracted, mutual aid and other cooperative or support agreements. Resources may also be available from governments, both nationally and internationally. The identified resources should be verifiable and their availability guaranteed to the extent practicable. Incident management systems and logistics for their coordination and integration should be demonstrable. Capability to mobilize and deploy resources under varying relevant conditions should be assessed. The escalation and cascading of resources from the different tier staging areas should be able to provide a realistic response in the context of the risks posed by the operation.

Table 2 Examples of factors influencing tiered response resources

Type	Influencing factors	Comments
Operational	• Likelihood of oil spills • Spill volumes • Oil types • Ability to mount a safe and effective response	For offshore installations, the potential location of incidents, oil types and volumes can usually be determined with reasonable accuracy, particularly during the production phase. See Part 1—the OSRA process.
Setting	• Season, climate, weather or operating conditions altering the fate and behaviour of oil or impeding response operations • Proximity to: - ecological resources; - socio-economic resources; - people/populations; and - availability and mobilization of response resources. • Accessibility and the capacity of infrastructure to receive external assistance	The prevailing conditions that determine the behaviour/fate of oil, together with the type of ecological and socio-economic sensitivities potentially at risk, will strongly influence the local and regional response resources. In remote geographic areas where potentially high consequences could arise, the response requirements at Tier 1 or Tier 2 levels could be significantly greater than for a similar operation in more accessible areas.
Legislative	• Political stability and culture of host country • Governmental requirements for specific response actions or performance criteria • Influence of national, provincial or local government authorities • Stipulated subscription to designated Tier 2 or Tier 3 support	Legislative and regulatory controls may dictate Tier 1 capabilities and also influence or mandate Tier 2 and Tier 3 arrangements. In some cases these requirements may not match the risk-based approach underlying tiered preparedness and response. It is recommended that, as a minimum, an operator ensures that the resources are commensurate with the risks, whilst also complying with required regulations.
Public/ stakeholder needs	• Value judgements and conflicts • Income source • Subsistence/dependency • Population density	Public and stakeholder needs, judgement, values and perceptions may vary considerably from group to group and will often be conflicting. It is recommended that, as a minimum, an operator ensures that all stakeholder views are incorporated within the OSRA.

Tiered preparedness and response is a structured approach, widely utilized by the oil and shipping industries and proven in its effectiveness. It is consistent with OPRC 1990, in which Article 6(2) states:

> *In addition, each Party, within its capabilities either individually or through bilateral or multilateral co-operation and, as appropriate, in co-operation with the oil and shipping industries, port authorities and other relevant entities, shall establish… (a) a minimum level of pre-positioned oil spill combatting equipment, commensurate with the risk involved, and programmes for its use; … and (d) a mechanism or arrangement to co-ordinate the response to an oil pollution incident with, if appropriate, the capabilities to mobilize the necessary resources.*

It is recommended that, during an incident, a proactive approach to the escalation of a response is adopted. This means that escalation of additional support from Tier 2 and 3 resources, through notification, alert and mobilization procedures, should take place as soon as the scale of the incident suggests a potential need for that support. This may include precautionary escalation on the basis of threat, noting that it is generally easier to stand down activated or alerted resources if they are not required than to undertake a reactive mobilization at very short notice.

Source: Wikimedia Commons/USCG

In response to the Deepwater Horizon *oil spill (2010), a crew member aboard the* USCGC Oak *lowers a skimmer into the apex of a boom during oil skimming operations in the Gulf of Mexico.*

Section 11: Determination of oil spill response resources

The output from the response planning for the chosen scenarios is a set of strategic, tactical and logistical requirements which the tiered response resources will need to fulfil. The determination of these resources should encompass the type, quantity, location and mobilization times of equipment and the organizational framework for effective incident management, including trained personnel and procedures for the integration of different organizations into the overall response effort.

Equipment, personnel and logistics

Consolidation of output from the detailed tactical planning process provides information concerning the overall equipment, logistics and personnel resources required to implement the identified tactics. The response planning team should evaluate the resources currently available to the operation at each tier, including the times for their mobilization and deployment within the theatre of response operations. Reduction in capability due to potential prevailing seasonal and climatic conditions should also be considered. This enables gap analyses to be carried out to identify whether the existing resources and their associated logistics are adequate, or whether they require alterations or expansion, as illustrated in Figure 9.

The potential actions arising from the resource gap analyses can include:

- verification that existing resources, including mobilization times, are adequate;
- procurement of additional resources at Tier 1 or Tier 2;
- repositioning of existing Tier 1 or Tier 2 resources to improve response times;
- taking up membership with existing Tier 2 facilities or developing new Tier 2 facilities;
- ensuring access to a Tier 3 cooperative through membership;
- improving the facilitation and integration of Tier 3;
- identification of additional logistical capacity (aircraft, vessels and trucks), including the potential need to procure, contract or retain services;
- minimizing the impact of barriers to the cascading of resources in from other countries or regions;
- developing waste management plans;
- expanding the incident management team/organization; and
- refining training and exercise programmes.

The specific methodology used by the response planning team to determine response resources at each tier should be transparent and documented, taking into account the above factors. An example of the process is provided in Appendix 5.

Figure 9 Identifying the need for additional response resources

Incident management

Comprehensive and coordinated incident management is fundamental to providing an effective response. Similar to the resource discussion above, procedures to establish an incident management organization utilizing a tiered concept should be included in oil spill contingency plans. The following key elements should be addressed:

- Incident management organization and coordination within the company responsible for the incident for each tier.
- Integration with the various governmental or private organizations likely to be involved for each tier in either overseeing or supporting the response.
- Roles and responsibilities of involved parties and individuals.
- Strategic and tactical decision making processes, including a defined cyclical set of procedures to collect, assess and plan response activities (the 'planning cycle').
- Expansion of the incident management team commensurate with tiered response.
- Communication procedures within the management team and with regard to external stakeholders.
- Tools to provide an Incident Action Plan and a Common Operating Picture of an incident's status and response activities.
- Documentation and log-keeping procedures to record actions taken and support post-incident analyses.

Organizational structure and procedures based on the Incident Command System (ICS) are widely adopted by the international oil industry. The use of ICS-based incident management systems may serve as a reference, as the approach addresses the key elements listed above. Furthermore, an aligned and consistent approach to incident management can facilitate integration of the various organizations supporting the response effort.

It is imperative that personnel who have been allocated roles in the incident management system have received adequate training and exercising. Appendix 3 provides guidance on relevant programmes.

The OPRC Convention Article 6(1) requires that each Party (i.e. signatory governments to the Convention):

> *… shall establish a national system for responding promptly and effectively to oil pollution incidents … (and) the designation of … a national contingency plan for preparedness and response which includes the organizational relationship of the various bodies involved, whether public or private …'*

Where Parties to the OPRC Convention have implemented this requirement, the country's national plan should stipulate an overall framework for incident management. Specific guidance for offshore operators may be established in these cases.

In those countries where the OPRC Convention is either not ratified or not fully implemented, it is recommended that clarity on national policy concerning the key incident management elements listed above is sought from relevant authorities. In the absence of such clarity, an offshore operator should ensure that a thorough internal incident management capability is available and maintained. In these countries, it is recommended that offshore operators promote the published IMO guidelines on Incident Management Systems[10] with the relevant authorities. Where scope exists, aligned and coordinated promotion of these guidelines by multiple operators within a country is encouraged, e.g. through a local industry association. Adoption of the IMO guidelines by governmental authorities enables seamless and efficient integration with operators utilizing an ICS-based approach.

Where the authorities utilize an organizational structure at variance with an operator's internal system and procedures, the operator should identify and document this within their oil spill contingency plan. The plan should provide information on the differences between organizations, and should assign a liaison function to facilitate their effective integration.

Cooperation and mutual aid

Oil companies commonly practise cooperative approaches to establishing and sustaining oil spill response resources at Tier 2 and Tier 3. These approaches can bring significant benefits and efficiencies to operations. Offshore operators are encouraged to utilize existing cooperative mechanisms to meet their oil spill resource needs and, where applicable, consider their further development.

For a Tier 3 response, the international oil industry maintains a network of cooperatives providing regional and global reach. Membership of these cooperatives should be considered by offshore operators to guarantee access to the available resources. The geographic location of the operation and output from the response planning will determine which Tier 3 cooperatives can provide the coverage required. In the case that corporate membership of a cooperative exists,

[10] IMO, 2012. *Guidance Document on the Implementation of an Incident Management System.*

Source: ITOPF

Response equipment stored in a warehouse and packaged for immediate transportation.

guaranteed access for an operator may already be available; this should be investigated and confirmed. In all cases the effective utilization of the Tier 2 and/or Tier 3 cooperative or mutual aid arrangements should be incorporated in the response planning, including their logistical and support requirements. Sharing resources across international boundaries can be a major challenge, with customs and immigration procedures creating potential barriers to rapid mobilization. Transboundary issues should be considered and addressed in the Tier 3 response planning.

An operator's Tier 2 response needs may also be fulfilled by a cooperative approach. In considering options, the operator should take into account two key features of Tier 2:

1. Bridging the response gap between Tier 1 and Tier 3: in this context the upper boundary of Tier 2 resource requirements is defined by the ability to make a realistic and credible response while Tier 3 resources are being mobilized and deployed into the theatre of response operations.
2. A role in facilitation of Tier 3 integration, if the scale of the incident requires Tier 3 support: this encompasses the seamless integration of Tier 3 resources into management and operational teams, alongside assistance with logistics for the deployment of Tier 3 providers' equipment (e.g. trucks, secure lay-down, boats, aircraft, etc.).

Practical implementation of shared Tier 2 capability can be achieved in various forms, including:

i. a simple mutual aid agreement, i.e. a mechanism to share the resources maintained by each operator;
ii. formation of an industry (or government) owned and managed cooperative with its own dedicated resources; and
iii. contracted services from commercial providers.

The chosen approach will depend on the local context and may incorporate a mix of the above. In locations with unfettered access to Tier 3 resources, a Tier 2 capability may not be necessary to provide the required resources in a timely manner.

Where offshore exploration activities are scheduled in a new or developing province, specific factors may influence how a cooperative Tier 2 and Tier 3 response is developed. Uncertainties may exist concerning the potential oil spill scenarios, including volumes and oil properties. The OSRA should provide guidance on these uncertainties and it is recommended that response planning is cautious, using worst credible case estimates of volume and oil viscosity/density in fate and trajectory modelling. If Tier 2 cooperation mechanisms either do not exist or are inadequate and there is more than one operator present, it is recommended that these operators jointly consider their Tier 2 risks and work together to investigate options for the establishment of cooperative approaches.

Furthermore, there may be limited or no experience of the province within the oil industry's Tier 3 network. In order to raise awareness of Tier 3 mobilization and integration issues, it is recommended that suitable steps are taken to engage the Tier 3 network. These steps may include:

- utilizing Tier 3 providers to assist with oil spill contingency planning or sharing draft plans for their technical review;
- utilizing or involving Tier 3 providers in training and exercise programmes; and
- Tier 3 providers supplying temporary packages of equipment as part of Tier 1 or Tier 2 provision, such as for a drilling programme.

Section 12: Format and updating of plans

Oil spill contingency plans are essential tools for the effective utilization of the determined response resources. A standardized approach to the format of a contingency plan can assist both industry and governments in their use, review and approval.

In the absence of any national requirements or guidelines concerning the format on an oil spill contingency plan, and in order to facilitate a consistent and aligned approach, it is recommended that IPIECA-OGP guidance[11] is adopted. This guidance is well-established and proven.

It is recommended that plans use clear methods (e.g. electronic bookmarks or physical tabs), referenced to a table of contents, to identify each section of the plan and its content. Each page of the plan should be numbered, including a notation on each page indicating the date of its latest revision and a controlled document number as applicable. Flow charts, maps, graphics and tables should be considered to improve the usability of the plan. Electronic versions of plans should have relevant linkages within the document to facilitate navigation.

A plan should be reviewed and updated at a frequency required by legislation and appropriate to the risk. A designated person responsible for the review process should be identified. Overall review of the content and effectiveness of the plan, including verification of contact lists and associated numbers, should typically be carried out at least annually. Procedures to review the plan's content and effectiveness should also be considered following simulation exercises or actual incidents to ensure that opportunities for improvement and lessons learned are captured.

In the event of major changes to operations, which affect, or could affect, the validity or effectiveness of an oil spill contingency plan, a formal management of change process or review should be undertaken. It is possible that under such circumstances national regulation may require re-submission of the plan for re-approval or verification of amendments. Major changes to operations may include changes to:

- a drilling programme (extent or timing);
- the infrastructure of an offshore installation;
- the oil characteristics or WCCD volume during the life of a well;
- ownership of facilities;
- the availability of oil spill response resources;
- available logistical support; and
- ecological or socio-economic sensitivities.

[11] Refer to the 'good practice guidance' series of publications produced by IPIECA-OGP based on input from the oil industry.

Section 13: Assessment of preparedness

Overall oil spill preparedness for an operation should be assessed in a structured manner. Such assessments can be undertaken as an internal activity by an operator or they may involve a third party. The assessment is triggered by the need to:

- check that a draft plan and its related procedures has addressed the required elements without gaps;
- verify that a finalized plan and its related procedures are fit for purpose, as an assurance step for management and/or prior to formal submission of documentation to a regulatory authority for approval;
- confirm that the preparedness measures and response capacity, including the incident management team, are as stated in the plan; and
- provide periodic review of a plan, possibly aligned with the updating procedures.

An assessment has the potential to identify opportunities for continuous improvement, as well as ensuring that regulatory requirements and good practices are being achieved. When a plan is updated (see the section on *Format and updating of plans*) consideration should be given to undertaking a full or partial preparedness assessment, depending on the scale of the changes to the plan. Assessments should be documented, and a controlled process to address any identified gaps in preparedness should be implemented.

Specific tools[12] to support oil spill preparedness assessments are available. These are suitable for offshore operations and offer comprehensive guidance on the assessment process. They enable a structured review of contingency plans and incorporate guidance on assessing the hierarchy of response strategy, tactics and operations. The assessment should cover the adequacy of incident management for Tier 1, 2 and 3 incidents, verifying procedures and other information stated in the plan, evaluating applicability of response equipment relative to the oil types, local environmental conditions and logistics, etc. Table 3 provides an illustration of the questions which may be asked, in this case to assess two equipment-related response options.

An example of the basic process steps that the oil spill response review team could follow are contained in Appendix 7. The subject review or assessment should complement the integrity assessment requirements of existing operations.

[12] IMO, 2010. *Manual on Oil Spill Risk Evaluation and Assessment of Response Preparedness.* 2010 Edition; and ARPEL, 2012. *Oil Spill Response Planning and Readiness Assessment Manual*.

Table 3 Hierarchy of questions for two equipment-related response elements (from IMO)

	Dispersant use	Protective booming
Strategy	• Is there a clear national dispersant policy? • Is there a list of licenced dispersant products?	• Have coastlines been mapped for sensitive areas? • Has oil spill trajectory modelling been used to identify coasts at risk?
Tactics	• Are effective mechanisms in place for approving use during an incident? • Are pre-approval mechanisms in place?	• Are protection priorities agreed? • Are stockpile locations agreed?
Operations	• Are there suitable stockpiles of dispersant (size and location) and application methods (type and number of units)? • Are personnel trained in the safe and appropriate application of dispersants? • Have procedures for dispersant use been properly followed?	• Have tactical response plans including the use of booming, equipment and logistical plans been developed? • Is suitable booming equipment available? • Are personnel trained in the safe and appropriate deployment of equipment? • Are supporting logistics available? • Are booming plans verified through deployment exercises?

Appendix 1

Definitions and abbreviations

This document broadly adopts terms and definitions used in ISO Standard 17776 in relation to risk assessment terminology. In addition, terms from ISO 73:2009[13] have been used. This Appendix defines the usage of the terms in this guidance.

[13] ISO, 2009. *ISO Guide 73:2009—Risk management—Vocabulary*

Definitions

As low as reasonably practicable (ALARP): ALARP expresses that the risk shall be reduced to a level that is as low as reasonably practicable.
- ALARP requires that the risk is reduced (through a documented and systematic process) to an extent that implementation of additional risk reducing measures cannot be justified.
- The term reasonably practicable implies that risk reducing measures shall be implemented until the cost (in a wide sense, including time, capital costs or other resources/assets) of further risk reduction is grossly disproportional to the potential risk reducing effect achieved by implementing any additional measure.

Common Operating Picture: an overview of an incident by all relevant parties that provides incident information, enabling the Incident Command and any supporting agencies and organizations to make effective, consistent and timely decisions.

Conservative assumption: assumption cautiously moderate or purposefully high or low, depending on the case. A conservative assumption is one that would assume higher potential ecological and/or socio-economic consequences when compared to other potential assumptions. Also referred to as a 'cautious assumption'.

Environment: the surroundings in which an organization operates, including air, water, land, natural resources, flora, fauna and humans, and their interrelation.

Environmental consequences/impact: any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organization's activities, products or services.
- Consequences can be expressed qualitatively or quantitatively.

Environmental Sensitivity Index (ESI): index ranging from 1 to 10 and expressing the sensitivity of environments and resources potentially exposed to oil spills. The ESI is mainly used for mapping an environment's sensitivity to oil pollution.

Event: occurrence or change of a particular set of circumstances.
- An event can be one or more occurrences, and can have several causes.
- An event can consist of something not happening.
- An event can sometimes be referred to as an 'incident' or 'accident'.
- An event without consequences can also be referred to as a 'near miss', 'incident', 'near hit' or 'close call'.

Hazard: potential source of human injury, damage to the environment, damage to property, or a combination of these potential sources of harm. In the context of ISO Standard 17776, the potential harm may relate to loss of life, or damage to health, the environment or assets or a combination of these.

Hazardous event: an incident which occurs when a hazard is realized.

Impact indicator: the impact indicator is the ecological- or socio-economic resources that are used in the risk assessment to evaluate the consequences from oil pollution

Incident Command System: a systematic tool and organizational structure used for the command, control, and coordination of emergency response, which is part of the US National Incident Management System.

Likelihood: the chance of something happening.

- In risk management terminology, the word 'likelihood' is used to refer to the chance of something happening, whether defined, measured or determined objectively or subjectively, qualitatively or quantitatively, and described using general terms or mathematically (such as a probability or a frequency over a given time period).
- The English term 'likelihood' does not have a direct equivalent in some languages; instead, the equivalent of the term 'probability' is often used. However, in English, 'probability' is often narrowly interpreted as a mathematical term. Therefore, in risk management terminology, 'likelihood' is used with the intent that it should have the same broad interpretation that the term 'probability' has in many languages other than English.

Liquid hydrocarbon: hydrocarbon fluid which is in a liquid physical state at the expected sea surface pressures and temperatures, i.e. oil and condensates.

May: verbal form used to indicate a course of action permissible within the limits of this guidance.

Metocean: a term used to describe the combination of meteorological and oceanographic data (commonly wind and current measurements in the context of oil spill trajectory and fate modelling).

Net environmental benefit analysis (NEBA): underlying approach to choosing response options that minimize the overall damage of an incident. It generally incorporates both ecological and socio-economic considerations.

Offshore installation: any fixed or floating offshore installation or structure engaged in gas or oil exploration, exploitation or production activities, or the loading or unloading of oil, including floating production, storage and offloading units and marine export pipelines.

- Activities which might give rise to the spillage of oil, condensate or fuel from offshore installations generally require consideration in oil spill contingency planning. It is therefore expected that risks from any shuttle tanker operations in the close vicinity of offshore operations would be incorporated in the plan. Installations exploring for, or producing, gas are typically not exempt from offshore oil spill contingency planning requirements (though the risk assessment will take into account how the presence of gas may reduce the oil spill risk).

Oil: see 'Liquid hydrocarbon'

Oil weathering: a combination of the various of physical and chemical changes that oil undergoes when spilled at sea.

Oil spill contingency plan: document describing the strategic philosophy behind the establishment of capability to respond to accidental oil pollution, the related tactical and operational response procedures and the response resources required. The oil spill contingency plan is integrated within the framework of broader emergency planning. It is synonymous with the 'oil pollution emergency response plan', 'oil spill response plan', 'oil pollution emergency plan' and similar variants.

Primary effect: an effect where the stressor acts directly on the environmental component of interest, not through other parts of the environment.

Qualitative: related to, or expressed in terms of, qualities (i.e. not necessarily measurable).

Quantitative: related to, or expressed in terms of, calculated numeric values, quantity or statistical comparison.

Recovery time: the time from when an unplanned event occurs, causing environmental damage, until the biological features have recovered to a pre-spill state or to a new stable state taking into consideration natural ecological variations, and are providing ecosystem services comparable to the pre-spill services.

Response: response incorporates equipment, personnel, logistics and the communication and coordination procedures required for integrated incident management.

Response planning: a process that considers, in tactical, operational and logistical detail, the preferred and viable response strategies proposed to combat the oil pollution associated with a scenario.

Risk: a combination of the likelihood of the occurrence of harm and the severity of that harm.
- Risk may be expressed qualitatively as well as quantitatively. Likelihood may be expressed as a likelihood value (0–1, dimensionless) or as a frequency, with the inverse of time as dimension.
- The risk combination can be expressed through different manners, such as a single number, aggregated numbers per severity classes, position of accidental scenarios on a risk matrix, etc.

Risk evaluation: the judgement, on the basis of risk analysis and risk tolerance criteria, of whether a risk is tolerable or not.

Risk picture: a synthesis of the risk assessment, with the intention to provide useful and understandable information to relevant decision makers.
- Establishing the risk picture includes reporting on the risk assessment process.

Risk tolerance criteria: criteria that are used to express a risk level that is considered as the upper limit for the activity in question to be tolerable.
- risk tolerance criteria are used in relation to risk analysis, and express the level of risk tolerable for the activity, i.e. the starting point for further risk reduction according to the ALARP principle. Risk acceptance criteria may be qualitative or quantitative.

Scenario: a postulated sequence or development of events.
- As an example, a spill scenario could be a well blowout originating from a loss of well control and leading to a definite flow of hydrocarbons being released over a certain period of time and at a specific location.

Secondary effect: the action of a stressor on the supporting components of the environment which, in turn, have an impact on the environmental component of concern.

Sensitivity: in the context of this guidance, sensitivity is a function of: (a) the degree to which the ecosystem, species or habitat will be affected by, or be responsive to, an oil spill; (b) the likelihood of exposure to oil; and (c) the adaptive capacity to cope with the impact of a spill.
- For simplification purposes, ‘sensitivity’ in the context of this guidance also includes the concept of vulnerability and is not limited to the biophysical effect of oil.

Should: verbal form used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required.

Socio-economic resources: socio-economic resources, within the scope of this guidance, will normally include fisheries (subsistence, artisanal and commercial fishing/harvesting, and fishing villages), aquaculture and tourism/recreation areas and activity.
- A wider definition of what can be interpreted as socio-economic resources may be applied, and can be found in IPIECA/IMO/OGP good practice guidance on *Sensitivity mapping for oil spill response*, 2011.

Strategy: the general plan or direction selected to accomplish incident objectives. The different options available to counter oil pollution are considered as response strategies.

System: common expression for installation(s), plant(s), system(s), activity/activities, operation(s) and/or phase(s) subjected to the risk assessment.

System basis: inputs (regarding the system subjected to assessment) used as basis for the assessment.

System boundaries: defines what shall, and what shall not, be subjected to the assessment.

Tactics: the deployment and directing of capability during an incident to accomplish the objectives designated by strategy. The tactics for each response strategy will include specific details of equipment, personnel, supporting logistics, deployment considerations and limitations.

Theatre of response operations: the geographic area where oil pollution response activities are deployed.

Tier 3 response organization: a term for the oil industry-owned cooperatives established to deal with major oil spill incidents. In totality, the network of these organizations is referred to as the oil industry's 'Tier 3 Network' or 'Tier 3 Resources.'

Tiered preparedness and response: the approach to establishing tiers of response resources to respond to potential incidents, commensurate with the risk. It incorporates the ability to escalate and cascade resources through the tiers in proportion to the needs of an incident.

Acronyms and abbreviations

ALARP	As Low As Reasonably Practicable
ENVID	Environmental (hazard) Identification (or Environmental HAZID)
EPC	Engineering, Procurement and Construction
FPSO	Floating Production, Storage and Offloading unit
FSO	Floating Storage and Offloading unit
ESI	Environmental Sensitivity Index
HAZID	Hazard Identification
HAZOP	Hazard and Operability analysis
HSE	Health, Safety and Environment
IBA	Important Bird Area
ICS	Incident Command System
IMO	International Maritime Organization
IPIECA	The global oil and gas industry association for environmental and social issues
ISB	In-Situ Burn
ISO	International Organization for Standardization
ITOPF	International Tanker Owners Pollution Federation Limited
NEBA	Net Environmental Benefit Analysis
OGP	International Association of Oil and Gas Producers
OPRC	International Convention on Oil Pollution Preparedness, Response and Co-operation, 1990
OSRA	Oil Spill Risk Assessment
RTC	Risk Tolerance Criteria
SCAT	Shoreline Clean-up Assessment Technique
THC	Total Hydrocarbon Concentration
TLP	Tension Leg Platform
WCCD	Worst Credible Case Discharge

Appendix 2

Example risk assessments

Introduction

This Appendix presents two examples of oil spill risk assessment for a fictitious oil and gas development project. Both examples relate to the same development concept, which consists of subsea wells connected to a floating production, storage and offloading unit (FPSO), with oil exported by offloading to tankers, and gas exported through a pipeline. For the purpose of this document, the fictitious field has been named the *Prudence Field*.

