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Oil spill monitoring and sampling

Good practice guidelines for incident management and emergency response personnel

Oil spill preparedness

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IOGP Report 639

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Contents

Summary

This publication is an addition to the IPIECA-IOGP Good Practice Guide Series which summarizes current views on good practice for a range of oil spill preparedness and response topics. The series aims to align industry practices and activities, inform stakeholders, and serve as a communication tool to promote awareness and education.

It builds upon experiences gained from recent spills and draws upon references from a wide range of sources, both from within the IOGP and IPIECA membership and across the wider response community.

This good practice guide has been developed to help operators navigate the steps and good practices involved in planning for, and implementing, a monitoring and sampling (M&S) programme. The guidance is presented in phases related to the complexity of the M&S activities required for a specific spill situation, and/or the point at which these activities are occurring within the spill response process.

The guide focuses on examples from incidents where the spill occurs in an offshore or nearshore situation, but the main steps and elements will also be relevant for an M&S programme in an onshore situation.

The guide describes a comprehensive approach to M&S, and presents the key steps that should be taken in preparing for, and implementing, an M&S programme. It focuses on a range of pre-spill requirements including, in particular, the need to establish pre-spill data for reference purposes, as well as on the steps that need to be taken once a spill occurs.

M&S programme implementation activities typically occur within the active response phase and are essential, not only to inform the response as to the effectiveness of the impact mitigation measures being implemented, but also to accommodate a wider scientific impact analysis. Following the active response phase, a longer-term monitoring and sampling programme focused on restoration and recovery may be required (this aspect is beyond the scope of this guide).

Appendices 1 and 2 draw on the information presented in this guide to provide a series of good practice checklists that operators can use to help develop processes and templates to prepare for, and implement, an oil spill M&S programme.

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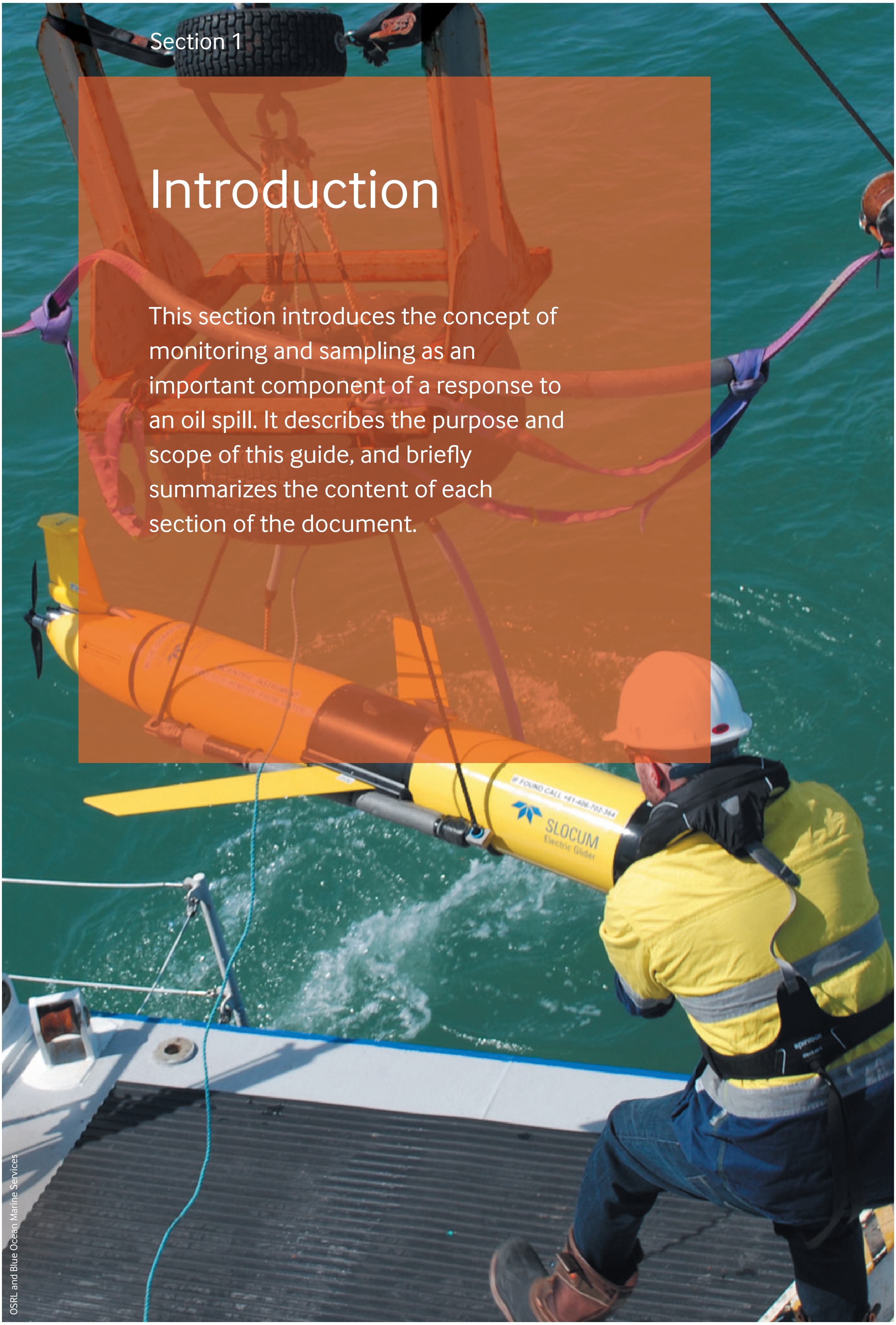
Section 1