The two examples are intended to provide two interpretations of the recommendations in this document, with two different levels of detail in the approach:

- Example 1 presents a qualitative approach, where the risk of oil spills is assessed per scenario. The risk assessment is based on limited information, both with regard to oil spill modelling results and environmental resources.
- Example 2 presents a more advanced quantitative approach where the oil spill risk is based on a broader and more refined set of spill scenarios (more scenarios, topside/subsea differences, seasonal variation, etc.). In addition, the total risk level of the *Prudence Field* is estimated. The approach requires more detailed information, and this is utilized to refine and detail the environmental risk assessment of the field.

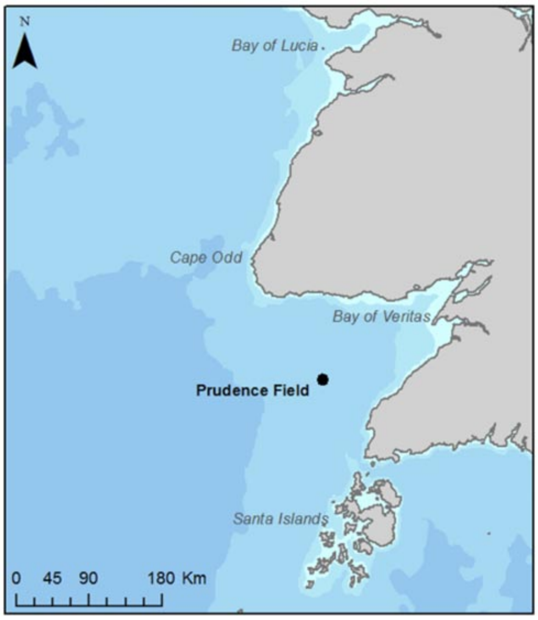
The documentation of the two examples is not representative of that recommended for a complete oil spill risk assessment. The aim of the examples is to provide a better understanding of possible approaches, input data and results, not to provide methods and complete solutions.

Figure A1 Illustration of the *Prudence Field* FPSO

Source: DNV, Designimations

The *Prudence Field* is located 38 km from the coast to the southeast, and 55 km to the north. The water depth at the location is 300 metres. Figure A2 provides an overview of the location of the field.

Figure A2 Map of the field location



Example 1: a qualitative approach

Introduction

This example presents a qualitative approach, where the risk of oil spills is assessed per scenario. The risk assessment is based on limited information, both with regard to oil spill modelling results and environmental resources. A qualitative approach is suitable when the available information is limited and/or the objective of the assessment does not require very detailed information.

Hazard identification

Hazards are identified through a HAZID/ENVID workshop with HSE representatives and various disciplines within the engineering team. Good practices and risk reduction measures already implemented in the design are taken into account during the hazard identification review. Table A1 provides an overview of identified hazardous events.

Table A1 Hazardous events identified

Hazardous event	Hazard
Loss of well control (blowout)	• Development drilling • Completion • Producing wells • Workover, including wireline, coiled tubing and snubbing
Leak from subsea systems	• Subsea production systems • Templates • Flowlines (field pipelines) • Risers
Spill from the FPSO	• Process system failure • Tank explosions • Collisions • Loss of stability • Structural failure • Loss of containment from diesel tank
Leak from offloading	• Offloading hose/pipe • Loading buoy
Spill from tanker	–

Analysis of hazardous events and selection of spill scenarios

The identified hazardous events are assessed, event by event, to estimate the potential quantities of hydrocarbon spilled, the location of the spill, duration of the spill, and its likelihood.

The blowout rates have been estimated by applying reservoir, well and fluid specific properties. The blowout durations with probability distribution as well as the event frequencies are based on statistics from historical events. Oil spill volumes and durations from subsea systems, risers and FPSOs are based on flow rates and expected duration for controlled shut-down. The event frequencies are estimated based on component reliability data, in combination with statistics from historical events.

Events overview

Table A2 presents an overview of the spill scenarios based on the identified hazardous events and also on the likelihood analysis.

For this specific field, it is estimated that a blowout event could last for up to 50 days, which corresponds to the time taken to reach a decision on drilling a relief well, and to subsequently mobilize a rig, drill the well and successfully kill the blowout at the *Prudence Field*.

Table A2 Spill scenarios at the *Prudence Field*

Scenario	Spill volume	Frequency (per year)	Spill duration (days, unless specified)			
			2	5	15	50
Blowout—development drilling and completion	2,000 t/d	4.15E-04	55%	18%	16%	11%
Blowout—producing wells	2,000 t/d	3.73E-04				
Blowout—workover	1,500 t/d	2.64E-04				
Subsea systems and risers leaks	600 t	3.50E-03	12 hours			
	100 t	3.60E-03	1 hour			
Leaks from FPSO (inc. offloading)	4,000 t	9.00E-05	1 hour			
	11,000 t	2.10E-04	2 hours			
	300 t	7.30E-04	1 day			
	1,300 t	4.68E-04	2 days			
	40 t	8.07E-03	1 hour			

Selection of spill scenarios

Scenarios to be used as a basis for the fate and trajectory modelling and subsequent risk assessment are selected among those presented in Table A2. To facilitate the selection, scenarios are presented in a graphical manner, as illustrated in Figure A3. All scenarios have the same release location (*Prudence Field*), and all of them have the same type of oil except a scenario for a leak from the diesel tank (1,000 metric tonnes released over 2 days). For simplification, the diesel leak scenario is also to be modelled with the expected oil type at the field .

The scenarios are selected for fate and trajectory modelling based on their likelihood and the quantity of oil potentially released. The selected scenarios are representative of challenges for the three different tiers for oil spill response:

- Tier 1: a smaller spill from a riser leak at the FPSO (lower amount of oil, greater likelihood);
- Tier 2: the weighted release of 470 tonnes, representing a medium leak from a subsea production flow line and a spill from the FPSO, and a leak from the diesel storage tank on the FPSO (medium amount of oil or diesel, lower likelihood); and
- Tier 3: a blowout, and a spill of 11,000 tonnes from the FPSO cargo tank (high quantity, low likelihood).

The highest of the possible blowout rates (2,000 tonnes/day) for 50 days was chosen as the blowout scenario. The frequency of this scenario was set equal to the sum of frequencies for all identified blowout events (during drilling, completion, production and workover).

The frequency for the 470-tonne spill is set equal to the aggregated frequency of the two initial scenarios; a medium leak from a subsea production flow line and a spill from the FPSO.

Smaller spills (<50 tonnes) of short duration are not addressed in the example as they are assumed not to contribute significantly to the oil spill risk of the *Prudence Field*. This is later confirmed by the results.

The blue rectangles on Figure A3 illustrate Tier 1–3 spills. The green borders indicate which events have been selected and combined as spill scenarios.

Figure A3 Overview of the spill scenarios (the axes use logarithmic scales)

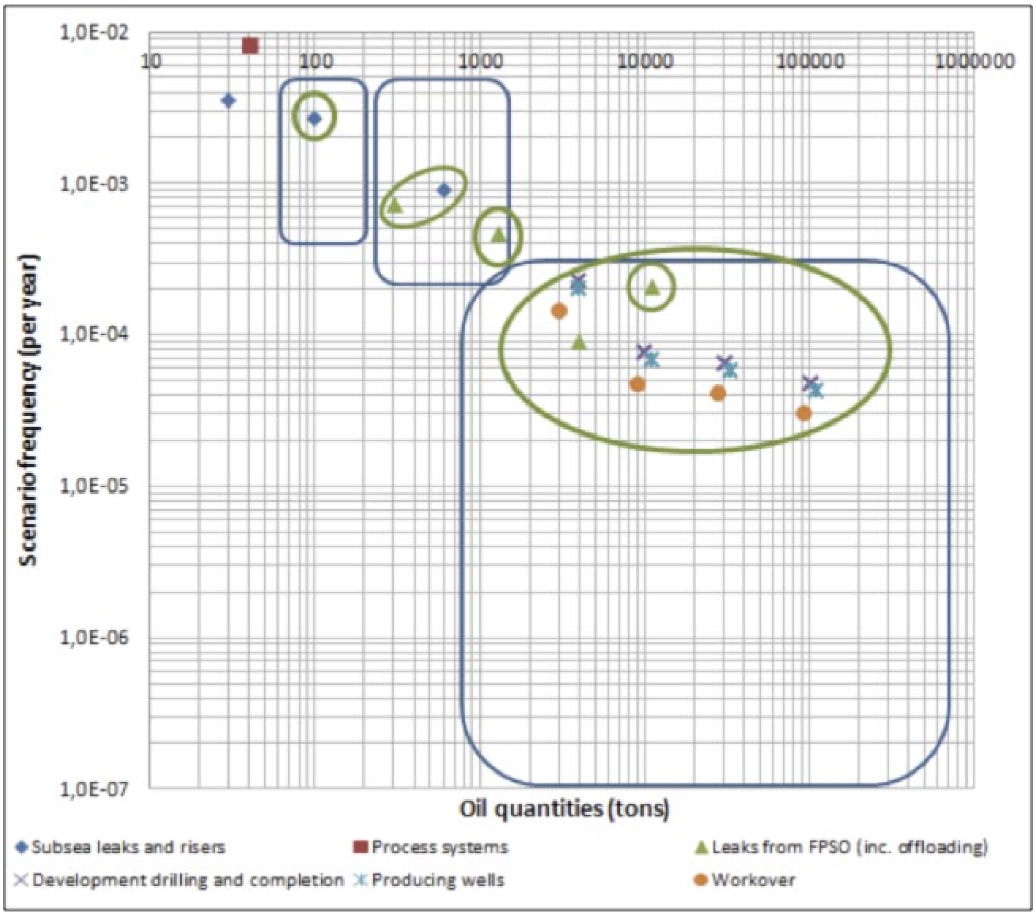


Table A3 Selected spill scenarios at the *Prudence Field*

Scenario	Spill volume	Frequency (per year)	Duration
Blowout—development drilling and completion	2,000 t/d	1.05E-03	50 days
Subsea systems and risers leaks/ leaks from FPSO (inc. offloading)	100 t	3.60E-03	1 hour
	470 t	4.23E-03	12 hours
	11,000 t	2.10E-04	2 hours
	1,300 t	4.68E-04	2 days

Modelling of oil spill trajectory and fate

An oil trajectory model is used to predict oil movements and potential impact areas for the selected scenarios. The model is used in a stochastic mode, and a large number of individual simulations form the basis for statistical results. For the purpose of the OSRA, the model provides output in 10 x 10 km grid cells.

The Statfjord blend crude oil is selected as the best available analogue for the oil at the *Prudence Field*. This selection is based on the oil characteristics (i.e. density, asphaltene and wax content). The model contains the Statfjord oil in its database, and its weathering properties are taken into account during the modelling. The most important oil properties are given in Table A4.

Due to limitations in the project, several simplifications are made with regard to the oil spill fate and trajectory modelling:

- All the oil spill scenarios are modelled as topside releases.
- The diesel spill scenario is modelled with the same oil type as the other scenarios. This is discussed in the results section.

Table A4 Oil properties of the Statfjord C Blend crude oil

Parameter	Value
Oil density	834 kg/m^3
Maximum water content	70 vol. %
Wax content	4.2 weight %
Asphaltene content	< 0.1 weight %
Viscosity, fresh oil (13 °C)	21 cP

Metocean data

Wind and surface current data are used for the area, covering the period 2000–08. The vertical salinity and temperature profiles are obtained from Levitus' atlas[14].

Results

Influence area

The influence area corresponds to the likelihood that more than 1 tonne of oil will hit a 10 x 10 km cell. Influence area is calculated by combining all the single spill simulations (stochastic), and is presented on a map for each scenario modelled. The influence area is defined as being greater than or equal to a 5% conditional probability for more than 1 tonne of oil to be present in a 10 x 10 km grid cell.

[14] Levitus *et al*., 1994. Hydrography atlas available at:
http://ingrid.ldgo.columbia.edu/SOURCES/.LEVITUS94/.MONTHLY/.temp
http://ingrid.ldgo.columbia.edu/SOURCES/.LEVITUS94/.MONTHLY/.sal

Figure A4 Conditional probability for more than 1 tonne of oil to hit a 10 x 10 km grid cell due to a topside blowout for 50 days (2,000 metric tonnes of oil per day)

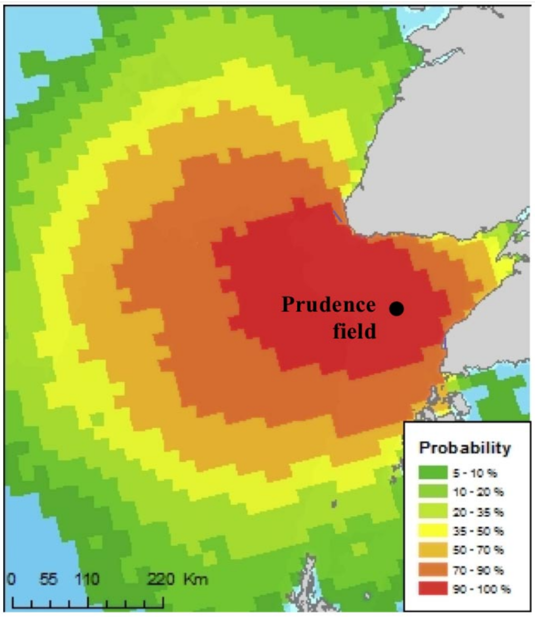


Figure A5 Conditional probability for more than 1 tonne of oil to hit a 10 x 10 km grid cell due to a spill from the storage tank on the FPSO (11,000 tonnes of oil over 2 hours)

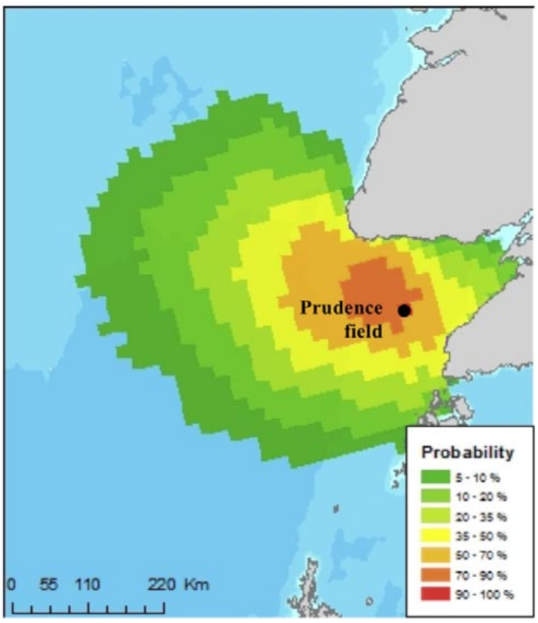
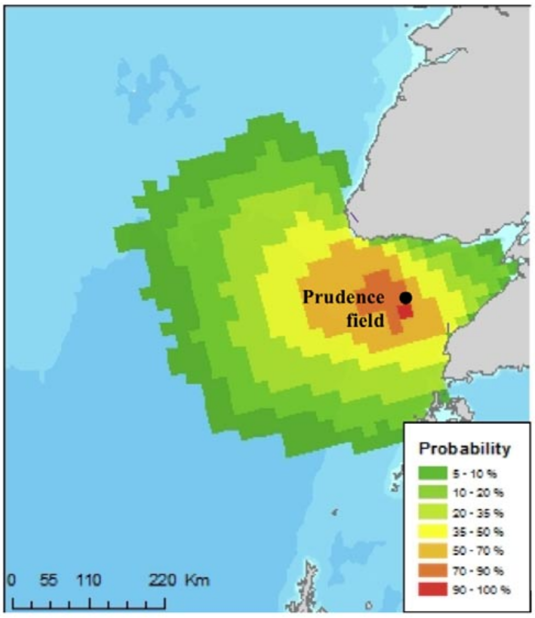


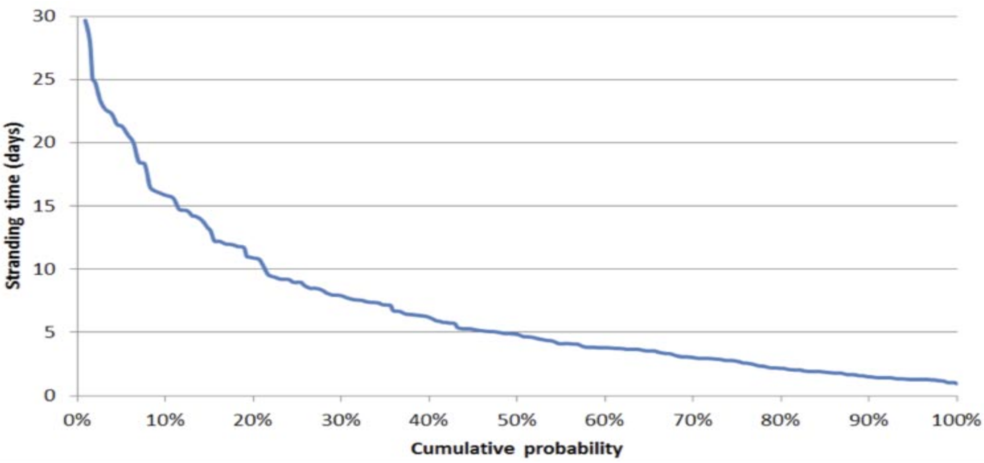
Figure A6 Conditional probability for more than 1 metric ton of oil to hit a 10 x 10 km grid cell due to a diesel tank spill (1,300 tonnes of oil over 2 days, modelled with Statfjord oil)



Drift time to shore

Figure A7 shows the minimum drift time for oil to reach the shore in the case of a blowout at the *Prudence Field*. While this time will vary according to the prevailing wind and currents, the minimum drift time to shore will be approximately one day. However, there is a >90% probability that the oil would take more than 1.5 days to reach the shore; and in about 50% of the cases the oil would reach the shore after 4.5 days or more.

Figure A7 Cumulative probability of minimum drift time to shore following a blowout



Selecting ecological and socio-economic impact indicators

Ecological and socio-economic impact indicators are selected based on existing mapping of natural resources in the area (not presented in this example). The mapping of ecological resources is based on national databases and other available information.

Impact indicators selected for this study are:

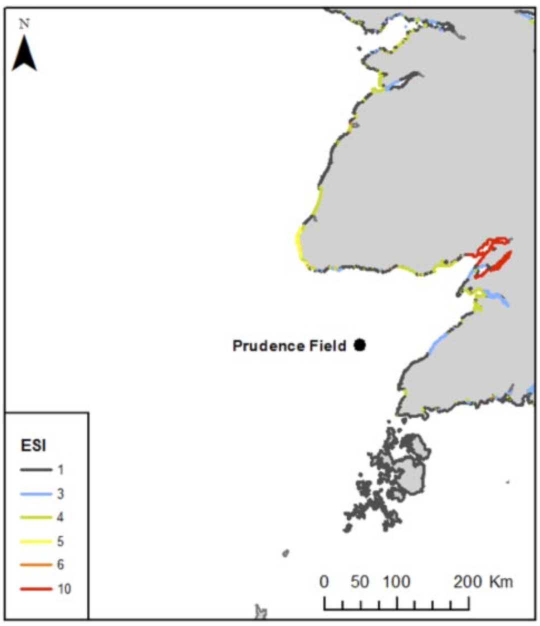
- shoreline habitats;
- seabirds;
- fish spawning areas;
- fishing areas; and
- areas important for tourism.

A description of the impact indicators is provided in the sections below.

Shoreline habitats

Mapping of the coastline substrate sensitivity according to the ESI categories had been carried out prior to the study, and sensitivity data were available. The map in Figure A8 provides an overview of the coastal sensitivities in the *Prudence Field* area. The higher the ESI number, the greater the sensitivity of the shoreline habitat to oil. The mangrove habitat (shown in red) in the Bay of Veritas is selected as an impact indicator due to the very high sensitivity of this habitat. This mangrove habitat also provides shelter for several rare species.

Figure A8 Sensitivity of coastal habitats



Seabirds

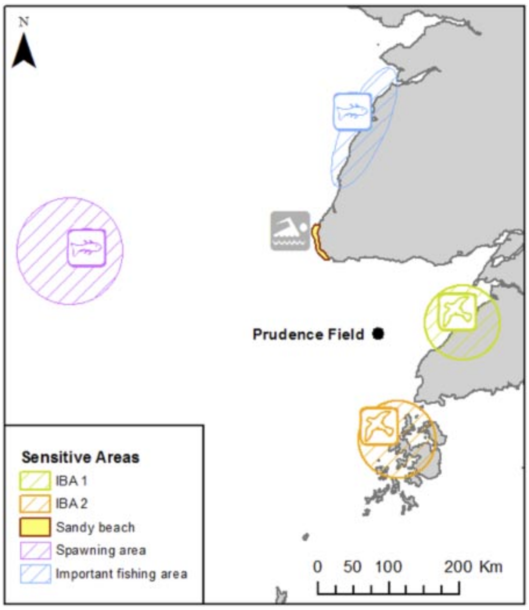
Limited information is available on seabird species and their geographical and seasonal distribution in the area. It is only known that there are two important bird areas (IBAs) located to the east and south-east of the *Prudence Field* (Figure A9). The IBAs are a nesting and nursing area for an endangered (Red List) coastal diving seabird species. Coastal diving seabirds have a behavioural pattern that increases their potential exposure to oil pollution at the sea surface and shoreline. This, in combination with the species' endangered status, makes it highly sensitive to oil pollution. A high sensitivity is therefore assigned to those two bird areas for the whole year.

Fish and fisheries

An important fishery area is located to the north of Cape Odd. After the tourist industry, the fisheries are the most important source of income in the region. The fishery area is assigned a moderate socio-economic sensitivity level.

The fish species that constitutes 90% of the commercial catches in the region has an important spawning area offshore Cape Odd. The spawning area is assigned a high sensitivity.

Figure A9 Sensitive areas within the influence area of the *Prudence Field*



Areas important for tourism

The Coco Beach, located at Cape Odd, is an important site for tourism due to its beautiful location and famous gigantic coconut trees (Figure A9). The income from the tourist industry is highly important for the region, and the site is therefore assigned a high socio-economic sensitivity level. There are other important sites for tourism in the area but these are of much lower importance. Coco Beach is therefore the only tourist site that is selected as an impact indicator.

Analysis of environmental consequences

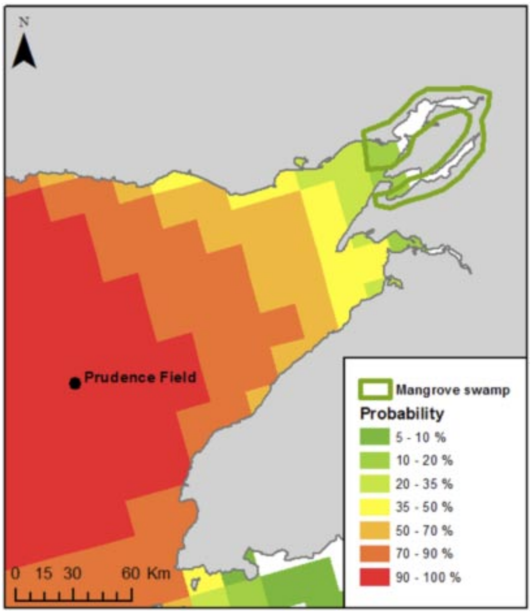
The analysis of environmental consequences is carried out for each scenario based on results from the oil spill trajectory and fate modelling, and on the distribution and sensitivity of selected impact indicators. For the purposes of this analysis, only the well blowout scenario is used to illustrate the process. Environmental consequences are organized in five categories: low; moderate; major; catastrophic; and disastrous. These categories should be more specifically defined, but this isn't done in the current example.

Coastal habitats

The consequences for coastal habitats affected by oil pollution depend on the shoreline type (grain size, slope), its exposure to waves (and tidal energy) and its general biological productivity and sensitivity. Consequences will also vary depending on the amount of oil reaching the habitat. However, oil volumes are not considered in this qualitative approach.

It is assumed that if the sensitive mangrove habitat is exposed to oil, the consequences will be disastrous, particularly considering that they are located in a low wave-energy environment. According to Figure A10, there is a 10–20% probability that the mangrove habitat will be exposed to oil resulting from a blowout at the *Prudence Field*.

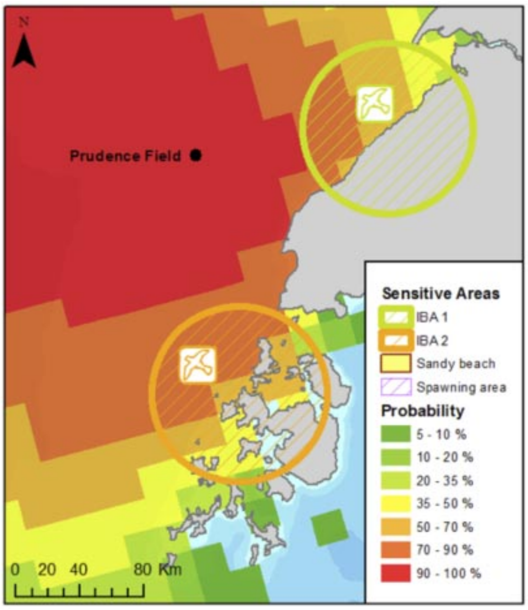
Figure A10 Probability of oil exposure of the mangrove habitat



Seabirds

The consequences for seabirds depend on their sensitivity to oil. Based on the available data, it is assumed that oil exposure of the important IBAs of high sensitivity would lead to catastrophic consequences at a population level. Figure A11 shows that there is up to a 70–90% probability for oil reaching the two IBAs following a blowout.

Figure A11 Probability of the exposure of sensitive bird areas to oil



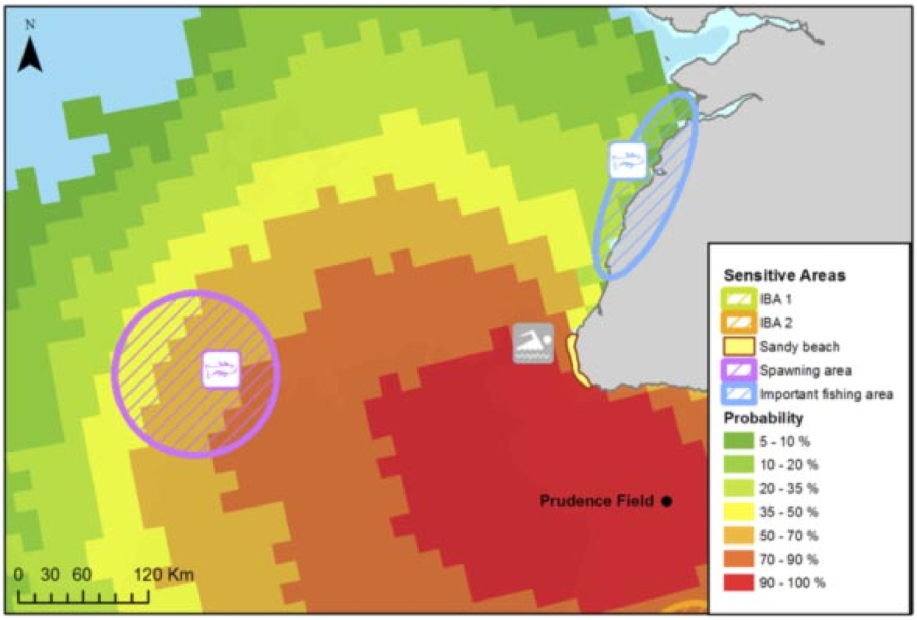
Fish and fisheries

The direct effect of oil on fish eggs and larvae depends on the total hydrocarbon concentration (THC) in the water column. However, the trajectory and fate model used in this example does not provide information on THC in the water column. As a conservative approach it is assumed that there are lethal concentrations of THC within the influence area of the spill. Exposure of eggs and larvae to lethal concentrations is assumed to have major consequences for the recruitment of the fish stock.

Oil on the surface of the water will, in most cases, lead to a halt in fishery activities, and may have a longer-term effect on the market for fish, crustaceans and shellfish from the region. Fishing is the second most important source of income for the region. The socio-economic consequences resulting from oil exposure are assessed to be moderate.

Based on the results from the trajectory and fate modelling shown in Figure A12, there is up to a 20–35% probability that the important fishing area located north of Cape Odd will be exposed to the oil, and a 35–90% probability of exposure of the spawning area offshore Cape Odd.

Figure A12 Probability of oil exposure of the tourism site (Coco Beach), the fish spawning area and the important fishing area



Areas important for tourism

The socio-economic consequences of the exposure of touristic areas to oil depend on the economic importance of the industry in the region, the importance of the exposed area for the industry, and the public perception of the damage. The tourist industry is the most important industry in the region, hence the socio-economic consequences of Coco Beach being exposed to the oil are assessed to be major.

Figure A12 shows that there is a 70–100% probability of oil reaching the Coco Beach given a blowout during drilling or completion activities at the *Prudence Field*.

Establishing and evaluating the oil spill risk

Environmental risks are established by combining the probabilities for consequences within the five consequence categories with the frequency for the accidental discharge scenarios.

In this case, each impact indicator is affected within only one consequence category. Table A5 presents the probabilities for each consequence category and the associated frequency for damage for each impact indicator. Although only the blowout scenario is included in the previous discussion, all modelled scenarios are included in Table A5 for comparative purposes.

Table A5 Environmental risks at the *Prudence Field*

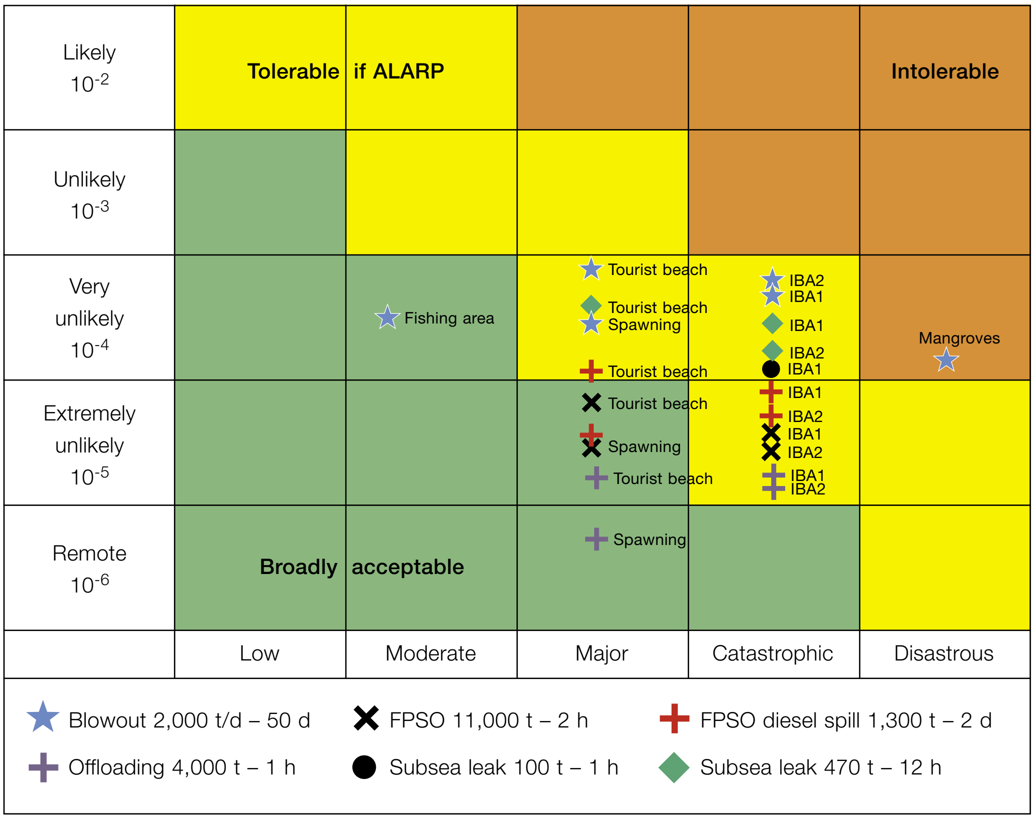
	Impact indicator:	Mangrove	IBA1	IBA2	Tourist beach	Fishing area	Spawning area
	Consequence category:	Disastrous	Catastrophic	Catastrophic	Major	Moderate	Major
Blowout (2,000 t/d during 50 d)	Damage probability:	20%	70%	70%	85%	30%	50%
Event frequency: 1.05E-03 per year	Damage frequency:	2.10E-04	7.36E-04	7.36E-04	8.94E-04	3.16E-04	5.26E-04
FPSO (11,000 t in 2 h)	Damage probability:	0%	30%	25%	45%	0%	20%
Event frequency: 2.10E-04 per year	Damage frequency:	/	6.30E-05	5.25E-05	9.45E-05	/	4.20E-05
Offloading (4,000 t in 1 h)	Damage probability:	0%	25%	20%	35%	0%	10%
Event frequency: 9.00E-05 per year	Damage frequency:	/	2.25E-05	1.80E-05	3.15E-05	/	9.00E-06
FPSO diesel (1,300 t in 2 days)	Damage probability:	0%	20%	15%	35%	0%	10%
Event frequency: 4.68E-04 per year	Damage frequency:	/	9.36E-05	7.02E-05	1.64E-04	/	4.68E-05
Subsea leak (100 t in 1 h)	Damage probability:	0%	5%	0 %	0%	0%	0%
Event frequency: 3.60E-03 per year	Damage frequency:	/	1.80E-04	/	/	/	/
Subsea leak (470 t in 12 h)	Damage probability:	0%	10%	5%	15%	0%	0%
Event frequency: 4.23E-03 per year	Damage frequency:	/	4.23E-04	2.12E-04	6.35E-04	/	/

Mangroves are the only affected impact indicator within the *disastrous* category, as a result of the blowout event. In the *catastrophic* category, IBA1 and IBA2 are the most affected, with the blowout scenario representing the highest risk. The tourist beach is the most affected area within the *major* category. Finally, the fishing area is the only impact indicator affected within the *moderate* category, with the highest risk caused by the blowout event.

Oil spill risk per scenario is measured against environmental tolerance criteria in the form of a risk matrix (Figure A13). Damage frequency is presented on the vertical axis, from the most frequent at the top to the least frequent at the bottom. The scenarios are plotted on the vertical axis, based on the combined information of scenario frequency and exposure probability. Consequences are presented on the horizontal axis, from the lowest damage on the left to the highest damage category on the right.

The example in Figure A13 presents an overview of the oil spill risk per spill scenario at the *Prudence Field* based on this qualitative approach. Results from the risk evaluation show that most risks are within the ALARP zone of the risk tolerance matrix. Only one risk is non-tolerable (red area): the potential damage to mangroves due to blowout. Risk reducing measures are a requirement for this scenario.

Figure A13 Oil spill risk per spill scenario at the *Prudence Field*



The environmental resources that undergo the greatest impact are the mangroves and important bird areas (IBA1 and IBA2), in both cases due to their sensitivity and to their probability of exposure to oil. The highest risks are caused by the blowout event, two subsea leak scenarios, and the FPSO diesel spill.

The use of a risk matrix and a limited number of scenarios does not enable a conclusion to be drawn on the overall risk level at the *Prudence Field*. To define the overall risk level of the field, all significant scenarios need to be included in the assessment, and their individual risk contributions must be combined (see Example 2 in this Appendix).

Risk reducing measures are identified following the OSRA. Measures are identified in priority for those scenarios that have the highest contribution to the risk picture. Those scenarios are located in the red (intolerable) and yellow (tolerable if ALARP) areas of the risk matrix.

The following main measures are identified:

- Plan for capping and containment (consequence reducing measure).
- Ensure proper testing and maintenance of the blowout preventers to be used during the drilling activities (probability-reducing measure).
- Employ the use of leak detection sensors for subsea production systems (spill size reduction).
- Carry out diesel tank integrity monitoring (probability reducing measure).
- Monitor diesel fuel transfer activities by personnel at all times (spill size reduction).
- Undertake a navigational risk study and further actions to avoid FPSO collisions (probability reducing measure).
- Prepare an oil spill response plan (consequence reducing measure).

Risk reduction measures related to the blowout scenario are to be implemented regardless of cost until it can be shown that the residual risk level is within the yellow (tolerable if ALARP) or green (broadly acceptable) area of the matrix.

For risks and residual risk within the yellow area, the risk reduction measures are evaluated following the ALARP principle, where the risk reduction achieved is considered against the costs of implementation.

Risks within the green area of the matrix are considered broadly acceptable given that good practice is implemented (already taken into account in the risk assessment process).

Input to oil spill planning

Information and results gathered throughout the OSRA process may be useful as an input to oil spill response planning. Information which is considered particularly valuable as an input to response planning and resource dimensioning includes:

- a list of potential spill scenarios, associated oil amounts and likelihood;
- oil weathering properties, and the potential challenges in relation to recovery or dispersion;
- results of the oil spill fate and transport modelling;
- mapping and evaluation of sensitive environmental resources in the influence area of the field;
- the oil spill risk of prioritized impact indicators, for response prioritization; and
- the oil spill risk of the different scenarios.

Example 2: an advanced approach

Introduction

This example presents a more advanced quantitative approach where the oil spill risk is based on a broader and more refined set of spill scenarios (more scenarios, topside/subsea differences, seasonal variation etc.). In addition, the total risk level of the *Prudence Field* is estimated. The approach requires more detailed information and this information is utilized to refine and detail the environmental risk assessment of the field. A quantitative approach is more suitable when there is an increased need for detailed information related to the decision making process, and when the activity/operation to be analysed is complex or the sensitivity of the environment is high.

Hazard identification

Hazards were identified through a HAZID/ENVID workshop with HSE representatives and various disciplines within the engineering team. Good practices and risk reduction measures already implemented in the design are taken into account during the hazard identification review. Table A6 provides a list of identified hazardous events.

Table A6 Hazardous events identified

Hazardous event	Hazard
Loss of well control (blowout)	• Development drilling • Completion • Producing wells • Workover, including wireline, coiled tubing and snubbing
Leak from subsea systems	• Subsea production systems • Templates • Flowlines (field pipelines) • Risers
Spill from the FPSO	• Process system failure • Tank explosions • Collisions • Loss of stability • Structural failure • Loss of containment from diesel tank
Leak from offloading	• Offloading hose/pipe • Loading buoy
Spill from tanker	–

Analysis of hazardous events and selection of spill scenarios

The identified hazardous events are assessed, event by event, to estimate the potential quantities of hydrocarbons spilled, the location of the spill, duration of the spill, and its likelihood.

The blowout rates have been estimated by applying reservoir, well and fluid specific properties. The blowout durations with probability distribution as well as the event frequencies are based on statistics from historical events. Oil spill volumes and durations from subsea systems, risers and FPSO are based on flow rates and expected duration for controlled shut-down. The event frequencies are estimated based on component reliability data and in combination with statistics from historical events.

Events overview

Tables A7 and A8 present an overview of the spill scenarios.

Table A7 Blowout scenarios at the *Prudence Field*

Scenario	Location	Spill volume (t/d)	Frequency (per year)	Spill duration (days)			
				2	5	15	50
Blowout—development drilling and completion	Surface	640	2.24E-05	55%	18%	16%	11%
		1,995	4.65E-05				
		3,507	5.75E-06				
	Subsea	681	1.02E-04	44%	17%	19%	20%
		2,079	2.12E-04				
		3,613	2.62E-05				
Blowout—producing wells	Subsea	2,227	1.53E-04	44%	17%	19%	20%
		1,513	2.20E-04				
Blowout—workover	Surface	1,879	6.60E-05	55%	18%	16%	11%
	Subsea	1,248	1.98E-04	44%	17%	19%	20%

Blowout durations are derived from statistics. It is estimated that a blowout event could last for up to 50 days, which corresponds to the time taken to reach a decision on drilling a relief well, and to subsequently mobilize a rig, drill the well and successfully kill the blowout at the *Prudence Field*.

Table A8 Spill scenarios from subsea systems, risers, process systems and other spills from the FPSO

Scenario		Spill volume (t/d)	Frequency (per year)	Spill duration	Release location
Subsea systems and leaks from risers	Flowline leak - S	28.7	2.59E-03	2 hours	Subsea
	Flowline leak - L	621	9.10E-04	12 hours	
	Riser leak - S	16	9.36E-04	1 hour	
	Riser leak - L	121	2.66E-03	1 hour	
Process systems	Second stage separator - L	43	9.69E-04	0.5 hour	Topside
	Second stage separator - M	21	2.12E-03	2 hours	
	Second stage separator - S	21	4.98E-03	2 hours	
Leaks from the FPSO (including offloading)	Offloading buoy	4,318	9.00E-05	1 hour	
	Fire and explosion in cargo tank	11,037	1.42E-04	2 hours	
	Fire and explosion in engine room	11,037	3.80E-06	2 hours	
	Structural failure	11,037	3.50E-05	2 hours	
	Ship collision	11,037	2.90E-05	2 hours	
	Loss of position	300	7.30E-04	1 day	
	Leak from diesel tank	1,292	4.68E-04	2 days	

Selection of spill scenarios

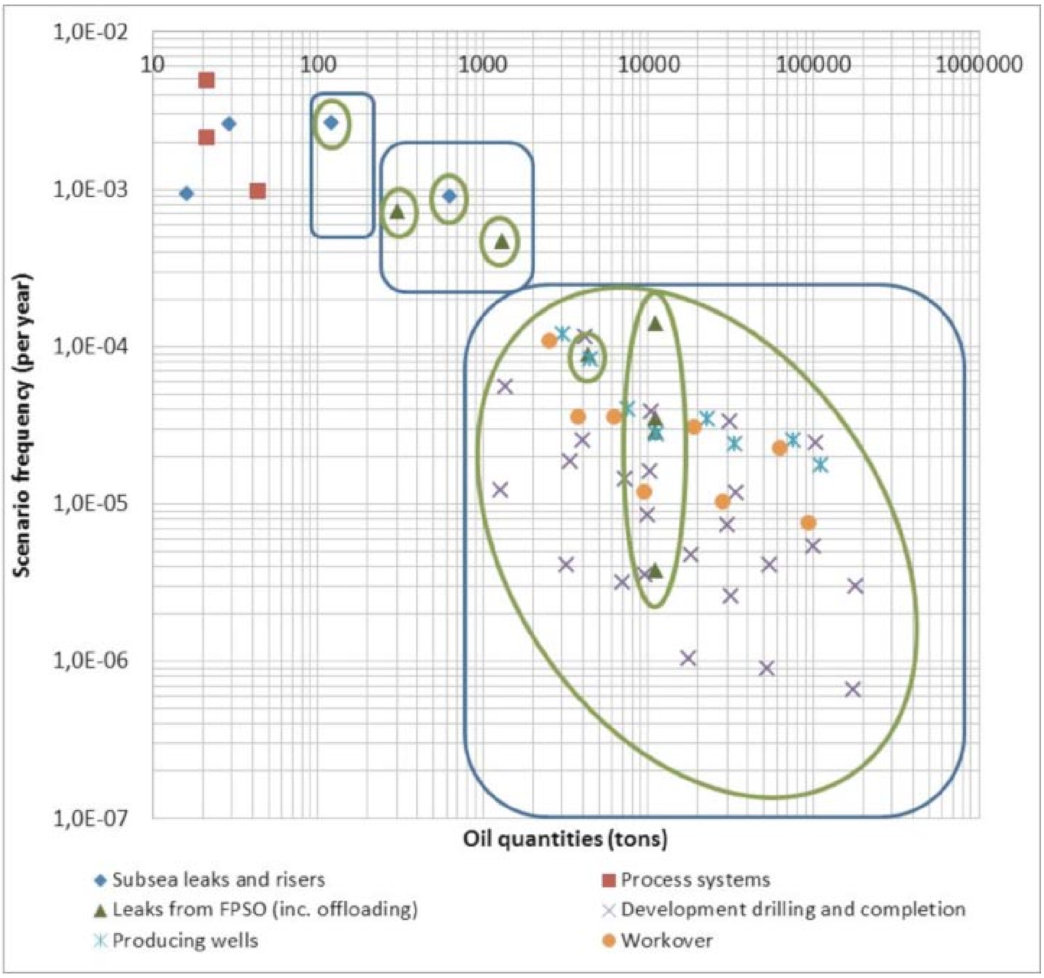
Scenarios to be used as a basis for the modelling and subsequent risk assessment are selected from those presented in Table A7. To facilitate the selection, scenarios are presented in a graphical manner, as illustrated in Figure A14. All scenarios have the same release location (facilities location), and all of them have the same type of oil except a scenario for a leak from the diesel tank (1,292 tonnes released over 2 days).

A few scenarios are selected for fate and trajectory modelling, based on their likelihood and the quantity of oil potentially released. Scenarios with the potential for a significant contribution to the risk picture are presented. Preliminary oil trajectory and fate modelling indicate that releases of less than 50 tonnes of oil would not create significant damage to the environmental sensitivities in the area of the *Prudence Field*; hence, only spill scenarios for releases of more than 50 metric tonnes are selected for the study.

Blowout events are selected to be modelled with a matrix of three potential flow rates, five different durations, and surface and subsea release locations. This will allow for a more realistic modelling of the potential consequences from a blowout at the *Prudence Field*.

The axes in Figure A14 use logarithmic scales. The blue rectangles illustrate Tiers 1–3 spills. The green borders indicate events that have been selected and combined as spill scenarios.

Figure A14 Overview of the spill scenarios



Some of the release scenarios have the same potential amount of oil released, oil type, and release location. These scenarios are therefore aggregated:

- fire and explosion in cargo tank;
- fire and explosion in engine room;
- structural failure; and
- ship collision.

The frequency of the resulting scenario is equal to the sum of frequencies from each aggregated scenario.

Table A9 Selected spill scenarios for oil spill trajectory and fate modelling

<table>
<tr><th rowspan="2">Scenario</th><th rowspan="2">Location</th><th rowspan="2">Spill volume (t/d)</th><th rowspan="2">Frequency (per year)</th><th colspan="4">Spill duration (days)</th></tr>
<tr><th>2</th><th>5</th><th>15</th><th>50</th></tr>
<tr><td rowspan="7">Blowout—development drilling and completion/ production/workover</td><td rowspan="3">Surface</td><td>640</td><td>2.24E-05</td><td rowspan="3">55%</td><td rowspan="3">18%</td><td rowspan="3">16%</td><td rowspan="3">11%</td></tr>
<tr><td>1,927</td><td>1.13E-04</td></tr>
<tr><td>3,507</td><td>5.75E-06</td></tr>
<tr><td rowspan="4">Subsea</td><td>681</td><td>1.02E-04</td><td rowspan="4">44%</td><td rowspan="4">17%</td><td rowspan="4">19%</td><td rowspan="4">20%</td></tr>
<tr><td>1,387</td><td>4.18E-04</td></tr>
<tr><td>2,141</td><td>3.65E-04</td></tr>
<tr><td>3,613</td><td>2.62E-05</td></tr>
<tr><th colspan="2">Scenario</th><th>Spill volume (t/d)</th><th>Frequency (per year)</th><th colspan="2">Spill duration</th><th colspan="2">Release location</th></tr>
<tr><td colspan="2" rowspan="2">Subsea systems and leaks from risers</td><td>621</td><td>9.10E-04</td><td colspan="2">12 hours</td><td colspan="2" rowspan="2">Subsea</td></tr>
<tr><td>121</td><td>2.66E-03</td><td colspan="2">1 hour</td></tr>
<tr><td colspan="2" rowspan="4">Leaks from the FPSO (including offloading)</td><td>4,318</td><td>9.00E-05</td><td colspan="2">1 hour</td><td colspan="2" rowspan="4">Surface</td></tr>
<tr><td>11,000</td><td>2.10E-04</td><td colspan="2">2 hours</td></tr>
<tr><td>300</td><td>7.30E-04</td><td colspan="2">1 day</td></tr>
<tr><td>1,300 (diesel)</td><td>4.68E-04</td><td colspan="2">2 days</td></tr>
</table>

Modelling of oil spill trajectory and fate

An oil trajectory model is used for modelling the selected scenarios. The model is used in a stochastic mode—a large number of individual simulations form the basis for statistical results. For this case, the model provides output in 10 x 10 km grid cells for the purpose of the OSRA. The model includes a 3D plume module which offers the opportunity to model subsea releases; this makes it possible to observe the influence of the plume expansion on the initial oil thickness at the sea surface, and the subsequent fate and trajectory.

The Statfjord oil is selected as the best available analogue for the oil at the *Prudence Field*. This selection is based on the oil characteristics, i.e. density, asphaltene and wax content. The model contains the Statfjord oil in its database and its weathering properties are taken into account during the modelling. The most important oil properties are given in Table A4. The oil will lose 30% of the lightest components during the first day at sea. It has a low asphaltene content (less than 0.1 wt%) and an average wax content at about 4 wt%. It emulsifies quickly and will form stable emulsions.

In this study the diesel leak scenario is modelled with the appropriate marine diesel. This leads to differences in modelling results compared to modelling the diesel leak scenario with the Statfjord oil.

Metocean data

Wind and surface current data are used for the area, covering the period 1972–2007. The vertical salinity and temperature profiles are obtained from Levitus' atlas[15].

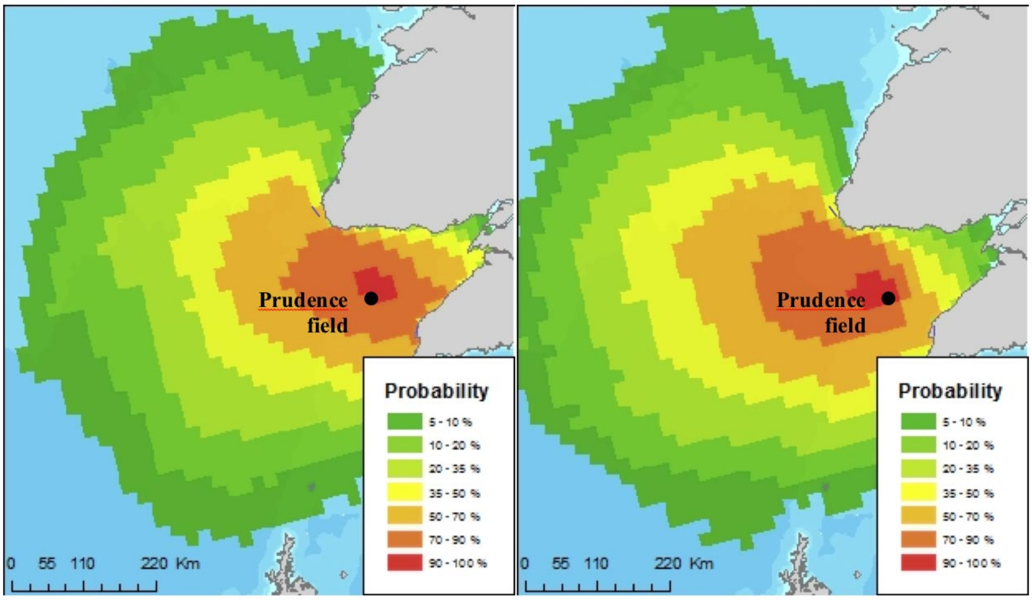
Results

Influence area

The influence area corresponds to the likelihood that more than 1 tonne of oil will hit a 10 x 10 km cell. Influence area is calculated by combining all the single spill simulations (stochastic), and is presented on a map for each scenario modelled. The influence area is defined for conditional probabilities over 5% only.