Introduction

This section introduces the concept of monitoring and sampling as an important component of a response to an oil spill. It describes the purpose and scope of this guide, and briefly summarizes the content of each section of the document.



OSRL and Blue Ocean Marine Services

Introduction

BACKGROUND

Regardless of the type, size or location of an oil spill, M&S activities are an important component of the incident response and are often a regulatory requirement. In the early stages of an oil spill response, these activities are of critical importance in understanding the spill situation, confirming the sources of the oil, gathering ephemeral (i.e. pre-impact baseline data), background and reference data, evaluating response options and developing a response plan. As the response progresses, M&S activities also help to evaluate the effectiveness of a response plan, determine the extent and severity of ecological and economic impacts, evaluate the recovery of affected resources, and determine appropriate restoration actions.

M&S activities should begin immediately after a spill occurs to facilitate decision-making, identify resources at risk and provide baseline data that can be compared with data obtained throughout the response time frame. During the first few days following an incident, a great deal of coordination is required, and it is important that M&S activities are focused on supporting response decision-making based on the specific spill scenario. Furthermore, spilled oil and evidence of its impacts can change rapidly over time, and key information may be lost if it is not collected immediately. Initiating M&S activities as early as possible is therefore essential, in particular with regard to the collection of ephemeral data. Failure to collect these important data can hinder the ability to properly confirm whether impacts are directly related to the spill in question.

This good practice guide provides information to help ensure that M&S activities are incorporated early in an oil spill response, by outlining the M&S aspects that may be planned in advance of a spill, and providing guidance and tools to facilitate the initiation of an M&S plan during the early days of an incident and as the incident evolves.

PURPOSE AND SCOPE OF THIS GUIDE

The main purposes of the guide are to:

- provide tools, guidance, examples and good practice checklists to facilitate the preparedness, planning and implementation of an M&S plan;
- highlight the critical priorities of M&S during the early days of an incident and as the incident evolves, and identify the M&S elements that may be missed or inadequately implemented;
- increase understanding of the appropriate scale and scope of M&S activities required for a particular spill and to meet regulatory requirements;
- ensure that M&S plans are developed and implemented in a safe and effective manner; and
- emphasize how an effective M&S plan can protect an operator's reputation and minimize potential liability from third-party claims.

It is important to note that these guidelines do not supersede local legislative requirements. Regulatory requirements associated with M&S vary greatly among regions, and users of this guide are encouraged to seek information and advice on the requirements prescribed by local regulatory authorities in relation to M&S activities.