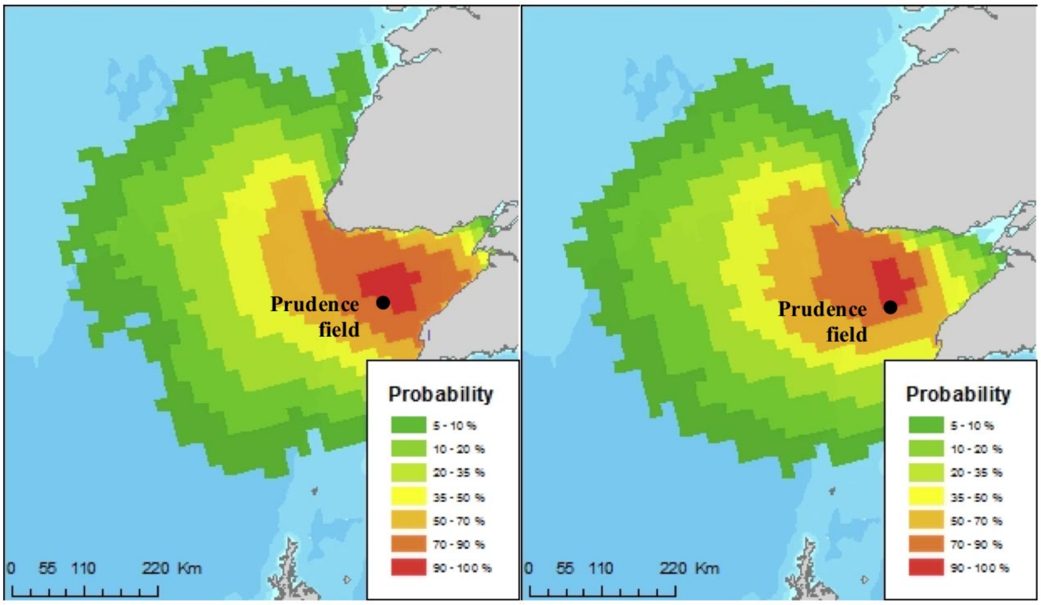
The figures below illustrate the results for a blowout during drilling or completion.

Figure A15 Conditional probability that more than 1 tonne of oil will hit a 10 x 10km grid cell from a topside blowout (modelled with 3 oil flow rates and 4 durations) during summer (left) and winter (right)



[15] Levitus *et al.*, 1994. Hydrography atlas available at:
http://ingrid.ldgo.columbia.edu/SOURCES/.LEVITUS94/.MONTHLY/.temp
http://ingrid.ldgo.columbia.edu/SOURCES/.LEVITUS94/.MONTHLY/.sal

Figure A16 Conditional probability that more than 1 tonne of oil will hit a 10 x 10 km grid cell from a subsea blowout (modelled with 3 oil flow rates and 4 durations) during summer (left) and winter (right)



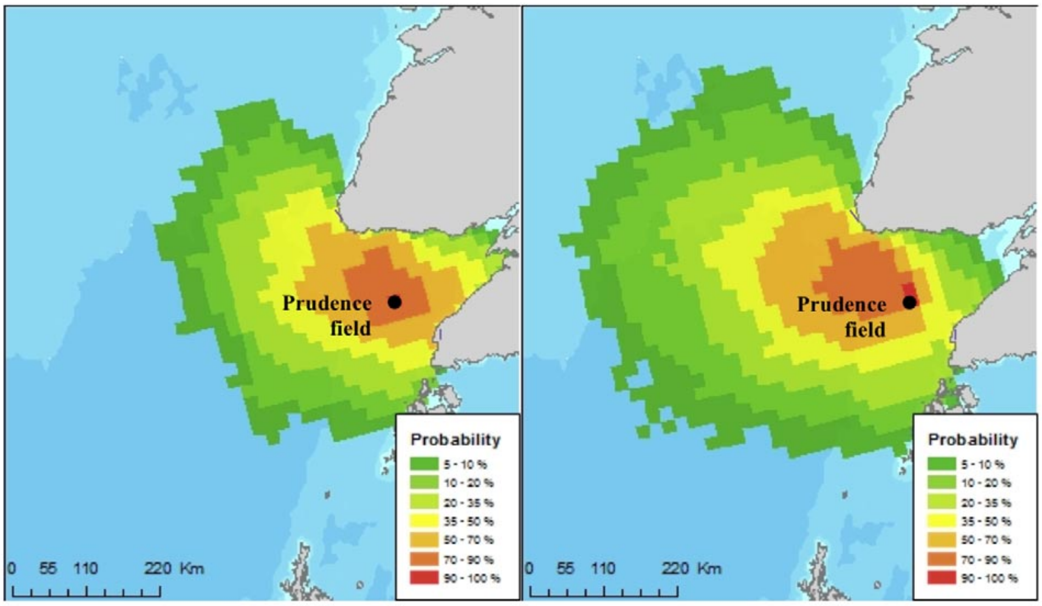
The blowout scenario above was modelled with three different oil flow-rates and four durations. This offers a better picture of the potential influence area and consequences from a blowout when compared to only one flow rate and duration (see also Figure A4 in the previous example).

Figures A15 and A16 show that the influence area from a subsea blowout is more limited than from a blowout at the surface. This is due to the effect of the plume expansion on the initial oil thickness at the sea surface, and the subsequent fate and trajectory.

Figure A17 (overleaf) illustrates the results for a scenario of a leak from the FPSO (11,000 tonnes of oil, 2 hours).

The results show a pronounced variation in the extent of the influence area between summer (on the left) and winter (on the right). This variation is due to the changes in sea currents and wind direction between the two seasons. Exposure of environmental resources in the area would therefore be different during summer and winter, and this would have an impact on the oil spill risk.

Figure A17 Conditional probability that more than 1 tonne of oil will hit a 10 x 10 km grid cell from a leak from the FPSO (11,000 tonnes of oil, 2 hours) during summer (left) and winter (right)



Figures A18 and A19 illustrate the results for a scenario of a leak from the offloading buoy (4,000 tonnes of oil, 1 hour), and a leak from the diesel tank (1,300 tonnes, 2 days), respectively.

Figure A18 Conditional probability that more than 1 tonne of oil will hit a 10 x 10 km grid cell from a leak from the offloading buoy (4,000 tonnes of oil, 1 hour) during summer (left) and winter (right)

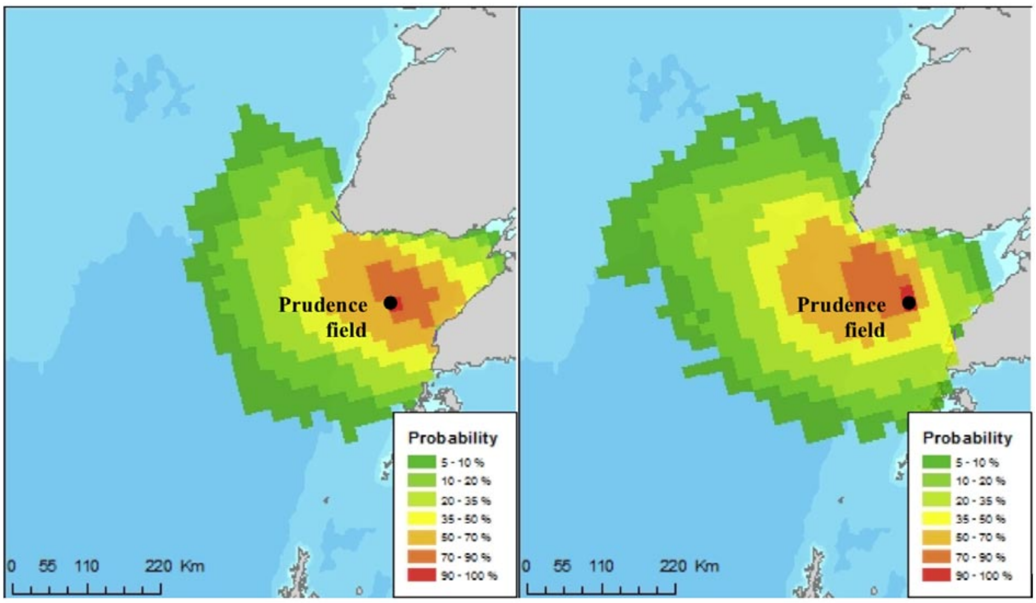
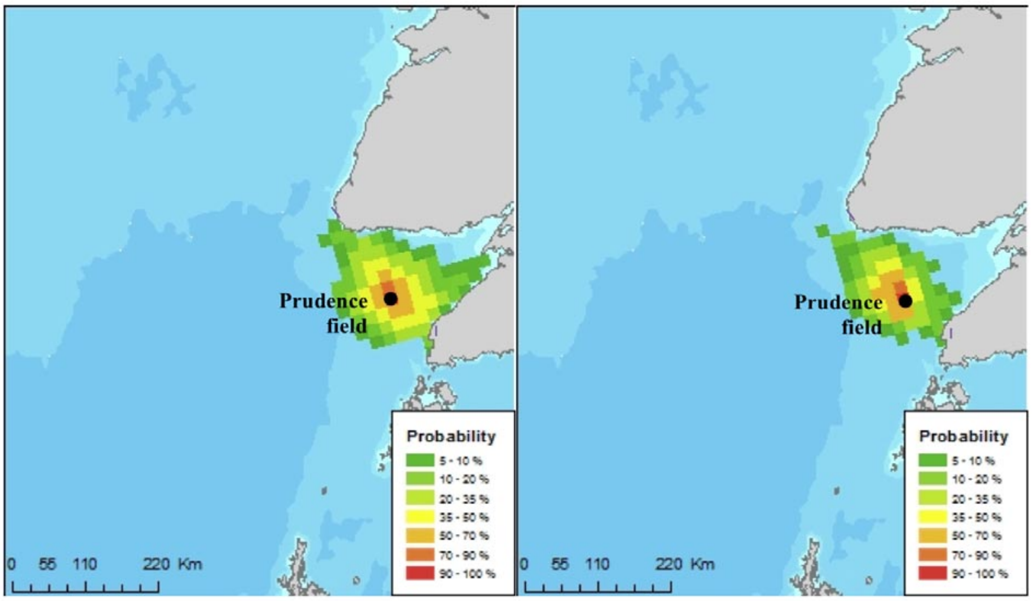


Figure A19 Conditional probability that more than 1 tonne of diesel will hit a 10 x 10 km grid cell from a leak from the diesel tank (1,300 tonnes of marine diesel, 2 days) during summer (left) and winter (right)



By modelling the scenario for the diesel tank leak with the appropriate marine diesel from the model's oil weathering database, it is possible to take into account the differences in weathering properties compared to the Statfjord crude. When comparing the influence area and probabilities in Figure A19 to those of the previous example (Figure A6), it can be seen that the influence area modelled with diesel is much more limited compared to the one modelled with crude oil. Among other parameters, marine diesel is lighter than the Statfjord crude, and would therefore evaporate more quickly; less hydrocarbon would remain on the sea surface and the influence area is therefore more limited. This shows the importance of using the appropriate weathering properties when modelling spill scenarios with different oil types.

Oil quantities at the sea surface

Average oil quantities at the sea surface are presented for quantities greater than 1 tonne within a 10 x 10 km grid cell. Oil quantities are organized into 7 categories: 1–10 tonnes; 10–30 tonnes; 30–60 tonnes; 60–100 tonnes; 100–200 tonnes; 200–300 tonnes; and > 300 tonnes.

Figures A20 and A21 show the average amount of oil at the sea surface from topside and subsea blowouts, respectively. The results illustrate the variations between summer and winter seasons. In particular, note the higher amounts of oil at the sea surface during summer in all directions.

The amounts of oil at the sea surface are generally lower for a subsea release when compared to surface release. This is due to the effect of the plume expansion on the initial oil thickness at the sea surface, and the subsequent fate and trajectory, and is similar to the effect observed in Figure A16.

Figure A20 Average quantity of oil in a 10 x 10 km grid cell from a topside blowout (all rates and durations) during summer (left) and winter (right)

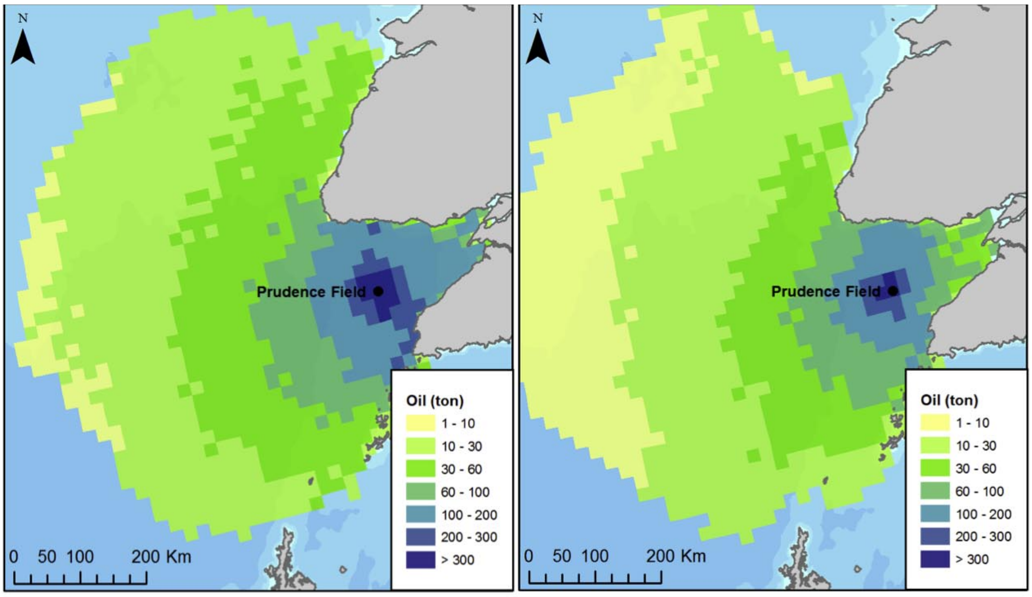
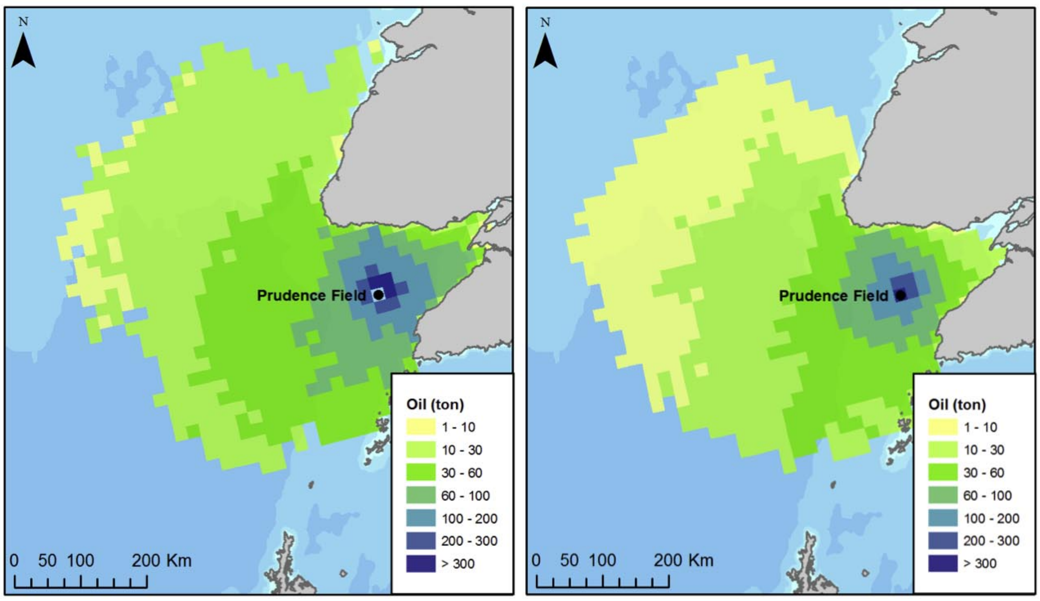


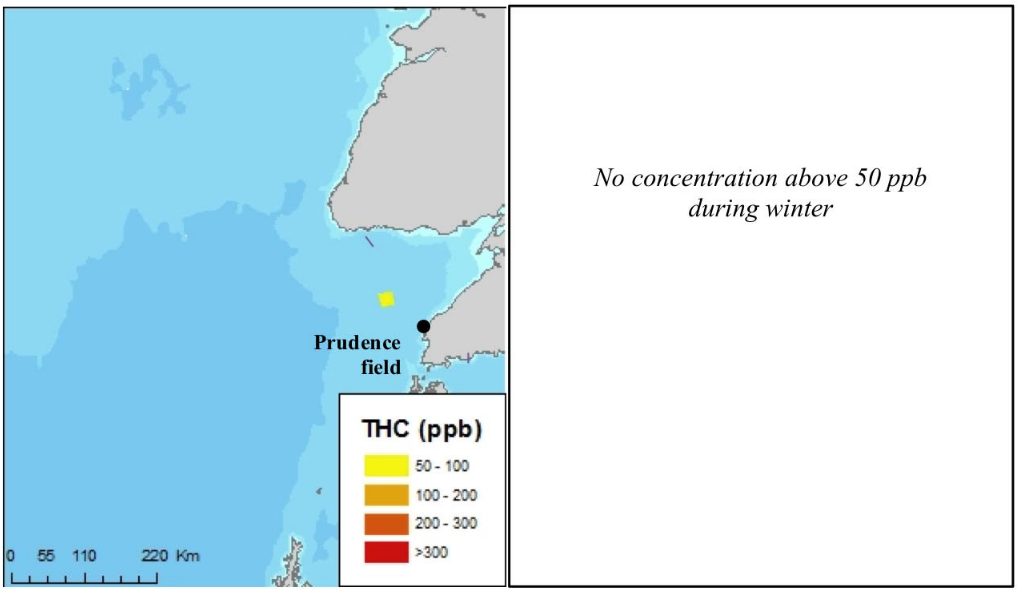
Figure A21 Average quantity of oil in a 10 x 10 km grid cell from a subsea blowout (all rates and durations) during summer (left) and winter (right)



Oil concentration in the water column

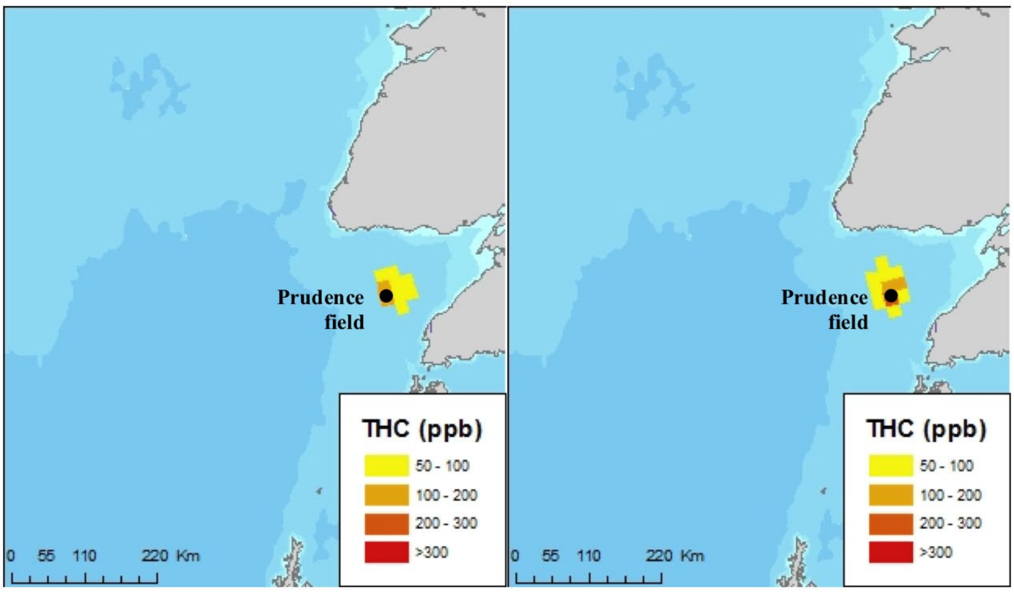
The concentration of oil in the water column is calculated based on a large number of single simulations and is presented for each 10 x 10 km grid cell. Concentrations are organized into four categories: 50–100 ppb; 100–200 ppb; 200–300 ppb; and > 300 ppb.

Figure A22 THC concentrations in a 10 x 10 km grid cell from a topside blowout (modelled with three oil flow rates and four durations) during summer



Left: the results showed no concentrations above 50 ppb during winter.

Figure A23 THC concentrations in a 10 x 10 km grid cell from a subsea blowout (modelled with three oil flow rates and four durations) during summer (left) and winter (right)



The results illustrate higher THC concentrations in the water column due to a subsea blowout compared to a surface release. This could influence the consequences for sensitive fish species.

Stranding of oil emulsion

In this advanced example, the fate and trajectory model provides the amount of oil emulsion reaching 10 x 10 km grid cells on the coastline. The type of coast and the backwashing of oil is taken into account during the modelling. These results do not include any oil spill response activities.

Figure A24 shows the average amount of oil emulsion reaching the shore after a topside blowout. The results show variations between the summer and winter seasons. In particular, they show less stranding of oil during winter on the coast of Cape Odd and further north towards the Bay of Lucia. The consequences for coastal habitats, as well as challenges for the oil spill response operations, would therefore vary with seasons.

Figure A24 Average volumes of stranded emulsion in a 10 x 10 km grid cell from a topside blowout at sea surface, summer (left) and winter (right)

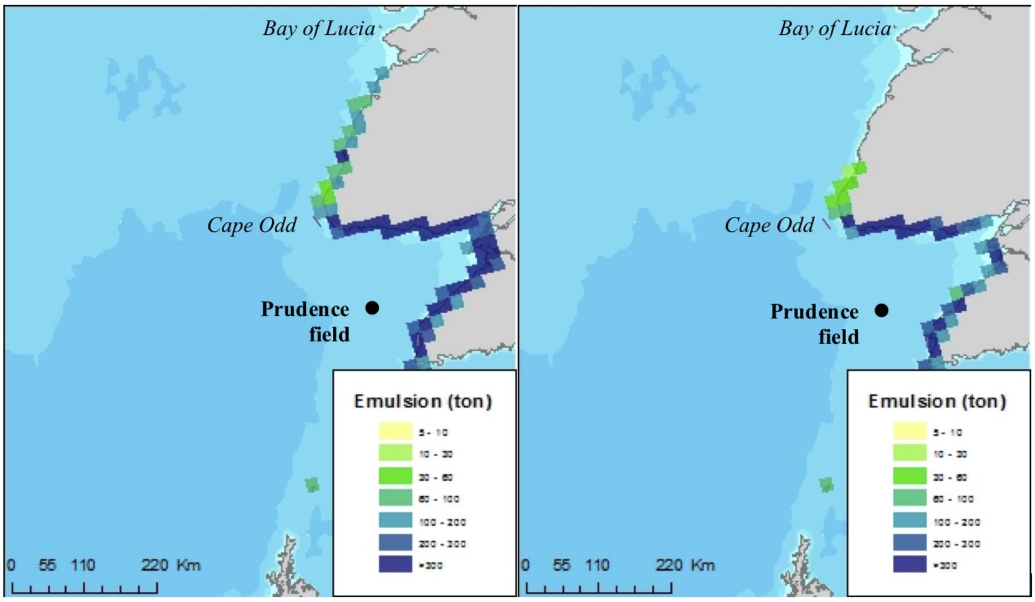


Figure A25 shows the same scenario (i.e. blowout) but with a subsea release. Comparing these results with Figure A24 reveals that a subsea blowout at the *Prudence Field* would most probably lead to lower amounts of oil reaching the coast.

Differences can also be observed between summer and winter in the case of a subsea release, with lower amounts of oil reaching the Bay of Veritas during winter.

Figure A25 Average volumes of stranded emulsion in a 10 x 10 km grid cell from a subsea blowout, summer (left) and winter (right)

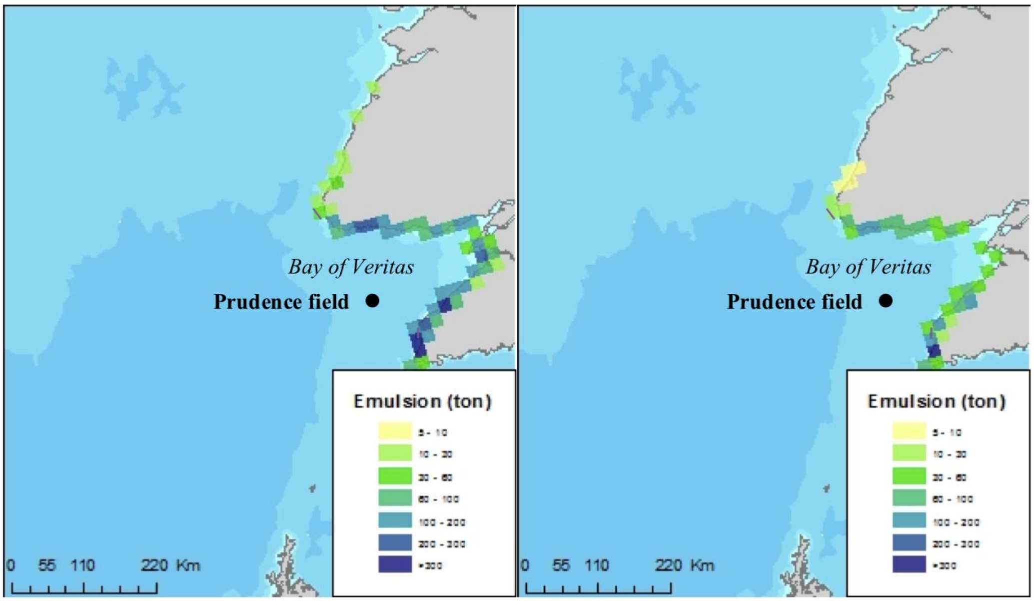


Figure A26 shows the average amount of diesel reaching the shore after a leak from the diesel tank. The volumes reaching the shore are generally low, with higher volumes during summer.

Figure A26 Average volumes of stranded diesel in a 10 x 10 km grid cell due to diesel spill at the FPSO, summer (left) and winter (right)

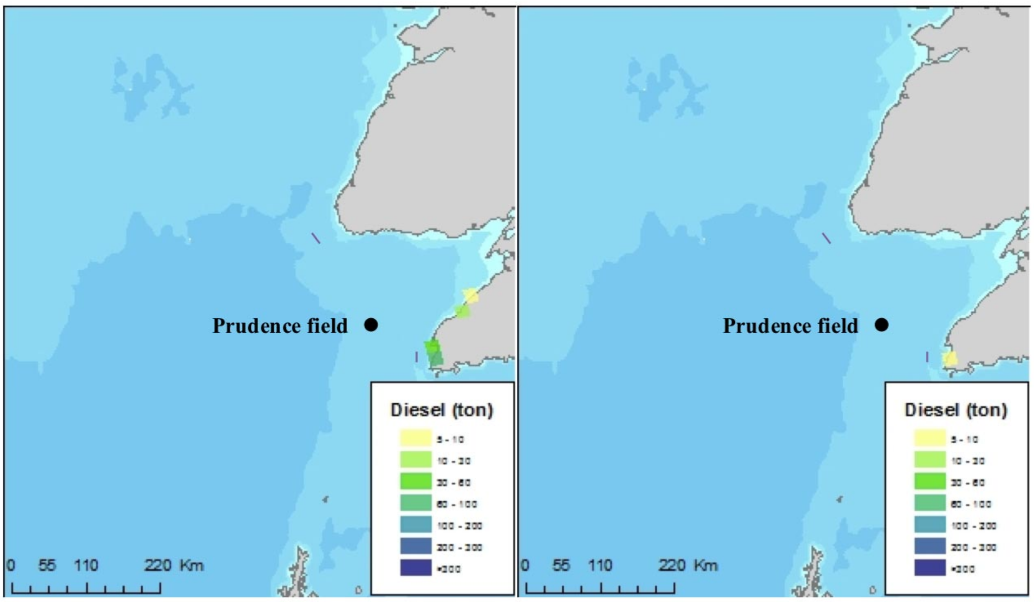
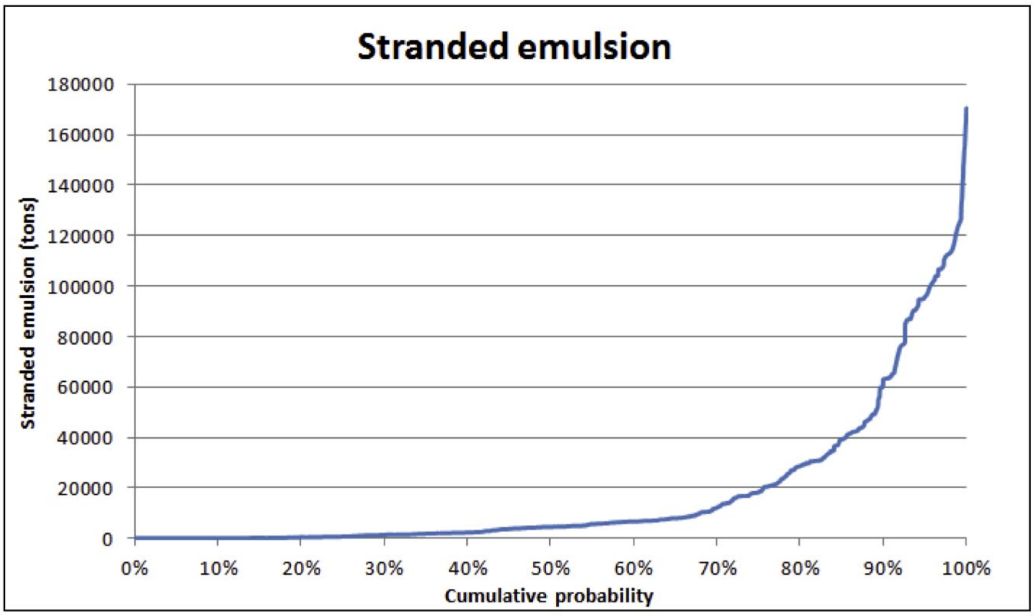


Figure A27 shows the total amount of emulsion reaching the shore in the case of a topside blowout during the summer months at the *Prudence Field*, without oil spill response. The amount of oil emulsion reaching the coast varies with the blowout scenario (rate and duration), and with the prevailing wind and current. There is a 90% probability that the total amount of oil emulsion accumulated on shore would be less than 65,000 tonnes. In 50% of the cases the stranded emulsion mass would be less than 4,500 tonnes, given a topside blowout during summer months.

Figure A27 Cumulative probability of stranding of emulsion from a topside blowout (all rates and durations) during summer



Drift time to shore

Figures A28 and A29 show the minimum drift time of oil to the shore in the case of a topside blowout at the sea surface during the summer months at the *Prudence Field*.

The drift time for oil to reach the shore varies with the prevailing wind and currents. The minimum drift time to shore is approximately one day. However, there is a more than 90% probability that the oil would take more than two days to reach the shore in the case of a blowout at the *Prudence Field*, and in about 50% of the cases the oil would reach the shore after four days or more.

Figure A28 Minimum drift time to shore for a topside blowout (all rates and durations) during summer (left) and winter (right)

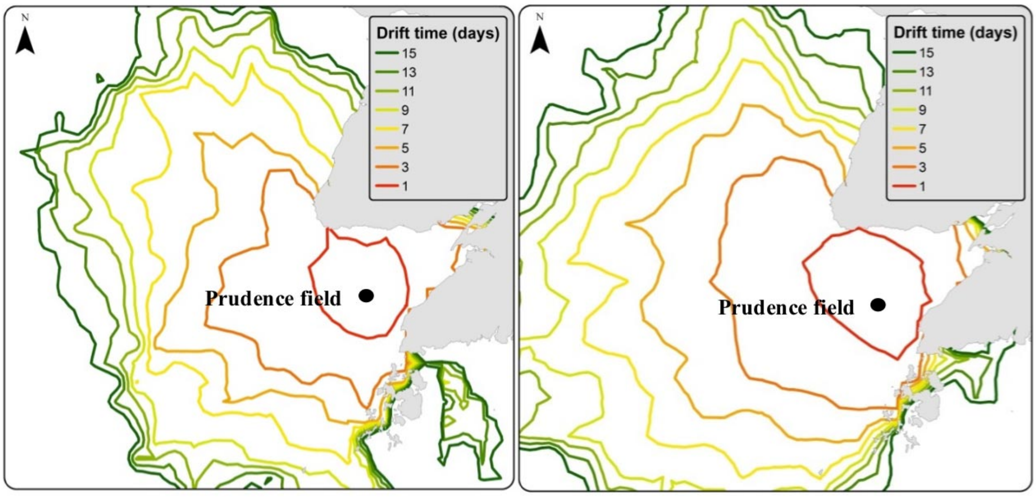
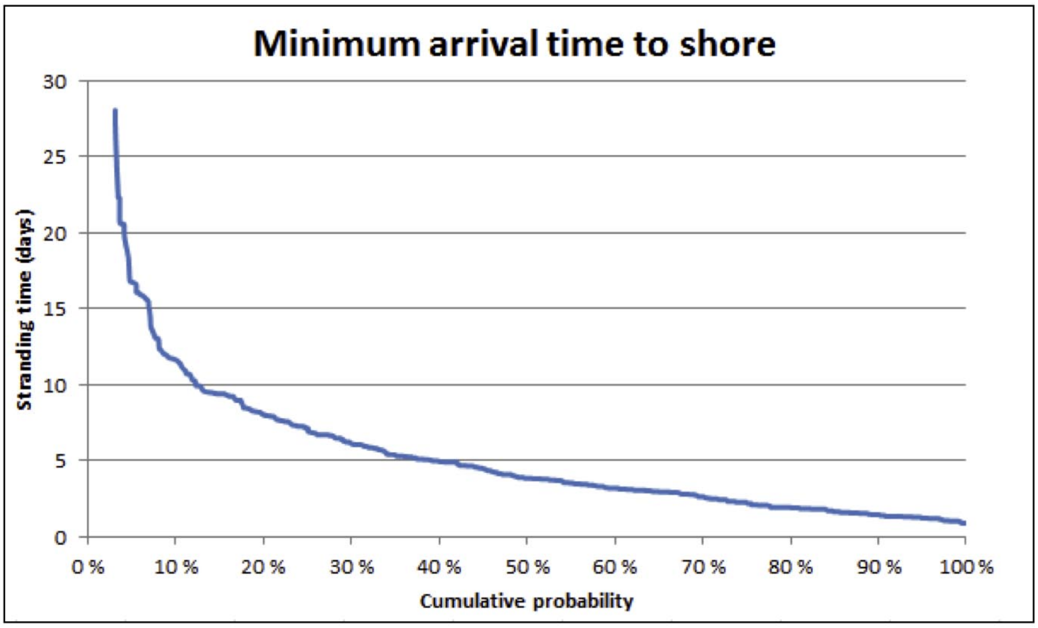


Figure A29 Cumulative probability of minimum drift time to shore following a topside blowout (all rates and durations) during summer



Selecting ecological and socio-economic impact indicators

Ecological and socio-economic impact indicators were selected based on existing mapping of natural resources in the area (not presented in this example). The mapping of ecological resources was based on national and regional databases, as well as on other available information.

For some of the resources, seasonal information is available. This can be coupled with seasonal results from the modelling of oil spill trajectory and fate in order to obtain a seasonal resolution on the final risk results.

Impact indicators selected for this study are:
- shoreline habitats;
- seabirds;
- fish spawning areas;
- fishing areas; and
- areas important for tourism.

A description of the impact indicators is provided in the sections below.

Shoreline habitats

Detailed mapping of the coastline substrate sensitivity according to the ESI categories had been carried out prior to the study. Figure A30 provides an overview of the coastal sensitivities in the area. The mangrove habitat in the Bay of Veritas was selected as an impact indicator due to the high sensitivity of this habitat. This habitat also provides shelter for several rare species.

Seabirds

There are two important bird areas (IBAs) located to the east and south-east of the *Prudence Field* (Figure A31). Both of these areas have populations of highly sensitive seabird species. It is known that most seabirds in the area do not migrate, and are therefore present all year long. However, the IBAs are nesting and nursing areas for an endangered (Red List) coastal diving seabird species. Coastal diving seabirds have a behavioural pattern that increases their potential exposure to oil pollution at the sea surface and shoreline. This, in combination with the species' endangered status makes it highly sensitive to oil pollution. These highly sensitive seabirds species are migratory birds that are only present in the area during the summer months. However, IBA 1 also has another highly sensitive seabird species that is not migrating; this species is not present in IBA 2. IBA 1 is therefore assigned a high sensitivity all year long, whereas IBA2 is assigned a high sensitivity during summer and a moderate sensitivity during winter.

Figure A30 Sensitivity of coastal habitats within the influence area of the *Prudence Field*

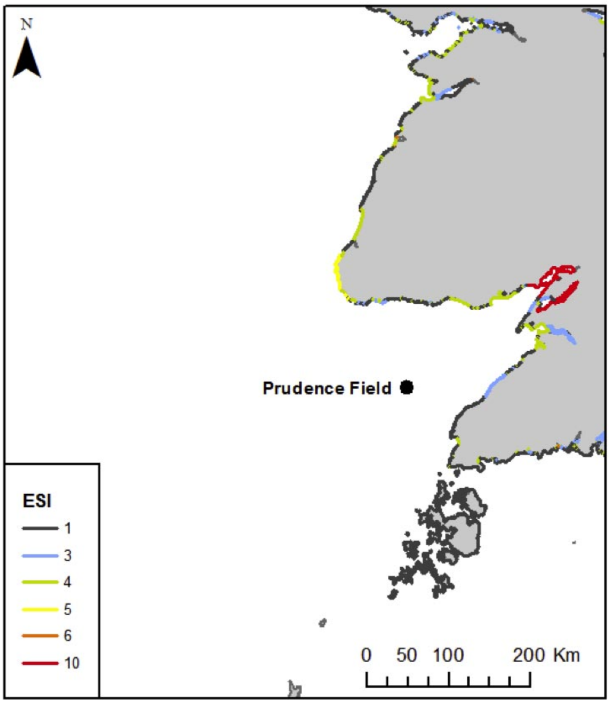
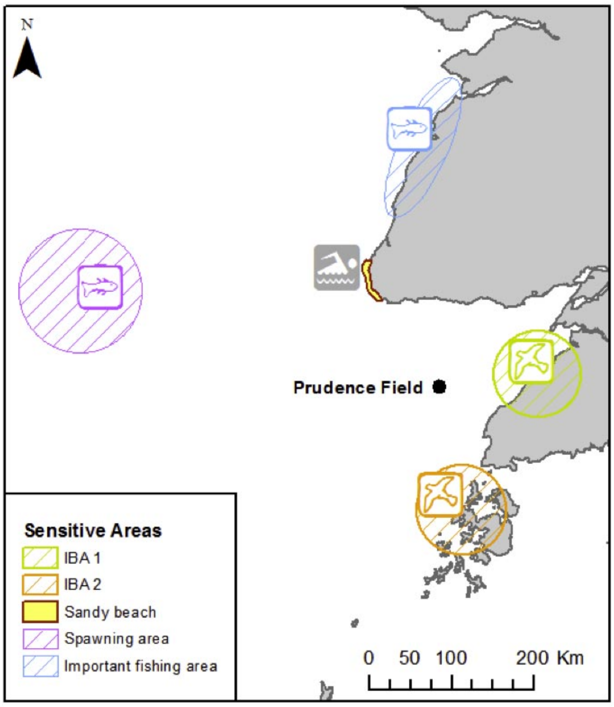


Figure A31 Sensitive areas within the influence area of the *Prudence Field*



Fish and fisheries

An important fishery area is located to the north of Cape Odd. The fisheries are an important source of income in the region, but the economic income is only one-third of that provided by the tourist industry. The fishery area is assigned a moderate socio-economic sensitivity level.

The fish species that constitutes 90 % of the commercial catches in the region has an important spawning area offshore Cape Odd. The spawning area is assigned a high sensitivity.

Areas important for tourism

The Coco Beach, located at Cape Odd, is an important site for tourism due to its beautiful location and its famous gigantic coconut trees (Figure A31). The income from the tourist industry is highly important for the region, and the site is therefore assigned a high socio-economic sensitivity level. There are other important sites for tourism in the area but these are of much lower importance. Coco Beach is therefore the only tourist site that is selected as an impact indicator.

Analysis of ecological consequences

The analysis of ecological consequences is carried out based on results from the modelling of oil spill trajectory and fate, and on the distribution of selected impact indicators. For some indicators the distribution or sensitivity varies between seasons; environmental consequences are therefore analysed on a seasonal basis. The potential quantities of oil are considered together with the probability for oil exposure. Smaller volumes of oil reaching the various impact indicators are assumed to lead to less critical damage. Examples for coastal habitats, seabirds and areas important for tourism are provided in this case.

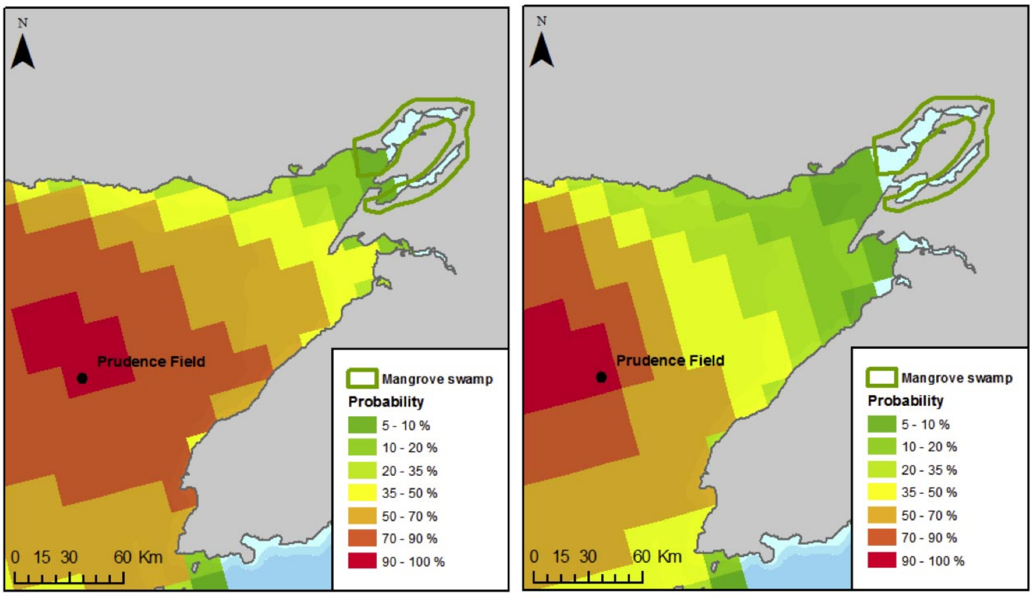
Coastal habitats

The consequences for coastal habitats affected by oil pollution depend on the shoreline type (grain size, slope), its exposure to waves (and tidal energy) and its general biological productivity and sensitivity. Consequences will also vary depending on the amount of oil reaching the habitat.

The mangrove habitat in the Bay of Veritas was selected as the impact indicator due to the high sensitivity of the habitat (ESI 10). See Figure A32.

Figure A32 shows that there is a 5–10% probability that the mangrove habitat will be exposed to oil in the event of a topside blowout in summer (left), and less than a 5% probability in winter (right). The average volumes of emulsion reaching the mangrove habitat are 200–300 tonnes during summer and >100 tonnes during winter (Figure A20). The consequences of a topside

Figure A32 Probability of oil exposure of the mangrove habitat due to a blowout at the sea surface, during summer (left) and winter (right)



blowout are assessed to be *catastrophic* for the mangrove habitat. A subsea blowout and some other scenarios lead to significantly lower amounts of oil reaching the mangroves. Consequences are therefore limited to the *major* category for those scenarios.

Seabirds

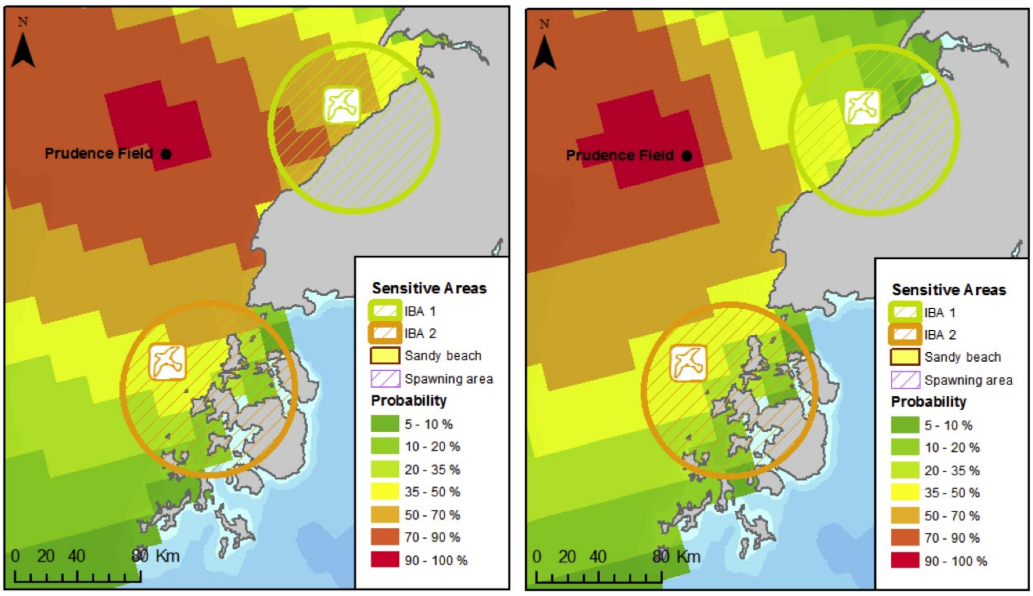
The consequences for seabirds depend on their sensitivity to oil. Based on the available data, it is assumed that oil reaching the important bird areas would lead to *moderate* to *catastrophic* consequences at a population level, depending on oil amounts.

Based on an overlap of the results from the fate and trajectory modelling and the important bird areas, as illustrated in Figure A33, it is possible to estimate the environmental consequences. In addition, the potential quantities of oil are included in the assessment (see Figures A22 to A25).

As shown in Figure A33, there is up to a 70–90% probability that oil will reach IBA1 given a blowout in summer. During winter this probability is lower, being up to 35–50%.

IBA2 has up to a 50–70% probability of exposure to oil given a blowout in summer. Again, the probability is lower in winter, being up to 35–50%. In addition, this area is considered to be less sensitive during winter due to the fact that the most sensitive seabird species are migratory and not present during that season. The consequences for IBA2 during winter are therefore limited to the *moderate* or *major* categories, depending on oil volumes.

Figure A33 Probability of oil exposure of sensitive bird areas due to a blowout at the sea surface, during summer (left) and winter (right)



Results for a subsea blowout are not presented here. Probabilities that the impact indicators will be exposed to oil are similar. However, oil quantities are lower, leading to lower consequences.

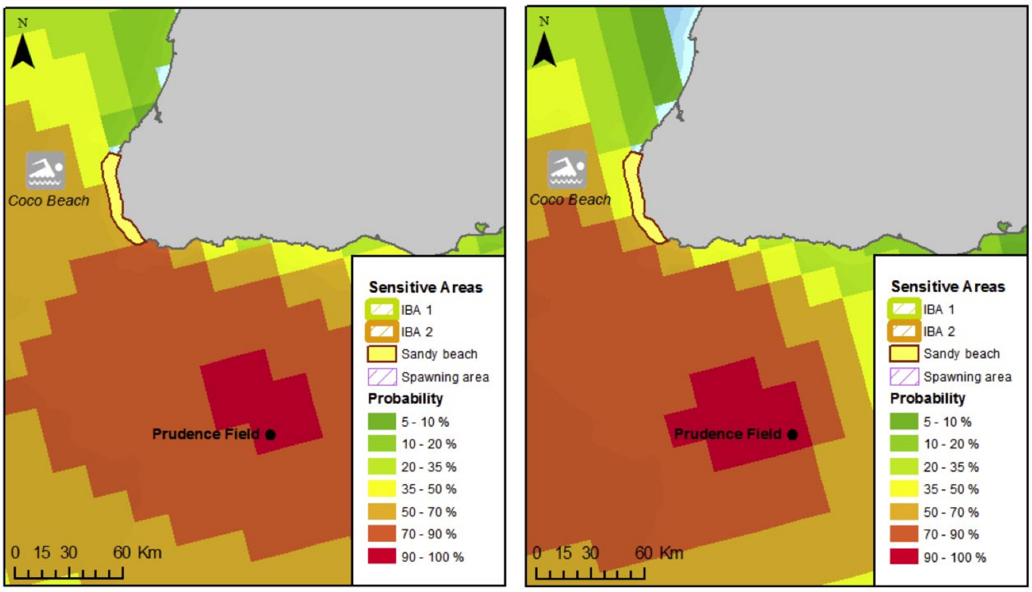
Areas important for tourism

The socio-economic consequences of the exposure of tourist areas to oil depend on the economic importance of the industry in the region, the importance of the exposed area for the industry and the public perception of the damage.

As illustrated in Figure A34, there is up to a 50–70% probability that the Coco Beach will be exposed to oil following a topside blowout at the *Prudence Field* during summer. The probability is slightly lower during winter. On average, more than 300 tonnes of emulsion (per 10 x 10 km grid cell) can accumulate at the beach in the case of a topside blowout (Figure A24) and up to 200 tonnes in the case of a subsea blowout (Figure A25). The socio-economic consequences of exposure of the Coco Beach to oil are assessed to be *major* in the case of a blowout.

The socio-economic consequences of a spill of 11,000 tonnes of oil from the FPSO are also assessed to be *major*, whereas other spill scenarios result in significantly lower volumes of oil reaching the Coco Beach and are assessed as *low* to *moderate*.