This guide covers the steps that need to be taken to prepare for an M&S programme before a spill, as well as the M&S programme implementation steps that take place immediately after a spill occurs, up to the point where a longer-term sampling programme can be developed and initiated with a focus on restoration and recovery. The guide discusses the M&S activities associated with all types of crude oil and petroleum products that may be spilled from typical sources (e.g. offshore installations, vessels, ports and terminals, rail, pipelines and tanker trucks) with the potential to affect a variety of environments (e.g. marine offshore, coastal/shoreline, and inland aquatic and terrestrial environments).

The intended audience for the guide includes the oil and gas industry, Environment Unit personnel within the incident management system (IMS), and the wider response community. The guide is written with the assumption that the reader has some experience with oil spill response and M&S procedures.

HOW THE GUIDE IS ORGANIZED

This guide has been developed to help users navigate through the various steps involved in properly planning for, and implementing, an M&S programme.

Section 2 of the guide, *Environmental monitoring and sampling—an overview*, provides a general summary of the ways in which an M&S programme can support the wider response. It introduces the phased approach to undertaking M&S activities, whereby the nature, extent and complexity of M&S activities change to reflect the needs of the overall response as it progresses from the initial decision-making phase, through the selection of response options, and onwards to the closure phase. This section also introduces the range of surveillance platforms that can be used for monitoring, and provides examples of the types of samples that could be collected and analysed during a response.

Section 3, *M&S preparedness*, presents seven key steps that can be performed before an incident occurs to maximize M&S preparedness and enable the fast implementation of an M&S programme if necessary:

- Step 1: Compiling information on regulatory agencies and external organizations.
- Step 2: Establishing a generic M&S Team structure.
- Step 3: Developing a generic M&S plan.
- Step 4: Acquiring and compiling baseline data.
- Step 5: Coordinating equipment, external resources and contracts.
- Step 6: Developing a generic data management system.
- Step 7: Developing a training and exercise programme.

Section 4, *Incident-specific M&S mobilization and implementation* presents eight key steps involved in developing and implementing an M&S programme for a specific spill situation:

- Step 1: Coordinating and mobilizing the M&S programme.
- Step 2: Designing an M&S plan.
- Step 3: Selecting the locations and methods for undertaking M&S activities.
- Step 4: Monitoring the effectiveness of the selected response techniques.
- Step 5: Selecting the appropriate sampling and analytical methods.
- Step 6: Implementing a data management system.
- Step 7: Evaluating health, safety and logistical considerations relating to M&S activities.
- Step 8: Determining the criteria for termination of the M&S programme.

Appendices 1 and 2 provide a series of good practice checklists which address each of the preparedness and implementation steps, respectively, as listed above. The checklists serve as a guide and a reminder of the aspects to be considered when preparing for, and implementing, an M&S programme.

Appendix 3 provides a list of selected references from a variety of jurisdictions that provide detailed procedures for M&S activities related to specific media.

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Section 2

Environmental monitoring and sampling—an overview

This section provides an overview of the objectives of an M&S programme, and introduces the three phases of a response, from initial decision-making, through the selection of response options, to response termination. It describes the range of surveillance tools that can be used to provide monitoring information, and lists the various types of samples that may need to be collected for analysis.

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Environmental monitoring and sampling overview

An M&S programme can support the wider oil spill response operation in several ways, including:

- ensuring the safety and health of responders and the public;
- confirming and characterizing the source of the oil spill;
- understanding the situation, spill fate and oil trajectory;
- collecting baseline and reference data;
- evaluating the feasibility of response options;
- evaluating the effectiveness of the selected response techniques;
- determining the extent and severity of ecological and economic impacts on affected resources;
- monitoring the recovery of affected resources and determining appropriate restoration activities; and
- preparing for possible third-party claims or damage assessments.

The extent to which each of these objectives apply to a spill incident, and the priority given to each objective during a response, are dependent upon many factors; they will also be specific to the particular spill situation and will not necessarily be related directly to the complexity of the overall response. The level of response capability required for a particular spill is typically described using the tiered approach depicted in Figure 1 on page 11, where the three tiers represent varying degrees of response capability. Tier 1 response resources are those which are available locally and which typically have relatively limited capability aimed at addressing smaller, localized spill incidents. Tier 2 resources represent additional, or more specialized, capabilities which are likely to be available either regionally or nationally, while Tier 3 resources will be the most highly specialized resources that are only likely to be available via international providers. Tiers of response capability are assigned to the individual components of an oil spill response (e.g. in-situ burning, dispersant application, etc.) based on a risk assessment which provides the basis for determining the most appropriate response techniques and levels of tiered capability required to achieve a net environmental benefit. A structured process, known as a spill impact mitigation assessment (SIMA), has been developed to help facilitate the selection of response options, and to support strategy development to minimize the ecological, socio-economic and cultural impacts of an oil spill (IPIECA/API/IOGP, 2017).