Figure A34 Environmental consequences for the tourism site (Coco Beach) following a blowout at the sea surface, during summer (left) and winter (right)

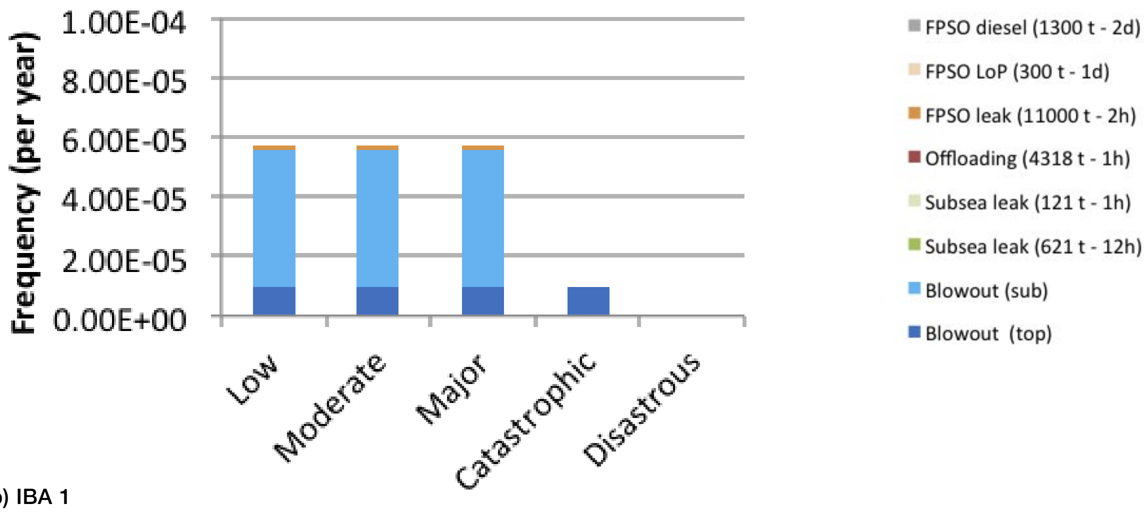


Establishing and evaluating oil spill risk

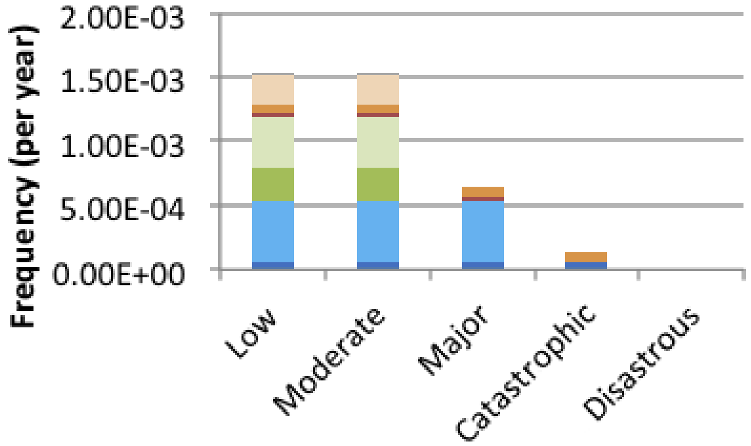
Oil spill risks are established by combining the probabilities for consequences within the five consequence categories with the frequency for the accidental spill scenarios. The risk of exposure to oil of the three important impact indicators (the mangrove habitat, IBA 1 and the tourist beach) is shown in Figure A35. For the mangrove habitat, only the blowouts contribute a significant risk, and only a topside blowout presents the potential for *catastrophic* consequences. In all of the risk indicator areas, the subsea blowout volumes are significantly lower than the topside blowout volumes, and are evaluated as one category lower in consequence. As the blowout probability is relatively low compared to other spill scenarios, the overall risk is at the 10^{-5} level. All spill scenarios may have an impact on the important bird area, and both the large FPSO spills and topside blowouts may have *catastrophic* consequences. The risks of minor consequences are at

Figure A35 Oil spill risk for the three most important impact indicators (mangrove habitat, IBA 1 and the tourist beach)

a) Mangrove habitat



b) IBA 1

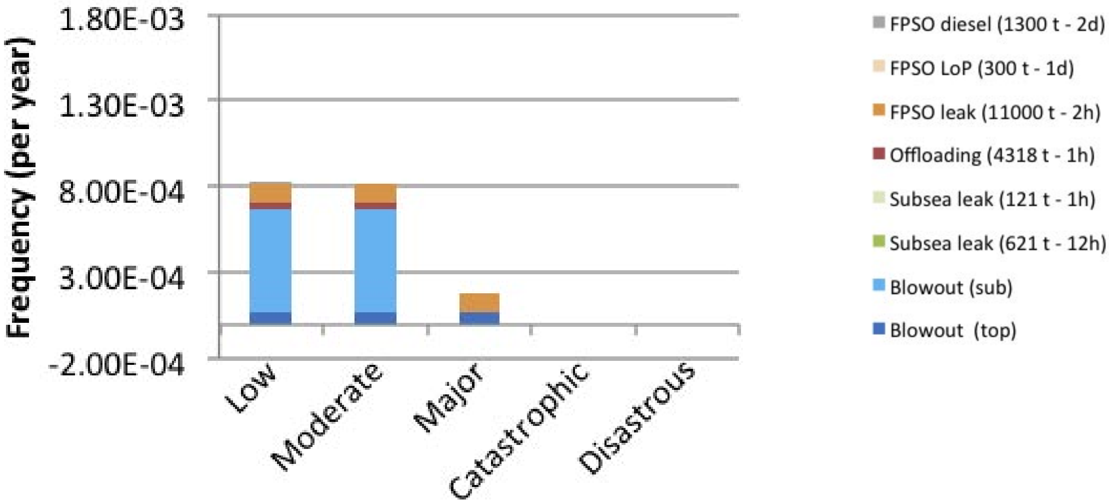


In Figure A35, the risk is shown as the frequency of environmental and socio-economic damage in the various consequence categories, with contributions from the modelled spill scenarios.

continued overleaf …

Figure A35 Oil spill risk for the most important impact indicators (continued)

c) Tourist beach



the $1.5x10^{-3}$ level. The highest oil spill risk level is identified for IBA1. The scenarios that contribute most to the risk of this impact indicator are blowouts, offloading and large FPSO spills.

Figure A36 shows the total oil spill risk for all environmental and socio-economic risk indicators that have the potential to be affected by accidental spills from the *Prudence* oil field. The risk for the fishing area is very low, with a low probability of impact from a limited number of spill scenarios; consequences for the fishing area are low and time limited. The areas of highest risk are the important bird areas (IBA1 and IBA2) and the important tourist area at Coco Beach.

Figure A36 Total oil spill risk for all environmental and socio-economic risk indicators that have the potential to be affected by accidental spills from the *Prudence Field*

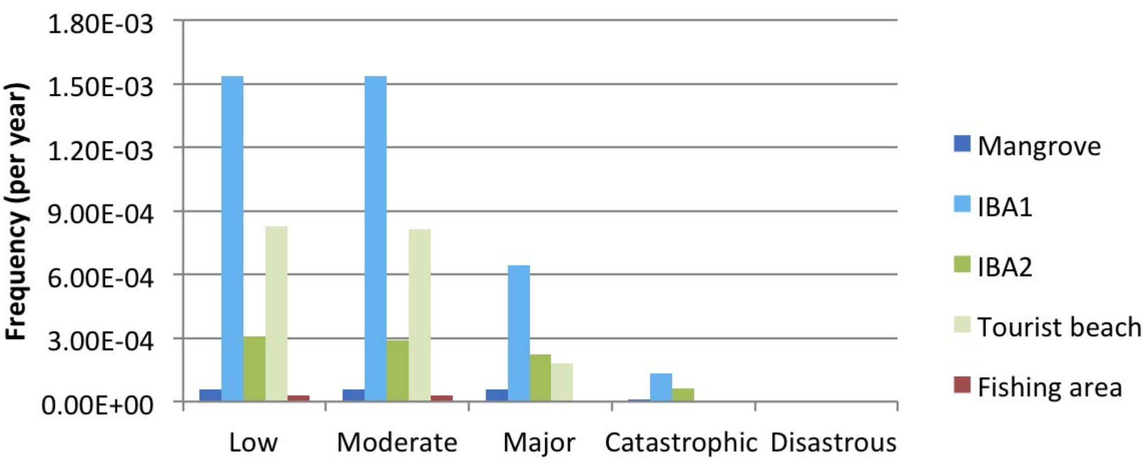
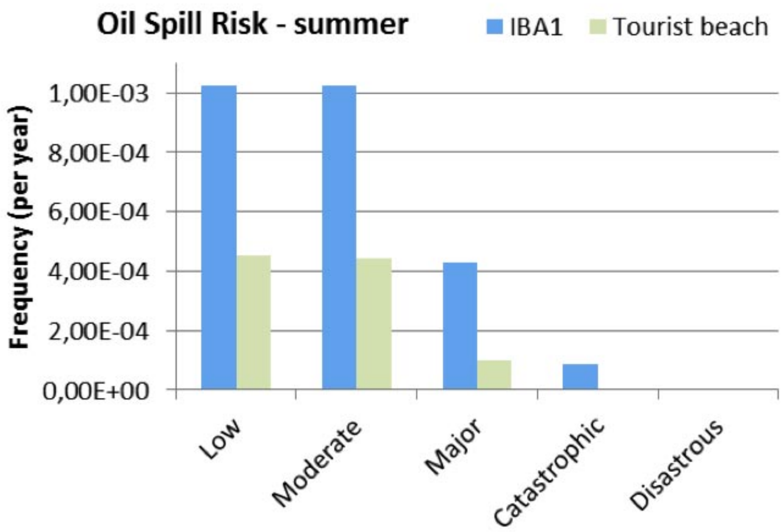
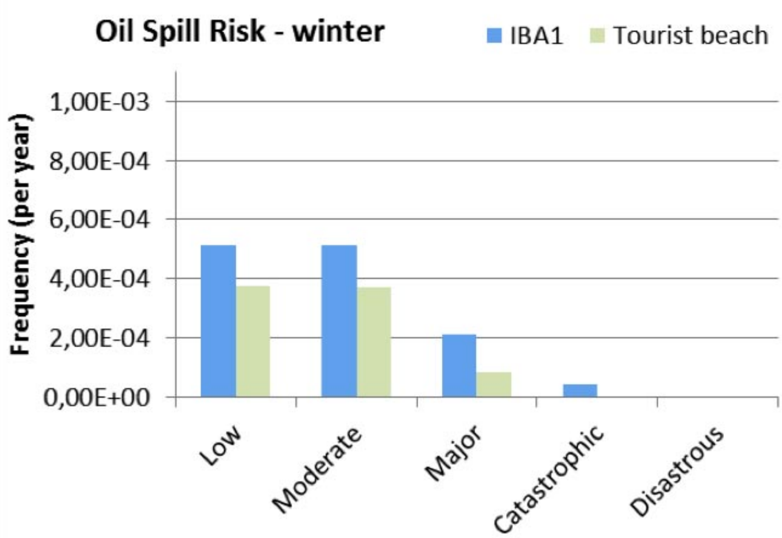


Figure A37 shows the total oil spill risk for the two impact indicators, IBA1 and the tourist beach, for both the summer and winter seasons. IBA1 is at a lower risk during winter due to a lower probability of exposure to oil during that season (as shown in Figure A33). In addition, the average volumes of oil reaching IBA1 during winter is lower than during summer (Figure A24).

For the tourist beach, there are fewer seasonal variations in the probability of oil exposure and volumes of oil, but the oil spill risk is slightly lower during winter. These findings indicate that it can be beneficial to plan for high-risk activities during the winter period. This will reduce the oil spill risk for the *Prudence Field* and minimize the potential consequences in the event of a spill.

Figure A37 Environmental risks for IBA1 and the tourist beach from accidental spill scenarios at the *Prudence* oil field, during summer (top) and winter (bottom)



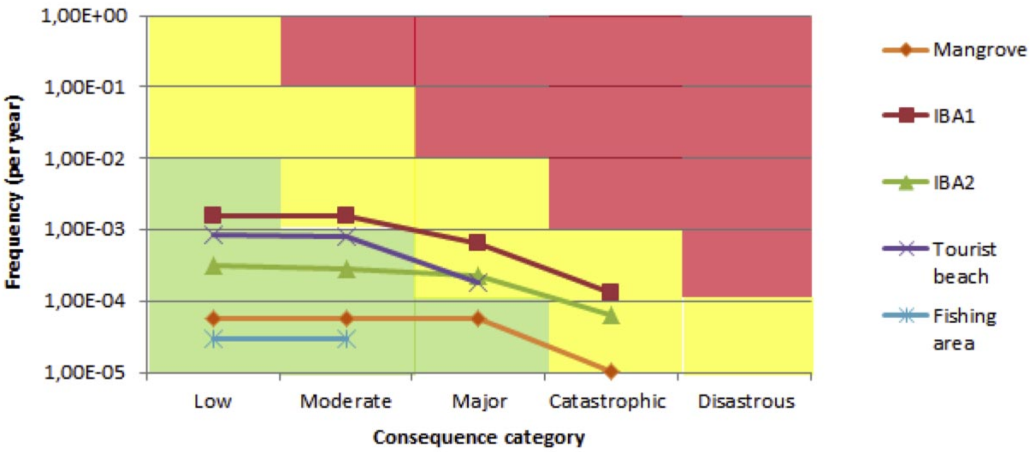


In Figure A37, environmental risk is shown as the frequency of environmental damage in the various consequence categories.

Figure A38 shows the risk levels plotted against the environmental tolerance criteria. Results show that the risk is tolerable for all risk indicators, but that the risk level is mostly in the yellow ALARP area and risk reducing measures should be evaluated according to the ALARP principle.

Figure A38 Oil spill risk for ecological and socio-economic resources from accidental spill scenarios at the *Prudence* oil field.

Right: oil spill risk is plotted against tolerance criteria for environmental damage in the various consequence categories. The red area represents an unacceptable level of risk.



According to the ALARP principle, risk reducing measures are identified as part of the OSRA. Measures are identified and placed in order of priority for those scenarios that have the highest contribution to the risk picture, i.e. blowout, offloading and spills from the FPSO (including ship collision).

The following main measures are identified:

- Plan for capping and containment (consequence reducing measure). Risk reduction related to capping and containment for the *Prudence Field* is presented in Box A1.
- Ensure proper testing and maintenance of the blowout preventers to be used during the drilling activities (probability reducing measure).
- Monitor offloading with use of topside sensors.
- Carry out a navigational risk study and further actions (probability reducing measure).
- Monitor subsea systems by using leak detection sensors at all times (spill size reduction).
- Use corrosion protection for subsea systems (probability reducing measure).
- Prepare an oil spill response plan (consequence reducing measure).

The risk reduction measures are evaluated following the ALARP principle: the costs of implementation are estimated, and each risk reduction measure is implemented unless it can be shown that the cost of a measure is grossly disproportionate to the benefit to be gained.

Input to oil spill planning

Information and results gathered throughout the OSRA process may be useful as an input to oil spill response planning. Information which is considered particularly valuable as an input to response planning includes:

- a list of potential spill scenarios, associated oil amounts and likelihood, for dimensioning purposes;
- oil weathering properties, and the potential challenges in relation to recovery or dispersion;
- maps of the influence area, oil amounts at the sea surface, emulsion amounts on the coastlines and concentrations in the water column, for dimensioning and prioritization purposes;
- maps and statistics on minimum oil arrival time at the shore;
- mapping and evaluation of sensitive environmental resources in the influence area of the field, including seasonal variations;
- the oil spill risk of prioritized impact indicators, for response prioritization; and
- the oil spill risk of the different scenarios, including topside/subsea evaluations.

Box A1 Example of evaluation of risk reduction of capping for the *Prudence Field*

Capping as a risk reducing measure

Capping may be used as an intervention measure in case of a loss of well control (blowouts) on subsea wells. It has the potential for reducing the overall duration of a blowout, hence reducing the overall amount of oil spilled to sea, and limiting the resulting environmental consequences.

In this example, capping is evaluated as a risk reducing measure at the *Prudence Field* in case of a blowout on a subsea well. The design of the capping stack available in the area would make it suitable for capping blowouts from drilling, completion, workover and producing subsea wells. The water depth and fluid characteristics are considered compatible with the use of such measure.

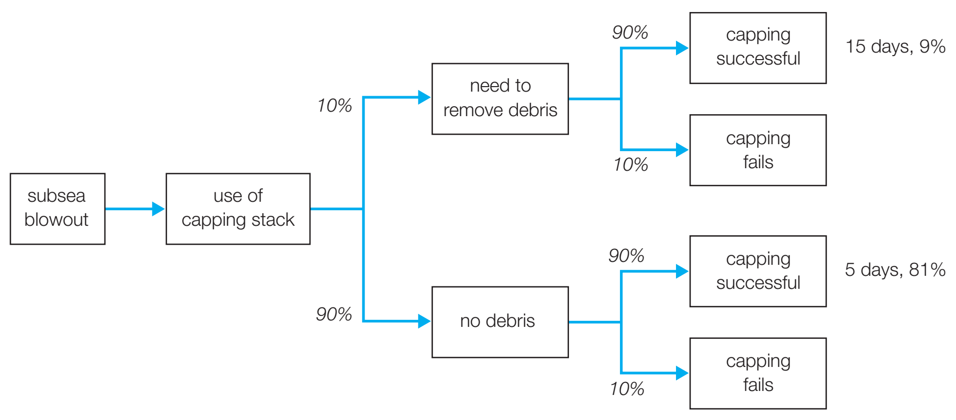
Appropriate equipment is available at port in the Bay of Veritas, circa 200 km from the field location. Therefore, it is estimated that, in case of a blowout on a subsea well, the equipment could be mobilized to site and successfully installed in about five days. This is considered to be the most likely duration for successful capping at the *Prudence Field*. However, should for example the facilities be lost due to the blowout, there is a potential need to remove debris to secure access and apply the capping stack on the wellhead. In that situation, it is estimated that debris removal could take up to 10 additional days, bringing the overall duration for successful capping to 15 days. Finally, there is a low probability for capping not being successful at the *Prudence Field* due to other unexpected factors, or that the operation may take more than 15 days. This probability is estimated to be 10% for this example. Containment complements capping capability, and is designed to support incident response in rare scenarios where well shut-in is not initially possible. A containment system that brings leaking oil from a subsea wellhead to the surface in a safe and controlled way, ready for storage and disposal could be operational within approximately 30 days and further reduce the impacts shown in this example.

The event tree below provides an overview of the potential scenarios:

continued …

Box A1 Example of evaluation of risk reduction of capping for the Prudence Field (continued)

Figure A: Event tree analysis for capping



Combining the capping scenarios with the blowout duration from Table A9 results in the duration probabilities for a subsea blowout as presented in Table A10 below. As no risk reducing measures are considered for topside blowouts in this example, the duration probabilities for a topside blowout remain unchanged. In some situations, a topside blowout from a floating installation may be converted into a subsea blowout if the floater is disconnected. This should be addressed in the topside versus subsea blowout frequency distribution.

Table A10 Blowout durations with the use of a capping stack

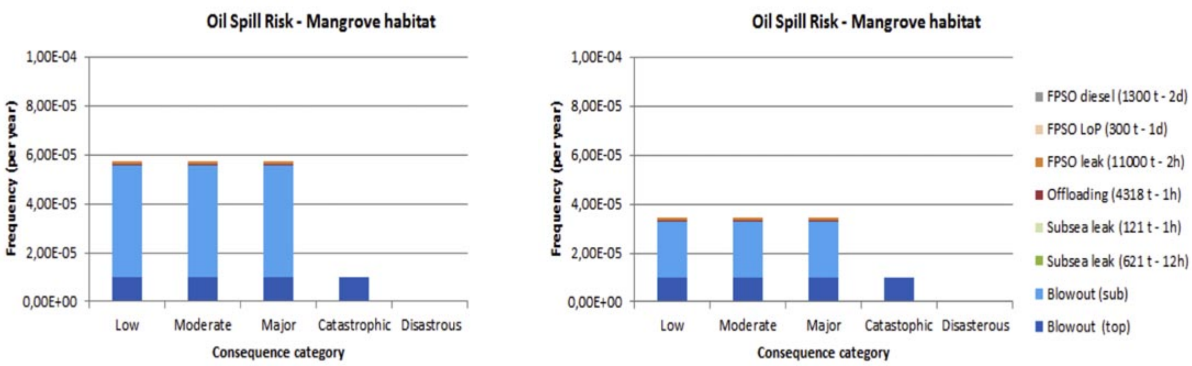
Scenario	Location	Spill duration (days)			
		2	5	15	50
Blowout—development drilling and completion/ production/workover	Surface	55%	18%	16%	11%
	Subsea	44%	49%	5%	2%

The resulting environmental risks are then evaluated. Figure B (opposite) present the risk to mangrove habitats without capping (left) and with capping (right).

continued …

Box A1 Example of evaluation of risk reduction of capping for the Prudence Field (continued)

Figure B: Oil spill risk for the sensitive coastal mangrove habitat, without capping (left) and with capping (right). Risk is shown as frequency for damage in the various consequence categories and with contributions from the modelled spill scenarios.

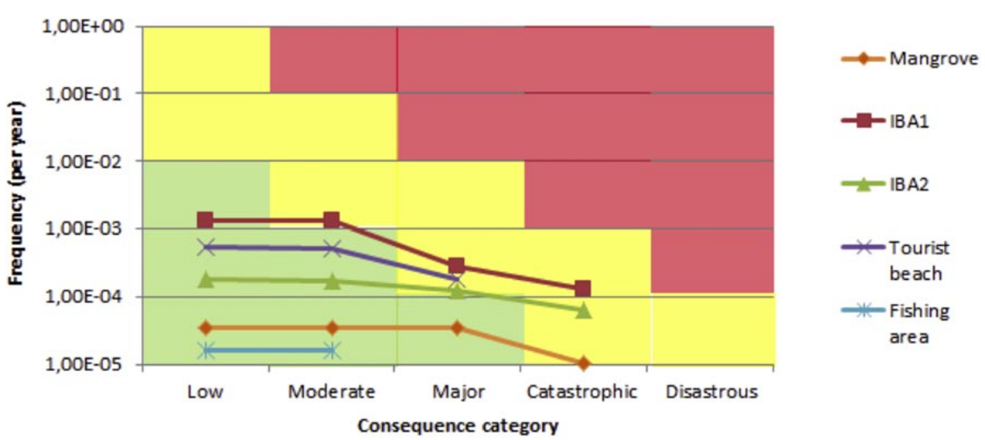


The implementation of capping as a risk reducing measure for subsea blowouts at the *Prudence Field* would lead to a frequency reduction of about 50% for damages to mangrove habitat.

Remark that other risk reducing measures can be implemented and the effect of these measures should also be included in the assessment.

Figure C shows the risk levels plotted against the environmental tolerance criteria. When compared to Figure A38, results show a risk reducing effect of capping for all ecological and socio-economic resources.

Figure C: Oil spill risk for ecological and socio-economic resources from accidental spill scenarios at the *Prudence Field*, with the use of capping as a risk reducing measure for subsea blowouts. Oil spill risk is plotted against tolerance criteria for environmental damage in the various consequence categories. The red area shows unacceptable risk level.



Comparison of the OSRA approaches shown in the previous examples

Tables A11 and A12 summarize the different approaches presented in the previous two examples. Table A11 presents the main conclusions that can be drawn from the results in these examples, and Table A12 gives an overview of the main input data that are required together with the types of results provided by the two approaches. Because of the different approaches taken, some aspects in the conclusions from the two studies are also different. In general, a qualitative approach taking into account less, or more, uncertain information is expected to provide more conservative risk results than a detailed quantitative approach. The more detailed quantitative approach may also provide slightly different conclusions relating to the risk of the different scenarios etc., as the input data is more refined and more aspects are taken into account.

Table A11 Main conclusions from the two different approaches

Aspects	Qualitative approach	Quantitative approach
Total risk level	Risk assessed per scenario	Total risk level quantified in addition to risk per scenario
Environmental resources most at risk	Mangroves and IBA1/IBA2	IBA1/IBA2 and Tourist beach
High risk scenarios	• Blowout • Medium subsea and FPSO spills • Small subsea spills	• Blowout • Offloading • Large FPSO spill (11,000 tonnes)
High risk season	NA	Summer
Tolerability	The risk for the mangrove habitat is not tolerable	The risk is tolerable
Risk reduction requirements	Required	ALARP requirements
Top three risk reducing measures (except for oil spill planning)	1. Ensuring proper testing and maintenance of blowout preventers (probability reducing measure). 2. Leak detection sensors for subsea production systems (consequence reducing measure). 3. Diesel tank integrity monitoring (probability reducing measure).	1. Ensuring proper testing and maintenance of blow-out preventers (probability reducing measure). 2. Monitoring of offloading by topside sensors (consequence reducing measure). 3. Navigational risk study and further actions (probability reducing measure).

Table A12 Main types of input data required, and output data provided by the two different approaches

Aspects	Qualitative approach	Quantitative approach
Accidental scenarios		
Scenarios	Tiered approach, few scenarios	Multiple scenarios, overall activity level
Degree of detail	Semi-quantitative evaluation	Fully quantitative evaluation (based on flow modelling, statistics)
Scenarios—blowout	1 rate, 1 duration	Matrix of different oil flow rates and durations
Trajectory and fate modelling		
Release location	Topside only	Topside and subsea (3D plume model)
Oil weathering	Statfjord C Blend	Statfjord C Blend and marine diesel
Wind and current data	8 years of data	35 years of data
Current data	4 km resolution for current	4 km resolution for current
Backwashing	Yes	Yes
Modelling results	Annual values	Seasonal values
Modelling results	• Influence area (probability for oil) • Minimum drift time to shore (statistics)	• Influence area (probability for oil) • Average oil amounts • Total hydrocarbons (THC) concentration in the water column • Emulsion volumes at the shoreline • Minimum drift time to shore (map and statistics)
Environmental resources		
Environmental resources	Map of vulnerable resources, no seasonal variations	Map of vulnerable resources, seasonal variations available
Coast type and sensitivity	Shoreline ESI map	Shoreline ESI map
Consequences		
Method	Overlap of influence area and impact indicators location	Overlap of influence area and impact indicators location
Consequence evaluation	Taking into account the probability of exposure	Taking into account the probability of exposure and oil amounts
Seasonal variations	No	Yes
Water column exposure	Not including THC levels	Including THC levels from model

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Appendix 3

Net environmental benefit analysis

Introduction

The primary objective of an oil spill response is to safely undertake actions to minimize the overall environmental and socio-economic damages that are caused, or likely to be caused, by an incident. The advantages and disadvantages of different response strategies need to be compared with each other and with the potential for natural recovery. The process of choosing response options that result in the least ecological and socio-economic damage is called net environmental benefit analysis (NEBA).

NEBA should take into account the circumstances of the spill, the practicalities of oil spill combatting actions, scientific understanding of the relative impacts of oil and clean-up options, and a value judgement of the relative importance of the social, economic and environmental resources at risk. Informed discussion and consensus-forming are as important as quantifiable scientific information in this process. The output of NEBA-based considerations is guidance on tactical deployment of strategies in the specific context of the operation's setting. Where there are large seasonal variations in climate and/or environmental and socio-economic sensitivities, the NEBA guidance should reflect this.

Aims of spill response

The aims are to minimize damage to environmental and socio-economic resources, and to reduce the time for recovery. This can involve:

- removing oil from the area of concern and disposing of it responsibly; and
- guiding or re-distributing the oil into less sensitive environmental components.

The initiation of a response, or a decision to stop cleaning and leave an area for natural recovery, should be based on an evaluation made both before an oil pollution incident (as part of the response planning process) and through field observations and assessments during ongoing response operations if an incident occurs.

The evaluation process

Evaluation should be integral to the response planning teams' consideration and discussions, and should typically incorporate the following steps:

- Collection of information on physical characteristics, ecology and human use of environmental and other resources of the area of interest.
- Review of previous spill case histories and experimental results which are relevant to the area and to response strategies which could be used.
- On the basis of previous experience, predict the likely environmental outcomes if the proposed response is used, and if the area is left for natural clean-up.
- Compare and weigh the advantages and disadvantages of possible responses with those of natural clean-up.

Conclusions

IPIECA has published guidance on NEBA, which draws the following conclusions. These are prefaced by emphasizing that some damage caused by specific response options may be justifiable if the response has been chosen for the greatest environmental and socio-economic benefit overall:

- Groundwork for evaluation of response options is best done before a spill as part of the scenario action planning.
- The advantages and disadvantages of different responses should be weighed up and compared both with each other and with the advantages and disadvantages of natural clean-up.
- Pre-selected response options need to be verified for applicability when a spill occurs, and such a review should be an ongoing process in cases of lengthy clean-up operations.
- Offshore and nearshore dispersant spraying can lead to an outcome of least environmental harm.
- For onshore evaluation, it is necessary to consider both the shore itself, and the systems which interact with the shore.
- In many cases of oiling there is no long-term ecological justification for clean-up.
- For extremely heavily oiled shores, moderate clean-up can facilitate ecological recovery, but aggressive clean-up may delay it.
- In most cases of shore oiling, where moderate clean-up is considered likely to reduce the damage to socio-economic resources, wildlife using the shore (such a turtle nesting, seal haulouts and bird roosting or feeding) or nearshore habitats, this will not make a significant difference to the ecological recovery times of the shore.

NEBA should form an integral part of the oil pollution emergency planning process, so that effective and justifiable response decisions are made rapidly. The response planning process should take into account national response policy, where developed, and also engage relevant stakeholders, such as fisheries and tourism interests, nature conservation agencies and local communities. This will allow these interest groups to provide input, so that their concerns can be raised, and compromises reached and explained where necessary. This should ensure that if an incident occurs, response decisions receive endorsement from competent national and local authorities and are understood by appropriate stakeholders.

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Appendix 4

Response strategies

Various strategies are available for responding to oil pollution on the open sea, near shore or stranded on shorelines. The main strategies are outlined below to provide guidance to the scenario action planning team. Further information is available through the Technical Information Papers produced by ITOPF—these are available from their website at www.itopf.com.

A variety of strategies may be used throughout the response to an incident. In the case of a major oil spill, it is likely that different strategies may be deployed simultaneously. In such cases, specific geographic area(s) should be allocated for each strategy, with a focus on utilizing and optimizing each strategy to maximize the net environmental benefit of the overall response. For example, in the case of a large offshore oil spill, an effective response strategy may involve the following:

- Addressing the spill as close to the source (and as far offshore) as possible, first controlling the subsea spill and then applying appropriate quantities of dispersants.
- Oil that surfaces nearest to the well head should be addressed through the surface application of dispersants and, when conditions allow, mechanical recovery and/or in-situ burning. Response activities close to the well head need to be coordinated closely with other spill response and well containment activities.
- Beyond the immediate vicinity of the well head, aerial dispersant application should be used to treat oil that has escaped the near-field mechanical recovery and in-situ burn efforts.
- Further from the well head, both dispersant application and mechanical recovery using vessels of opportunity should be deployed to combat floating oil. Accurate targeting of oil through visual observation and remote sensing from manned and unmanned aircraft, satellites and other platforms should form a key part of the response.
- Finally, protective booming of priority areas should be conducted as identified through shoreline assessments and clean-up teams.

Safety, health and security considerations

Ensuring the safety and health of workers and the general public is paramount, and a response to oil pollution should be carried out without undue safety risks. This means that safety risk mitigation measures, such as establishing controlled entry at polluted sites, wearing personal protective equipment and the use of safe working practices supported by suitable training, should be an integral part of response operations.

In cases where available measures to reduce the risk of injury or detrimental health implications cannot achieve tolerable levels of safety, the use of a response strategy may be not viable until conditions change. Examples include situations where fresh oil is releasing vapours, or where sea conditions prevent safe working on the deck of a vessel. Where there are security threats to response personnel, limitations on operations may also need to be imposed.

The IPIECA-OGP guidance, *Oil spill responder health and safety* provides further information on ensuring effective safety during oil spill response operations.

Surveillance and assessment

Although surveillance is not an active intervention to treat or remove oil pollution, it is critical to effective response both in the initial stages of an incident and during ongoing response operations. The assessments stemming from surveillance should be used by the incident management team to ensure timely and suitable mobilization and the coordination and prioritization of oil spill response activities. This includes decisions concerning which response strategies to employ and their geographic extent. In some scenarios, surveillance may be used to observe the natural break-up and dissipation of oil pollution without the need for active intervention.

Observation of floating oil slicks may be possible either from a high point on an offshore installation or from a vessel. These viewpoints may be used in the initial assessment of a reported spill. However, both of these viewpoints suffer from serious limitations—the angle of view and areal coverage is restricted. The oil pollution emergency plan should therefore contain procedures for the rapid implementation of an aerial surveillance plan. The following elements should be addressed in the oil pollution emergency plan:

- Provision for 24-hour availability of aerial surveillance, set within the operation's practical constraints. Mobilization of an initial aerial surveillance platform should typically be within a maximum of six hours of a confirmed report of spillage during daylight hours. For ongoing incidents, capability for at least twice-daily overflights should be planned, and the availability of aerial platforms should be established to support the number of planned overflights. The selection of aircraft should take into account practicalities including safety performance, location of airstrips and helicopter landing pads, navigational aids, and the endurance/range of aircraft and their ability to provide all-round viewing.
- In addition to aerial assessment of the extent and appearance of oil on water, the efficiency of an offshore response strategy can be significantly increased by targeting oil spill response operations using aerial support. This can include directing containment systems and dispersant spraying operations to thicker patches of oil slicks. The availability of aerial platforms should take account of these requirements (i.e. the number and capability of aviation contractors).
- Procedures for joint flights with a representative from a relevant authority with responsibility for oil pollution are recommended. This will facilitate a consistent approach to oil observation and allow any differences of interpretation to be addressed during the flight.
- Observers should be trained in a systematic and consistent approach to recording and reporting observations. The oil pollution emergency plan should provide guidance on recording formats and terminology. Quantification of observed slicks should be attempted following either national requirements or published guidance, e.g. guidelines from IMO. Where available, remote sensing techniques may be integrated into the surveillance plan; this may include either satellite monitoring or specialized airborne detectors (e.g. infrared and side-looking radar).
- If regulations and permitting from aviation authorities allow their use, small unmanned aircraft can provide safe and effective aerial surveillance covering both visual and infrared wavelengths. These may be used to supplement or replace manned surveillance flights.

Containment and recovery of oil

The use of floating barriers (booms) and devices to recover contained oil (skimmers) can be an effective method to limit the spread of oil and remove spilled oil from the marine environment. It is common for national regulations to identify containment and recovery as either a primary or preferred strategy for offshore response.

> IMPORTANT: there are significant potential constraints and limitations to the effectiveness of this strategy in open waters offshore, due to the nature of most spilled oils to spread freely and fragment, coupled with the relatively slow encounter rate of containment systems, and restrictions on their ability to operate safely and effectively in rougher sea conditions.

A systematic approach to planning offshore containment and recovery operations is recommended and should include:

- a suitable length and type of containment boom, matched to anticipated sea conditions and available deployment vessels;
- a recovery device with the ability to match the anticipated oil characteristics and amount of oil which can realistically be expected to be contained in the boom, taking into account the encounter rate of the system; predicted changes in oil characteristics, particularly viscosity, should be considered, as this may lead to either different or adaptable recovery devices being required through the incident;
- the ability for response vessels to communicate directly with a command centre or aerial surveillance ‘spotter’ aircraft;
- offshore storage capacity commensurate with the system’s expected recovery rates of oil/water mixture during a stated operational period;
- vessel(s) capable of deploying the boom and recovery device in suitable configurations, which may include various techniques to enhance recovery, such as gated U-booms to concentrate the oil;
- trained vessel crew(s) and operators for the specialized equipment; and
- ports or harbours able to act as staging areas for equipment loading and reception of recovered oil/water when offshore staging is full.

The number of systems available at each tier should be clearly stated and take into account the practical limitations and prevailing sea conditions associated with potential discharge scenarios. It is not recommended that discharge volumes are used to mathematically calculate the number of offshore containment and recovery systems, based on nominal capacity of recovery devices. The number of systems available should reflect the ability to mount a response within realistic operational and practical constraints. For example, once oil slicks have spread and fragmented over large sea areas it is not feasible to expect containment to be efficient, hence the addition of more systems is unlikely to make significant additional practical contribution to the volume of oil recovered, despite a theoretical increase in recovery capacity.

The performance requirements and suitable metrics for offshore systems should be stated, and should include, as a minimum, the mobilization and deployment time to the operational theatre.

Dispersants

Dispersants are chemicals that are formulated specifically for use in oil spill response operations. They act to enhance the natural dispersion of oil into tiny droplets in the water column, which subsequently dilute and degrade. This response option has high potential to increase the effectiveness of a response for large offshore spills, as it has higher encounter rates than other options and enables the treatment of oil far offshore, mitigating the potential for oil to reach the shoreline.

There are limitations to the ability of dispersants to disperse oil in some cases—this is primarily a function of the oil's viscosity. Some oils are too viscous to be dispersed when spilled, and other oils may change their properties over time due to weathering and become difficult to disperse. This imposes a window of opportunity for dispersant use, which can usually be estimated in the scenario action planning, through reference to the oil fate modelling. Having pre-approvals in place for dispersant use is strongly recommended as it allows responders to take action within the window of opportunity if dispersants are found to be a favourable strategy.

Surface dispersant use

Where dispersants are a viable response option for use on the sea surface, the following elements should be addressed in the oil pollution emergency plan:

- The regulatory framework and policy, including the dispersant products approved and the circumstances under which their use is, or may be, approved: in those countries where dispersants are a viable option but where no established dispersant products or approvals for their use are in place, it is recommended that an operator's oil pollution emergency plan presents procedures mirroring those from a country where dispersant policy is mature and proven. Operators should consider working with the relevant authorities to either develop or clarify national dispersant policy.
- The anticipated effectiveness of selected approved dispersants on the actual or expected oils associated with exploration and production operations, under the prevailing climatic conditions: particular consideration should be given to the oils' viscosity, pour point and seasonal temperatures.
- The potential for pre-approval of dispersant use under defined conditions (often relating to depth of water and distance from shore): criteria for dispersant use should be based on NEBA considerations.
- Development of detailed operational procedures for effective dispersant use, taking into account:
  - Safety concerns: material safety data sheets (MSDS) should be available to all personnel handling dispersants. Dispersants should be applied in line with published guidelines and be geographically discrete from other offshore oil pollution response activities.
  - Dispersant stockpiles and supply chain: quantities of dispersant stockpiles can be calculated in alignment with planning the scenarios' tiers. The recommended (concentrate) dispersant to oil ratio is typically 1:20 for planning purposes, though this ratio may be modified where specific information exists, e.g. from laboratory testing of the oil and dispersant. Credible worst-case discharge will determine the maximum quantity of dispersant which may be needed per day. Where scenarios require access to global dispersant stockpiles, the oil pollution emergency plan should identify the mobilization time

    to the operational theatre and the logistical means for delivery to forward staging locations. Dispersant stockpiles capable of addressing any Tier 1 or Tier 2 scenarios, or mounting a response prior to arrival of global stockpiles, should be either established or identified.
    - Specialized dispersant application equipment: suitable means to target and apply dispersant (vessel and aerial spraying systems) should be identified for each tier.
- Procedures for monitoring the dispersant application's operational efficacy.
- Periodic testing of dispersant stockpiles for integrity of storage containers and continuing effectiveness of the product: it is recommended that samples are collected and tested for effectiveness every five years.

Subsea dispersant use

Direct injection of dispersants into a subsea oil discharge is a viable tool for subsea oil spill response. Systems have been developed that integrate emergency well capping and dispersant injection. It is recommended that consideration be given to the use of subsea dispersant as a primary response tool, provided that it is appropriate with respect to the risk profile and environmental setting.

Where subsea dispersant application is considered, the following additional elements should be addressed in the oil pollution emergency plan:

- The timescale for mobilizing and deploying an injection system as quickly as possible, as documented in a logistics plan.
- Regulatory approvals for the use of subsea injection, including product pre-approval for the major global stockpiles identified as the source of dispersant for large-scale application. Where procedures for approval do not exist, consideration should be given to encouraging the development of such procedures by relevant authorities.
- The direct injection of subsea dispersant may substantially reduce the volumes of dispersant required. A dispersant to oil ratio of 1:100 or more may be suitable for subsea planning purposes; this figure can be modified where specific testing data are available.
- Procedures for monitoring the dispersant application operations including dispersant efficacy.

In-situ burning

In-situ burning (ISB or 'controlled burning') is the deliberate ignition of contained floating oil to rapidly remove it from the marine environment. Containment and concentration of floating oil for burning is carried out using specialized fire-resistant booms or through natural containment (e.g. oil held against a shoreline or trapped in ice).

Where ISB is considered a viable response option, the following elements should be addressed in the oil pollution emergency plan:

- Pre-approval from relevant authorities for the use of ISB.
- Development of detailed operational procedures for effective deployment of the strategy, taking into account safety concerns, air emissions, specialized equipment as needed (e.g. fire-resistant booms and igniting tools), prevailing and forecast current/wind data and logistical requirements.
- The use of aerial support to target offshore ISB operations addressing thicker patches of oil to significantly increase the efficiency of at-sea operations.

- Procurement routes for additional fire-resistant booms where it is envisaged that ISB operations may be ongoing.
- Procedures for monitoring ISB operations, taking account of potential environmental impacts and burn effectiveness.

Shoreline protection and clean-up

The oil spill trajectory and fate modelling should provide an indication of which shorelines are under threat of oiling with regard to the representative discharge scenarios. This information should be used to determine the scope and extent of shoreline protection and clean-up contingencies. The relevant coastal local authorities will typically have jurisdiction or responsibility for either directing or overseeing shoreline response operations; liaison with such authorities is usually required prior to undertaking clean-up and protection activities. When planning a shoreline response, close cooperation with the relevant authorities should be considered a high priority.

The oil pollution emergency plan should take into account the following elements in relation to shorelines at risk of oiling:

- How offshore response strategies can either reduce or remove floating oil slicks and thereby enhance protection of shorelines.
- Integration with existing local authority contingency plans.
- Protection priorities or prioritization process for sensitive coastal features (ecological and socio-economic).
- The feasibility of protecting coastal features using shoreline protection measures (barriers/booms). A robust technical appraisal of the viability of considered protection measures should be undertaken. This will avoid unrealistic expectations in terms of the feasibility of protecting certain features. The timescales for mobilizing and deploying protection measures should be commensurate with the expected time that it takes for oil to reach the shoreline in the event of an incident. This will have a direct bearing on the location and extent of shoreline equipment inventories for Tier 1 and Tier 2 spills, as well as the availability of trained personnel and logistics support for deployment. Shorelines at risk of oiling within 24–48 hours are likely to require more detailed guidance in the form of pre-developed tactical protection plans in the oil pollution emergency plan. Shorelines at risk over greater timescales can be considered in a more general context, with detailed protection measures developed during the incident as required.
- Appropriate clean-up techniques for different shoreline types, or references to suitable published guidelines, noting that areas of low recreation or socio-economic value may be considered for natural cleaning, particularly if these areas are subject to high wave exposure.
- Procedures to access non-specialist equipment, labour and consumables likely to be needed for shoreline operations.
- A plan or procedure to establish a Shoreline Clean-up Assessment Technique (SCAT) approach, integrated with the overall incident management team. Published guides[16] to SCAT

[16] NOAA, 2000. *Shoreline Assessment Manual.* Third Edition, August 2000;
IMO/UNEP (2009). *Regional Information System; Part D, Operational Guides and Technical Documents, Section 13, Mediterranean Guidelines on Oiled Shoreline Assessment*. REMPEC, September 2009.

may be referenced to support implementation. Any guides referenced should be easily accessible to management and field personnel.

It is unlikely that significant oiled wildlife activities will take place offshore, due to practical and logistical constraints. Measures to mobilize and establish oiled wildlife response, commensurate with the risks (taking into account the distribution and species of threatened wildlife) should focus on the near shore and shorelines. Published guides[17] to wildlife hazing and rehabilitation may be referenced, though it is likely that specialist groups will be needed to assist in developing wildlife response plans.

Waste management

Oil spill response activities can generate significant quantities of waste, the management of which can become one of the most expensive components of a response. While decisions on the disposal of waste may not need to be made during the emergency phase of a response, it is imperative that waste storage and transportation procedures are established rapidly to ensure that oil spill combatting activities are not compromised by a waste 'bottleneck'.

The following waste management elements should be addressed in the oil pollution emergency plan:

- Regulations relating to waste storage and handling, including any emergency dispensations/procedures which may be applied. Vessels may require specific licensing before waste may be stored using on-board tanks.
- Specific documentation and procedures required for waste tracking, storage and handling.
- Potential waste types and volumes and the range options available for storage offshore and on shorelines.
- Availability of offshore storage to match containment and recovery systems and reduce transit times to storage locations, increasing operational efficiencies.
- Opportunities to decant recovered water from vessels; such opportunities should be considered with a view to maximizing the offshore storage capacity for recovered oil. Where national regulations proscribe oily water discharge, dialogue with relevant authorities is encouraged to seek emergency exemptions allowing the discharge of recovered oily water back into the polluted zone, in the event of oil spill combatting activities at sea.
- Procedures for the segregation of waste streams. Unless other overriding factors are present, the clean-up techniques chosen, particularly on the shoreline, should be ones that result in the minimum amount of waste collected.

Waste handling and disposal can potentially have adverse impacts on the environment. This should be borne in mind and mitigated wherever possible. The potential impact of waste management can be included in a net environmental benefit analysis when comparing strategic options, and can thereby influence strategic decisions during oil pollution emergency planning.

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[17] IPIECA, 2004. *A guide to oiled wildlife response planning.* Oil Spill Report Series Volume 13, January 2004.

Termination of response

Procedures for determining the termination of oil spill combatting activities should be incorporated into the oil pollution emergency plan. An ongoing response should continue to deliver a net environmental benefit and not incur unreasonable costs in relation to the benefits gained. Guidelines concerning criteria or end points for termination of a response may be discussed with stakeholders in advance and included in plans. Termination and sign-off of operations at affected areas is usually undertaken in conjunction with the relevant national authorities. Joint shoreline surveys utilizing the aforementioned SCAT approach may be useful to identify areas where a continued response is likely to be ineffective or fail to achieve a net environmental benefit. It is important to liaise with those undertaking the clean-up to ensure that a consistent approach is taken to terminating operations in accordance with agreed criteria, for example:

- ceasing operations at sea when oil slicks become extremely small and patchy or when only thin oil sheens remain;
- demobilizing inshore and shoreline protection measures when any realistic threat of oiling is gone;
- establishing clean-up endpoints on oiled shorelines, based on beach usage and environmental sensitivity; and
- establishing a longer-term monitoring and clean-up strategy in coordination with key stakeholders, where circumstances dictate.

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Appendix 5

Examples of tactical response planning

Examples of tactical response planning

This Appendix presents examples of tactical response planning, and illustrates how such planning is used to help determine the degree of oil spill response capability.

The examples are based on the qualitative oil spill risk analyses in Appendix 2. These provide oil spill scenarios for a fictitious oil well and FPSO unit, representing the three response tiers as follows:

- Tier 1: a spill of 100 tonnes from a riser leak at the FPSO;
- Tier 2: a spill of 470 tonnes from the FPSO; and
- Tier 3: a blowout causing a spill of 2,000 tonnes per day for 50 days.

The response planning team first identifies the most appropriate response strategies (Appendix 4) for a given scenario and then determines the tactics to be used to implement the selected strategies. The planning team then uses the outputs from the detailed tactical planning to determine whether existing resources can mount an appropriate and credible response to the incident, and to identify specific gaps that may exist in the available resources. Gaps may be addressed by:

- the allocation of additional oil spill response resources;
- the relocation of existing oil spill response resources; and
- improving the cascade of resources into the operational theatre by overcoming potential obstacles to escalation through the tiers.

Existing response resources

The operator of the *Prudence Field* has taken up membership with a Tier 2 cooperative located in a small port on the north side of the Bay of Veritas. This port also serves as the supply base for the *Field's* operations. The Tier 2 facility also provides response services to two other offshore operators in the region.

The main shareholder (60% holding) in the operator is a member of a global Tier 3 oil spill response cooperative and has guaranteed access to their resources. The estimated response time from the nearest facility operated by the Tier 3 cooperative is 20 hours. An airport capable of receiving international cargo jets is located 50 km north of the Bay of Veritas.

The three response scenarios are summarized in Tables A13, A14 and A15.

Table A13 Tier 1 scenario

Spill location:	*Prudence Field* FPSO
Duration of spill:	1 hour
Spill description:	Riser leak
Volume of oil discharged:	≤100 tonnes
Oil type:	Crude oil with properties similar to Statfjord blend
Activity	**Anticipated response actions**
Incident management	Incident Command and Response team is established under the leadership of the Offshore Installation Manager. Notifications are made to onshore headquarters and external agencies in conformity with the oil spill emergency plan.
Surveillance and assessment	A crew transfer helicopter is mobilized within two hours and a trained observer makes an initial overflight. The helicopter provides targeting for vessel dispersant spraying operations, and monitors dispersion and dissipation of the slicks.
Dispersant	Stand-by vessel has an on-board spray system and 5 m^3 of dispersant. The dispersant is deployed within 45 minutes, treating the leading edge of the surface slick in the vicinity of the FPSO. The spilled oil is likely to remain amenable to dispersant up to 24 hours after discharge under ambient conditions. There is sufficient dispersant available on the vessel to treat the spilled oil (dispersant to oil ratio of 1:20) within six hours and no further resource requirements are anticipated. A call is made to the Tier 2 and Tier 3 resources as a precaution but their capability is not mobilized.
Containment and recovery	A supply vessel, equipped with an offshore containment/recovery system (side-sweeping arm) is deployed to the location from the Tier 2 facility as a precaution but not utilized.

Table A14 Tier 2 scenario

Spill location:	*Prudence Field* FPSO
Duration of spill:	12 hours
Spill description:	Riser leak
Volume of oil discharged:	450 tonnes
Oil type:	Crude oil with properties similar to Statfjord blend
Activity	**Anticipated response actions**
Incident management	Incident Command and Response team is established under the leadership of the Offshore Installation Manager. Notifications are made to onshore headquarters and external agencies in conformity with the oil spill contingency plan. A supporting incident management team is established at the onshore headquarters to aid coordination of response and handle media enquiries.
Surveillance and assessment	Day 1 A crew change helicopter is mobilized within two hours and a trained observer makes an initial overflight. A helicopter provides targeting for initial dispersant operations and monitors dispersion and dissipation of the slicks. A proprietary oil spill trajectory model is run to provide prediction of slick movement under prevailing weather. The Meteorological Office provides latest weather forecasting. Day 2 A schedule of ongoing twice-daily overflights is agreed, with company and authority representatives on all flights. The contracted aviation company has three twin-engined helicopters available. The overflights are used to track oil slicks and target vessel dispersant spraying operations to thicker patches of oil. Day 3 Overflights continue to spot remaining slicks, including potential for patches of emulsion. The offshore containment system is directed to observed areas of significant emulsion. *Continued…*

Table A14 Tier 2 scenario (continued)

Activity	Anticipated response actions
Dispersant	Day 1 Stand-by vessel has on-board spray system and 5 m^3 of dispersant. This is deployed within 45 minutes, treating the leading edge of the surface slick in the vicinity of the FPSO. The spilled oil is likely to remain amenable to dispersant for up to 24 hours after discharge under ambient conditions. There is sufficient dispersant available on the vessel to treat approximately 100 m^3 of the spilled oil (dispersant to oil ratio of 1:20) within 6 hours. An additional spraying vessel is mobilized from the Tier 2 facility, with 10 m^3 dispersant. Overnight, the standby vessel collects an additional 5 m^3 from the shore base. A call is made to the Tier 3 resources as a precaution, but their capability is not mobilized. Day 2 Two vessels continue spraying and apply a further 10 m^3 of dispersant, treating up to 200 m^3 of oil. At the end of day 2 dispersant operations cease as the majority of oil is treated (or evaporated), and due to weathering and the emulsification of any remaining spilled oil.
Containment and recovery	Day 1 A supply vessel, equipped with an offshore containment/recovery system (side-sweeping arm), is mobilized from the Tier 2 facility. The vessel is on site within 10 hours, and ready for operation at first light on day 2. Day 2 The supply/containment vessel is directed to commence operations targeting thicker patches of oil under guidance from the surveillance helicopter. The operation is controlled to be geographically discrete from the dispersant spraying activities.
Shoreline protection and clean-up	Days 1–4 As a precaution a small SCAT team is organized by the Tier 2 facility working with the local authorities. Using information based on oil spill modelling and ongoing overflights, protection and clean-up preparations are made for relatively low volumes of emulsion threatening the coast.