The extent of M&S activities required depends on the complexity of the M&S programme, and is often determined more by the locations that may be impacted by the spill, and by the sensitivities of those locations, than by the size of the spill itself. As an example, a response to a small spill near a sensitive site may require a complex M&S programme involving international equipment or laboratories. As the number and sensitivity of the locations requiring monitoring or sampling increases, the complexity of M&S activities required for a particular spill also increases. Typically, for larger spills, as the response to the spill proceeds, the extent and complexity of M&S activities also increase. For the purpose of this guide, M&S activities and their complexity are presented using the phased approach described in Table 1 on page 11.

The first phase involves simple activities at the beginning of an incident, which are used to help understand the situation and ensure that initial response activities can be undertaken while ensuring the safety of responders and protecting people and the environment. For smaller spills, this may be the only phase required. For larger spills, as the incident response proceeds, M&S activities typically move into the second phase where more in-depth M&S activities would be required to confirm and augment response decisions, determine the effectiveness of response activities, help to ensure the safety of response personnel and the public, and monitor nearby sensitive environments. The final phase occurs when the response is well under way, and includes M&S activities required to determine environmental and human health impacts, and the termination points for various M&S activities. This phase is usually completed once a longer-term sampling programme begins that would be focused more on recovery and restoration activities. Using this phased approach ensures that M&S activities evolve as the response progresses. As an example, the first phase of M&S activities would not usually require a great deal of equipment and resources, hence response activities would not be delayed while waiting for M&S resources to arrive and/or for complex M&S activities to begin.