Table A15 Tier 3 scenario

Spill location:	*Prudence Field* FPSO
Duration of spill:	50 days
Spill description:	Blowout
Volume of oil discharged:	2,000 tonnes per day = 100,000 tonnes
Oil type:	Crude oil with properties similar to Statfjord blend
Activity	**Anticipated response actions**
Source control	All operations are shut down and a Well Operations Safety Engineer called in for assistance within 6 hours. Additionally a well control consultant is retained and called in; they are expected on site within 12 hours.
Evacuation and fire hazard control	Non-essential personnel are evacuated to the mainland. During the first few hours of the spill, the Site Safety Officer verifies that all sources of ignition are shut down or removed from the area. A shipping exclusion zone of 5 km is established and broadcast.
Well control plan	Day 1 The well control plan is activated, including implementation of well capping backed up by a relief well drilling plan. It is estimated that it will take 9 days to mobilize the capping device with the high potential to shut in the uncontrolled well. It will take approximately 10 days to mobilize relief well rig and spud the well. A further 40 days are estimated to complete the relief well and kill the blowout. Day 5 The capping device is on site and being deployed. Day 9 The capping device is functional and at this point no further oil would be spilled. However, oil spill planning is cautious and anticipates the highly unlikely event that technical problems could occur with the capping mechanism, and envisages that oil spill response operations may need to continue until the relief well is drilled. Day 10 Relief well rig is on site and the well spudded. Day 50 Relief well successfully completed. *Continued…*

Table A15 Tier 3 scenario (continued)

Activity	Anticipated response actions
Incident management	Day 1 An incident management team (IMT) is assembled at the onshore emergency control centre within 60 minutes of the initial report. Working to an Incident Command System (ICS), the team quickly establishes the key management team sections and undertakes initial procedures in conformity with guiding action checklists in the oil spill emergency plan. An Incident Action Plan for the next operating period (the following day) is drafted by the end of the day. Notifications to external authorities are made as detailed in the oil spill emergency plan. Day 2 The IMT embeds liaison officers with relevant authorities and a joint unified command is established. Technical support from both the Tier 2 resources and the Tier 3 industry cooperative is on site and fulfilling roles within the ICS sections. Corporate company support is en route via a regional response team, with a view to establishing a sustainable IMT for the coming weeks. A media and public affairs team is established with staffing of 10 persons drawing on corporate support. A website providing incident data directly to the public is live. Day 3 An ICS planning cycle is fully functional. The IMT is fully staffed, with future support identified to ensure ongoing sustainability. The IMT is re-located to a pre-identified hotel conference suite facility with full communications and accommodation capacity. Offers are received from the broader industry to provide technical support personnel; these are held on file and relevant personnel put on alert for potential mobilization if needed. Day 4 Eight persons from the Tier 2 resources and 12 persons from the Tier 3 cooperative are on site and integrated into the IMT, providing a variety of technical expertise and operational support. Day 5 onwards The IMT is regarded as a sustainable entity, with staff rotations in place to ensure all personnel receive an adequate number of rest days. *Continued…*

Table A15 Tier 3 scenario (continued)

Activity	Anticipated response actions
Surveillance and assessment	Day 1 A crew transfer helicopter is released from evacuation duties at 15:00 and a trained observer liaises with the pilot to undertake an overflight to observe the oil slicks. The authorities have been notified and the Coastguard (Ministry of Transport) representative accepts an offer to join the overflight. A proprietary oil spill trajectory model is run to provide a prediction of slick movement under the prevailing weather. The Meteorological Office provides the latest weather forecasting. Day 2 A schedule of ongoing twice-daily overflights is agreed, with company and authority representatives on all flights. The contracted aviation company has three twin-engined helicopters available. Aerial observations identify the oil pollution covering an area of around 15 km^2 containing an estimated 2,500 m^3 of oil. Days 5 and onwards By agreement, the Coastguard mobilizes fixed-wing dedicated pollution monitoring aircraft (with remote sensing capability from a neighbouring country through a cooperative regional agreement mechanism). This aircraft provides primary aerial surveillance and pollution-targeting capacity for the remainder of the incident, supplemented by helicopters.
Dispersant	Day 1 A decision is made that dispersant application should be the primary strategy to combat the spill. There are two justifications for this decision: (1) the removal of surface slicks at the source, reducing volatile organic compounds (VOCs) and ensuring a safe working environment for personnel on vessels involved in well intervention; and (2) the protection of shorelines and coastal habitats from large quantities of weathered emulsion, thereby providing net environmental benefit. Particular consideration is given to the protection of the mangrove and the Important Bird Areas (IBA1 and IBA2) in reaching this decision. It is accepted that the use of dispersants will lead to additional levels of oil in the water column. This may increase the exposure of fish eggs and larvae to the oil, but an assessment is made which determines that dispersed oil concentrations will rapidly dilute and degrade over the medium term. The additional consequences for fisheries resulting from the use of dispersants is therefore assessed to be acceptable in relation to the benefits of removing oil at, or reaching, the surface. *Continued…*

Table A15 Tier 3 scenario (continued)

Activity	Anticipated response actions
Dispersant (continued)	A stand-by vessel has an on-board spray system and 5 m^3 of dispersant. This is deployed by 14:00, treating the leading edge of the surface slick approximately 3 km from the FPSO. The spilled oil is likely to remain amenable to dispersant for up to 24 hours after discharge under ambient conditions. A decision is made at 12:00 to mobilize an international cooperative with large-scale aerial dispersant application capability. The dispersant aircraft is expected on site within 36 hours. Practical aircraft application capacity is estimated at 3 full sorties per day, with approximately 20 m^3 of dispersant per sortie. To increase the effectiveness and extent of dispersant application (reduced dispersant to oil ratio of 1:100 and an operating window with 24-hour capability and few weather dependencies), a subsea dispersant injection system is mobilized. This is expected on site and available for operations within 6 days. Logistics are mobilized to access and supply additional dispersant volumes as follows: • Days 3–5: 60 m^3 per day aerial application • Days 6–50: 20 m^3 per day subsea injection. Initial planning for total dispersant required = (60 x 3 days) + (20 x 45 days) = 1,080 m^3. Global dispersant stockpiles are available to supply this quantity, and cargo aircraft are sourced to deliver the required amounts to a local airfield which is capable of receiving suitable cargo aircraft. Trucks and supply vessels are mobilized to transport the dispersant to the quay and offshore. Haulage contractors are identified in the oil spill emergency plan, and the availability of logistical capacity in the area is assessed to be very good and will not limit operations. The main dispersant manufacturers are requested to commence acquisition of feedstock and blending of additional dispersants at their maximum capacity, working to a medium-term (20+ days) horizon. It is not planned that newly manufactured dispersant will be required for use during this incident. However, this provides a contingency and facilitates replacement of the volumes used from global stockpiles during the incident. Day 2 The stand-by vessel continues to spray dispersant, and a second vessel is mobilized, having resupplied its dispersant stocks overnight (from Tier 2 resources). In a 10-hour *Continued…*

Table A15 Tier 3 scenario (continued)

Activity	Anticipated response actions
Dispersant (continued)	operating day, 15 m^3 of dispersant are sprayed by the vessels. The surveillance helicopter provides targeting assistance to direct the vessel to thicker areas of the slick. Day 3 Large-scale aerial dispersant application begins. One of the contracted helicopters is dedicated to the role of spotter for the application process. A relief crew is mobilized with the dispersant spraying aircraft to allow ongoing sorties without restrictions due to crew flying hours. Day 4 Formal approval for subsea injection of up to 20 m^3 dispersant per day is granted by the relevant authorities. Day 6–10 Subsea injection system is on site and commences operation. The system has a dramatic effect on the volume of oil surfacing, with newly surfacing oil slicks reduced by more than 90%. Aerial dispersant continues on an ad hoc basis, i.e. where surface slicks are detected by regular surveillance flights. Day 6–50 A subsea monitoring programme is established alongside the ongoing dispersant injection operation.
In-situ burning	Historic weather data indicate that conditions suitable for effective offshore containment prevail for approximately 50% of the time. Dispersant is maintained as the primary response strategy, supported by offshore containment and recovery when sea conditions allow. Consequently, in-situ burning is not a chosen strategy.
Containment and recovery	Opportunities for at-sea containment are limited due to prevailing sea conditions (wind speeds greater then 20 knots for more than 50% of the time) which restrict the effectiveness of containment systems. Day 1 A supply vessel, equipped with an offshore containment/recovery system (side-sweeping arm), is mobilized from the Tier 2 facility. The vessel is on site within 10 hours, ready for operation at first light on Day 2. *Continued…*

Table A15 Tier 3 scenario (continued)

Activity	Anticipated response actions
Containment and recovery (continued)	Day 2 The containment vessel is directed to commence operations targeting thicker patches of oil under guidance from the surveillance helicopter. The operation is controlled to be geographically discrete from the dispersant spraying activities. Day 3 The vessel has remained on station overnight and permission is given to discharge separated water from storage tanks to maximize on-board storage capacity (550 m^3). Over subsequent days the offshore system can operate for 50% of the time and collects an average of 150 m^3 per day of oil/water mixture (15% oil content). Days 6–20 The subsea dispersant operation significantly reduces floating oil slicks of significant thickness and extent. To combat oil slicks resulting mainly from the oil released in the first three days of the incident, three additional systems are mobilized from the Tier 3 cooperative. Suitable vessels for deployment together with storage vessels have been sourced and relocated to the area through the regional agreement. The four systems now available operate when sea conditions allow and collect a total of 15,000 m^3 of oily water with an average 15% oil content. Days 20–40 The offshore containment operation is relocated to the nearshore zone. A further 10,000 m^3 of oily water are collected with an average 10% oil content. Days 40–55 On-water recovery is diminishing in effectiveness. A further 5,000 m^3 of oily water are collected with an average of 5% oil content. Day 55 On-water containment operations are stood down. A total of approximately 3,500 m^3 of oil has been recovered offshore.
Transfer and storage of recovered oil	Day 6 The offshore vessel returns to port and discharges 500 m^3 of oil/water mixture (approximately 80% oil content). Three road tankers shuttle the mixture to the refinery for treatment and disposal. *Continued…*

Table A15 Tier 3 scenario (continued)

Activity	Anticipated response actions
Transfer and storage of recovered oil (continued)	A coastal tanker is sourced to receive the oily water from the on-going offshore recovery operations. Days 4–15 Bagged shoreline waste is transported to a secure temporary holding area within the refinery. Approximately 50 bags are collected. Days 16–25 150 bags of oily sand from beach clean-up are transported to a secure temporary holding area within the refinery. Days 18–40 Bagged shoreline waste is transported to a secure temporary holding area within the refinery. Approximately 200 bags are collected.
Shoreline protection and clean-up	Days 1–4 No shoreline oiling occurs prior to Day 4. Detailed booming plans have been developed to protect key areas of mangrove, where this is technically feasible. Access points and the needs for specific equipment at each site are included in the booming plans. The Tier 2 facility holds a stockpile of 750 m of inshore boom, ancillaries and portable skimming devices with associated temporary storage to meet these priority protection requirements. A SCAT approach is organized to confirm pre-identified and possible additional key shoreline sensitivities and their protection potential, for those parts of the coastline predicted by the computer modelling to be under threat. An additional 4 km of inshore boom and shoreline clean-up packages are mobilized from the Tier 3 cooperative to a forward staging post on the coast. No equipment is deployed, pending reports from surveillance that shoreline sites are under specific threat from floating slicks. Bird hazing (scaring) equipment is procured and two on-water containment and recovery systems placed on standby for operation in the near-shore waters adjacent to the mangroves. Days 4–10 SCAT surveys record small tar balls on two sandy beaches along the coast. Shoreline clean-up teams (150 persons in total) are deployed for tar ball removal using hand tools. *Continued…*

Table A15 Tier 3 scenario (continued)

Activity	Anticipated response actions
Shoreline protection and clean-up (continued)	Days 11–55 Sporadic reports of tar balls continue, and these are cleaned up when identified (25 persons dedicated to this task). SCAT surveys continue. Small quantities of oil are found on exposed rocks but these are left to natural clean-up by wave action and microbial degradation. There are no reports of oil affecting the wetland.
Wildlife response	Day 2 Concern is focused on migratory wildfowl, especially in the vicinity of the Important Bird Areas. Day 3 The Wildlife Response Plan is put on alert status and two international experts mobilized to provide guidance on procedures. Information on how to report sightings of oiled wildlife is made available and distributed to the public through media contacts. Day 4 Bird hazing equipment is available for deployment at the wetland site. Day 10 Reports are received of oiled birds on one of the sandy beaches. This is investigated, and 25 oiled sea ducks are subsequently recovered and brought to a rehabilitation facility established at a pre-identified warehouse. Days 11–15 100 additional oiled birds are recovered and taken for rehabilitation. Day 25 75 birds out of a total of 125 birds brought for treatment are released back into the wild.

Assessment of oil spill response capability

The three scenarios provide a tactical planning framework enabling the determination of oil spill response resources, as described earlier in this document.

The response planning team is required to analyse each response element based on the tactical planning, to ensure that the necessary resources are both available and verifiable. The process should also consider the supporting logistics required to mobilize deployment within an appropriate timescale, manage the incident and sustain the operation.

For example, a summary of the resources and logistical considerations in relation to the dispersant strategy is provided in Table A16.

Table A16 A summary of the resources and logistical considerations for each Tiered response

	Tier 1	Tier 2	Tier 3
Dispersant	5 m^3 stored on stand-by vessel	15 m^3 stored at onshore facility.	80 m^3 per day from international stockpiles
Spraying equipment	Vessel spraying system #1 on stand-by vessel	Vessel spraying system #2 at onshore facility.	Large-scale aerial application system Subsea injection system
Logistics	Stand-by vessel available within 45 minutes Helicopter available within two hours to provide aerial support to target operations to thickest areas of oil	Supply vessel available within six hours	Aerial system operational on Day 3—operating from international airport Two helicopters to provide spotter capability for aerial spraying Subsea injection system operating from supply vessel offshore. Three flatbed trucks and an additional supply vessel to transport dispersant
Personnel and training	Crew trained in use of dispersant application system	Crew trained in use of dispersant application system	Trained crews for aircraft operations Specialized personnel mobilized from Tier 3 cooperative oversee spraying operations

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Appendix 6

Training and exercise programmes

Training and exercise programmes

Training and exercise programmes are a fundamental and integral part of oil pollution emergency arrangements. The detail of these programmes will be specific to an operation's oil pollution emergency plan but there are universal principles underpinning their development as well as regulatory requirements in some countries. Ensuring that personnel are aware of their allocated emergency response roles and are practised in the execution of these roles is critical for effective oil spill preparedness. Similarly, an appropriate exercise programme can provide the assurance that the equipment, logistics, systems and communications required during an oil spill response are in a state of readiness.

The OPRC Convention obliges governments to establish a programme of exercises for oil pollution response organizations, together with the training of relevant personnel. The operator of an offshore installation should endeavour to integrate their programmes within the governmental framework, where these have been developed at the national level.

Exercises

The guiding principles summarized below should be followed to help maximize the benefits that exercises can provide:

- Ensure that all management, from the top down, supports the exercise activity.
- Set clear, realistic and measurable objectives for an exercise.
- Remember that the thrust of exercising is to improve—not to impress.
- Simpler, more frequent exercises lead to faster improvements initially.
- Do not tackle complex exercises until personnel are experienced and competent.
- Too many activities, locations and participants can overcomplicate an exercise.
- Evaluating the exercise successfully is as important as conducting it successfully.
- Planning and conducting a successful exercise is a significant accomplishment.

A well-coordinated programme of oil spill exercises includes activities of varying degrees of interaction and complexity. It is recommended that the programme incorporates the following four exercise categories:

- notification exercises;
- table-top exercises;
- equipment deployment exercises; and
- large-scale incident management exercises.

These exercise categories can involve offshore and land-based personnel, corporate support teams, specialized contractors and other technical advisors or relevant stakeholders. It is also advantageous for appropriate government representatives to be involved in industry-led exercises, and vice versa. This enables all parties to explore and understand their roles and responsibilities, along with the mechanisms for an integrated and coordinated response.

National jurisdictions may stipulate the inclusion of certain elements and frequency of activities within an exercise programme. However in the absence of such requirements, guidance on the minimum level of exercising for typical offshore operations is presented below. Specific factors in an operation's setting may require approaches that are different from those provided in this guidance. Such factors should be identified in an oil pollution emergency plan.

Notification exercises

- Notification exercises test the procedures to alert and call out the response teams and are conducted through telephone and other means of communication, as stipulated in the oil pollution emergency plan. They can be used to test communications systems, check availability of personnel, evaluate travel options for supporting resources at Tier 2/Tier 3 and the speed at which travel arrangements can be made, and assess the ability to transmit information quickly and accurately. Such an exercise will typically last for one to two hours and may be held at any time, day or night, announced or unannounced.
- Notification exercises should be held once every six months or twice per year, and should incorporate notification of external authorities as appropriate and as identified in the emergency plan.

Table-top exercises

Table-top exercises normally consist of interactive discussions of a simulated scenario among members of a response team but do not involve the mobilization of field personnel or equipment. They are usually conducted in a conference room or series of rooms connected by telephone lines, and focus on the roles and actions of the individuals, the interactions between the various parties, and the development of information and response strategies. A simple and early form of table-top exercise would be a response team going through the contingency plan, page by page, testing each other's activities in response to an imaginary situation. A more complex table-top exercise might involve several groups, including outside parties, playing their roles in a given scenario. A table-top exercise might typically last from two to eight hours and should be announced well ahead of time to ensure availability of personnel.

Where third-party subsea tiebacks exist, and the subsea operator takes responsibility for oil spill response using external resources, exercises should be carried out to ensure the effectiveness of the relationship between the operator of the tieback and the facility providing the resources.

In-house table-top exercises should be held a minimum of once per year. Table-top exercises involving external parties, such as government agencies, should be held a minimum of once every two years. It is possible to combine a notification exercise and the annual internal table-top exercise.

Equipment deployment exercises

Equipment deployment exercises involve the deployment of oil spill response equipment at particular locations in response to an oil spill scenario and in accordance with strategies laid down in the plan for a particular spill scenario. These exercises test the capability of a local team to respond to a Tier 1 or Tier 2 spill, provide experience of local conditions and spill scenarios, and enhance individual skills and teamwork. It is important that other parties that would normally be part of such a response, such as the providers of boats, barges and trucks, be involved so that their availabilities and capabilities can be assessed; other organizations might also be invited to observe. Such an exercise would typically last from four to eight hours and should be repeated frequently until teams are acquainted with the equipment. In some instances, an equipment deployment exercise might be run in conjunction with a table-top exercise or incident management exercise. This can enhance the reality of the exercises but can be more complicated to oversee.

Equipment deployment exercises should be held a minimum of once per year for workers on each shift/rotation that would be directly involved in mobilization and deployment operations.

Incident management exercises

Incident management exercises are often more complex in that they simulate several different aspects of an oil spill incident and involve third parties. Such an exercise may either be of limited scope, for example, using an organization's personnel to role-play the main external parties, or of full scope, when outside agencies and organizations are invited to provide personnel to play their own roles within the exercise. Whilst internal exercises are beneficial in the early stages of team development, it is only by exercising with the actual people who would be involved in a real emergency that a response team can be properly tested and trained.

Incident management exercises require significant planning in terms of the availability of personnel, the development of an adequate scenario and the physical arrangements for staging such events. Normally, an Exercise Steering Committee is formed to develop and run the exercise. Although not as realistic, it is most convenient from the point of view of controlling the exercise and debriefing participants at the end if the main players are accommodated in the same building. If players are dispersed over several locations, maintaining control of external communications becomes difficult and care should be taken to ensure that the exercise does not spread beyond its defined boundaries.

Often, incident management exercises last for one long day, typically 10–14 hours, followed by debriefing sessions on the second day. If the exercise is to be extended into a second day, efforts should be made to maintain the atmosphere of emergency overnight and to plan specific events for the following day. Debriefing might then be scheduled for the third day.

Large-scale incident management exercises should be held prior to commencing drilling operations, and a minimum of once every four years for production facilities. Like the table-top exercises, they can be combined with any/all of the above exercises.

When one operator in a geographic area holds an exercise, outcomes with a bearing on the relationships and integration involving the authorities and Tier 3 responders should be shared with other operators within the same area or jurisdiction.

Training

The IMO has developed a range of training courses to address all aspects of oil spill planning, response and management. These are known as the OPRC Model Courses. These courses have been designed and developed by an international group of experts from governments and industry. The courses on oil pollution preparedness and response have been developed for three levels of competency: operational staff (Level 1), supervisors and on-scene commanders (Level 2) and senior management personnel (Level 3).

Whilst the OPRC does apply to offshore installations, the focus of the OPRC Model Courses has been on ship-source oil pollution. However a significant proportion of the Courses' content is relevant to any marine oil spill regardless of source, and they provide the best international syllabus for a training programme relating to offshore activities. Training courses should be tailored to take into account the specific features of an operation's oil pollution emergency plan (e.g. subsea dispersant strategy), the national and regional response systems and local variations in the environmental setting.

Some jurisdictions have implemented national training requirements or guidelines for personnel identified in offshore oil pollution emergency arrangements. This can include accreditation of training organizations approved to provide such training. Where such requirements exist they should be followed, while ensuring that the training programmes meet as a minimum the syllabus of the OPRC Model Courses.

The operator's oil pollution emergency plan should clearly identify training requirements for all personnel involved in the plan, including the level, duration and syllabus for training courses, where not already stipulated in national regulations. Personnel receiving training should also undertake refresher courses periodically (typically every three years), though a system of crediting structured involvement in the exercise programme can replace the need for formal refresher training. Overlaps with broader emergency response training and exercise programmes can also be incorporated into oil pollution emergency plans, and likely synergies identified.

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Appendix 7

An example of an oil spill preparedness review process

The oil spill preparedness review process

The following is an example of the basic process steps that the Oil Spill Response Review Team should follow. These steps begin before the actual review, and include the steps needed to set up the review.

Table A17 An example of the steps necessary for conducting an oil spill response review

Task no.	Action
1.	The lead Business Unit Manager requests an external oil spill response (OSR) review. The Business Unit Emergency Response (ER) Coordinator serves as host and liaison contact.
2.	Prepare a Charter to document the OSR review, including: • Goals • Key objectives • Sponsor • Deliverables • Timing • Scope and boundaries • Approach • Team make-up • Special key steps
3.	Circulate the Charter for review and endorsement by the sponsor.
4.	Identify and resource the OSR Review Team, including: • Team Leader, having tactical OSR leadership experience and technical oil spill/clean-up expertise. • One or more OSR experts having ER process and plan knowledge. **Note:** these team members may be hired from a third-party OSR organization. • An internal on-site/in-country OSR Review Coordinator who serves as the team's host and review facilitator. The Coordinator should have an in-depth knowledge of the organization's operations and facilities, and have skills and experience in setting up detailed team-level assessments, review or audits.
5.	Identify potential types and sources of spills, including various leak scenarios involving all facilities and equipment in order to better understand the scope and boundaries of the OSR review. These might include: • Pump stations • Pipelines/flowlines • Platforms • FPSOs/FSOs • TLPs • Subsea completions • Drilling operations • Marine operations
6.	Using a risk-based review, determine the relative likelihood, size and locations of potential spills. *Continued...*

Table A17 An example of the steps necessary for conducting an oil spill response review (continued)

Task no.	Action
7.	Conduct oil spill modelling of the most probable or higher risk spills and use modelling results to determine, for example: • Spill impacts and the OSR capability required • Requirements for responding to the spill
8.	The OSR Review Team Coordinator conducts pre-OSR review activities, including: • Making available OSR-related documents such as OSR plans, equipment and dispersant inventory lists, OSR waste disposal plans, and agreements with third-party OSR organizations. • Establishing an interview schedule and confirming the availability of interviewees. • Confirming site visits and supporting travel logistics. • Confirming OSR equipment inspection activities, equipment deployment demonstrations and exercises. • Determining whether the review scope includes interviews/reviews of third-party OSR mutual aid support parties or joint industry OSR cooperatives. • Scheduling the management-level kickoff and closeout meetings; confirming attendance and location. • Identifying and completing any necessary pre-OSR review next steps.
9.	Conduct a kick-off meeting with the sponsor and applicable groups such as HSE, operations, engineering, and OSR staff.
10.	Conduct a detailed OSR review over a designated period, for example 3–5 days.
11.	The OSR review assesses: • Planning and documentation • Equipment and resource readiness • Personnel and organization **Note:** it is recommended that the local OSR team conducts a table-top exercise for evaluation of OSR response effectiveness including capability.
12.	Compile observations with recommendations into a closeout presentation.
13.	Conduct close-out meeting with sponsor.
14.	The OSR Review Team returns to the home location to complete the report package that includes an executive summary and detailed report. **Note:** it is not normally expected that the OSR Review Team will complete the final reporting package on site.
15.	Circulate a draft of the report package for review and comment.
16.	Edit the draft as needed to account for relevant comments.
17.	Finalize the OSR review report and actions list, and issue to the sponsor.
18.	Include actions in local stewardship in the action tracking process.

IPIECA is the global oil and gas industry association for environmental and social issues. It develops, shares and promotes good practices and knowledge to help the industry improve its environmental and social performance; and is the industry's principal channel of communication with the United Nations. Through its member led working groups and executive leadership, IPIECA brings together the collective expertise of oil and gas companies and associations. Its unique position within the industry enables its members to respond effectively to key environmental and social issues.

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