Figure 1 The tiered preparedness and response model

IPIECA-IOGP, 2015

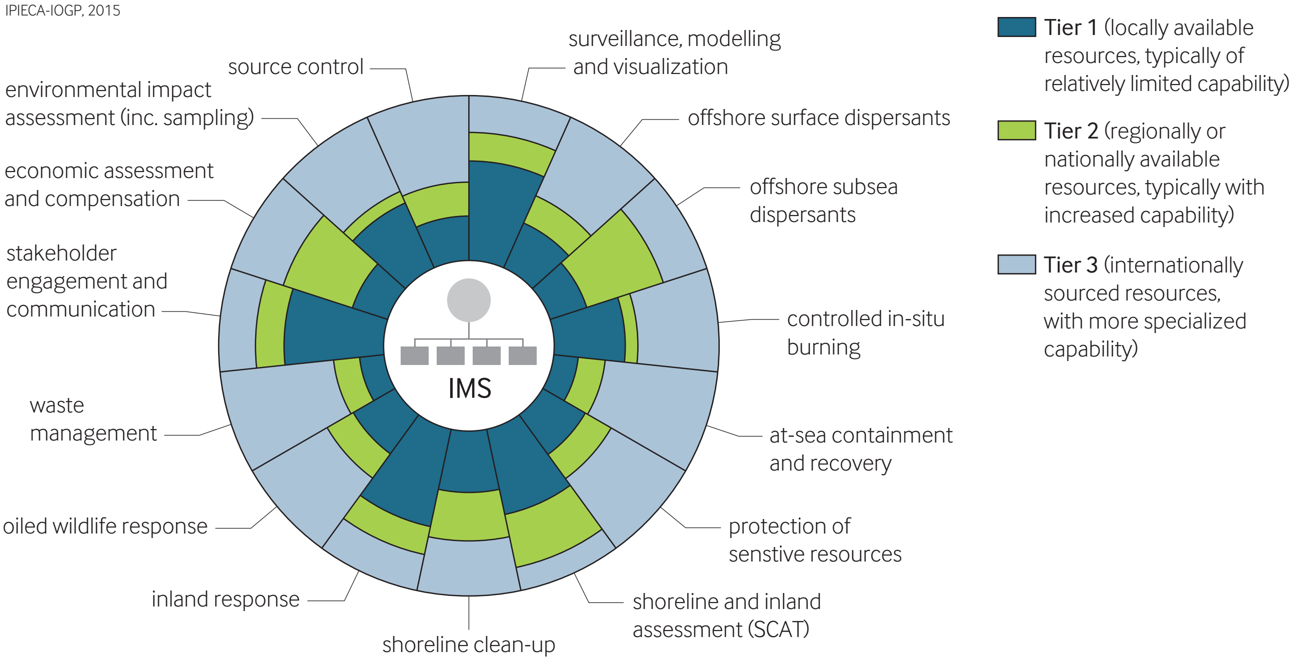


Table 1 The phased approach to M&S activities

PHASE OF M&S ACTIVITIES	Increase in complexity of M&S activities ▼		OBJECTIVES OF M&S ACTIVITIES
Phase 1: Situational analysis/ initial response decision-making		Initial few days of the response	Objectives of M&S activities performed during the early stages of a spill: • Characterize the source of the oil • Confirm the source of slick areas • Delineate slick areas • Understand the properties of the oil slicks • Determine background concentrations of petroleum hydrocarbons • Ensure the safety of responders and the public
Phase 2: Selection and effectiveness of response options			Objectives of M&S activities associated with response selection and operations: • Determine the properties of the oil slicks to aid response decision-making, and to evaluate response effectiveness and determine termination criteria • Determine waste disposal options for recovered oil and burn residues • Ensure the safety of responders and the public
Phase 3: Impact assessment and termination of response activities		Response termination	Objectives of M&S activities associated with understanding the impacts of the spill: • Determine environmental impacts on nearshore/shoreline/terrestrial/inland areas and biota, and on human-made infrastructure • Select response options for the above areas and determine the criteria for termination • Ensure the safety of responders and the public

Oil spill M&S activities generally involve qualitative and quantitative techniques to provide information on the situational analysis, oil fate and behaviour and potential impacts on affected resources, and to track changes to these elements over time. M&S activities can include:

- monitoring changes over time using surveillance techniques to provide situational data that inform response operations in the early days of a spill and as the response progresses; and
- sampling and analytical techniques to acquire additional data from specific media types (e.g. oil, water, sediment, biota, air).

As shown in Figure 2 on page 13, monitoring can use information from a variety of surveillance tools, including:

- satellites (using optical, infrared and radar techniques);
- unmanned underwater vehicles (UUVs), including autonomous underwater vehicles (AUVs) (e.g. gliders) and remotely operated vehicles (ROVs);
- unmanned surface vessels (USVs), including autonomous surface vehicles (ASVs) (e.g. AutoNaut, wave gliders);
- manned surface vessels (using techniques including optical and radar, photography and video, and trained observers);
- buoys, trackers and mounted systems (e.g. instruments mounted on rigs or moored independently);
- onshore observers (using trained observers, photography and video);
- aerial platforms such as fixed-wing aircraft and helicopters (using techniques including trained observers, optical and radar surveillance, photography and video);
- unmanned aerial vehicles (UAVs) (using optical and radar techniques); and
- tethered balloon systems (i.e. aerostats, using optical and infrared techniques).

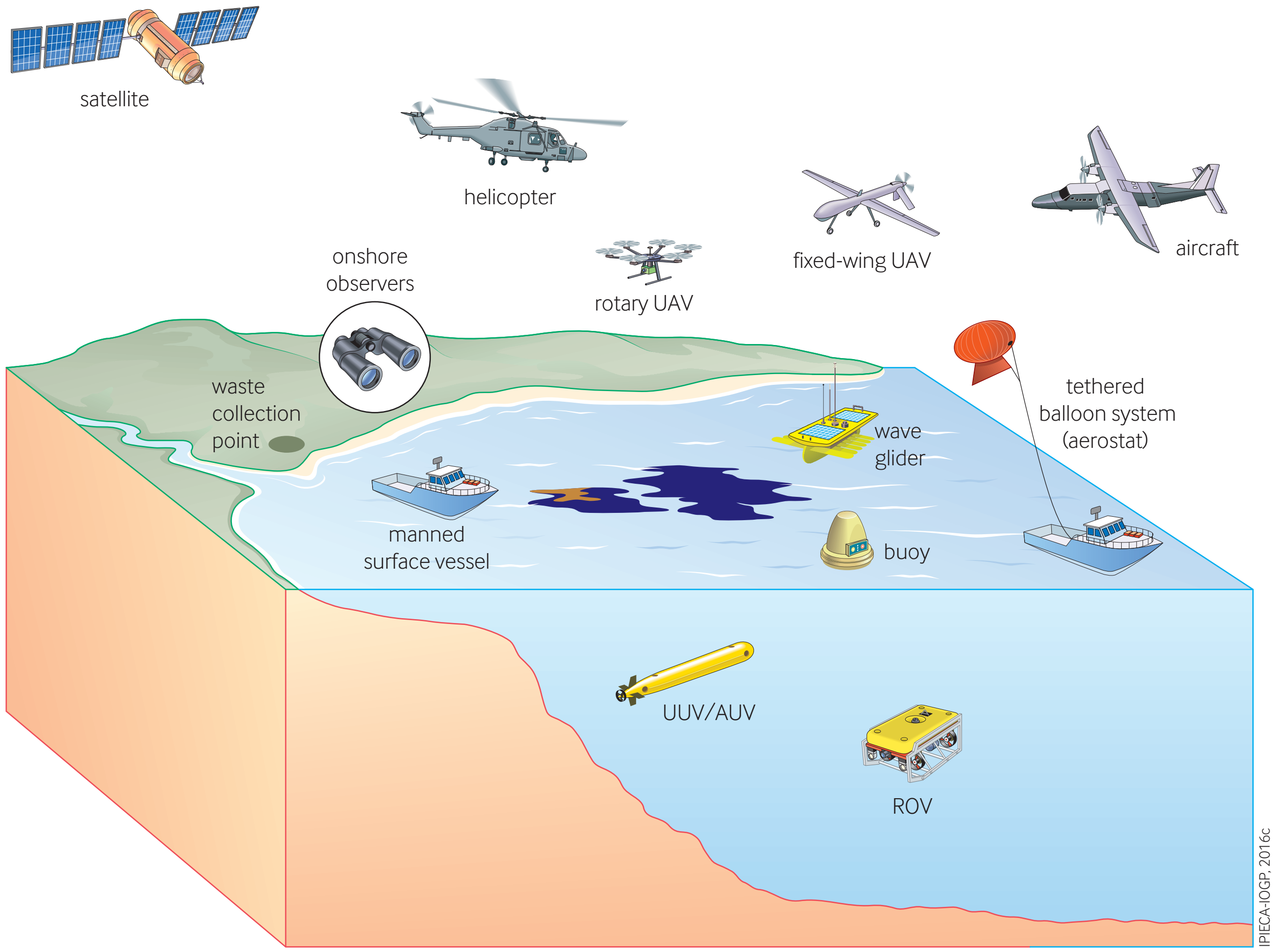
(IPIECA-IOGP, 2016b)

The IPIECA-IOGP good practice guides on satellite remote sensing (IPIECA-IOGP, 2016b) and in-water surveillance (IPIECA-IOGP, 2016c) provide detailed information on the applicability and use of some of the surveillance techniques mentioned above.

As required, surveillance can be supported and verified by sampling activities and analyses to determine the physical and chemical properties of oil, water, sediment and soil, biota, solid surfaces (boulders, human-made infrastructure) and air samples. The analytical results are used to verify the source, fate, behaviour and impacts of the released product, assess the situation and determine response options, and evaluate the efficiency of the response. Examples of the types of samples that could be collected and analysed during a spill response operation are summarized below:

- Oil samples:
  - source oil;
  - oil slick/sheen areas—pre-response;
  - oil slick/sheen areas—post-response;
  - recovered oil from skimming or other recovery operations; and
  - burn residue from in-situ burn operations.
- Water quality samples:
  - water column samples from an unimpacted area;
  - water column samples from below the slick/sheen area; and
  - water quality samples from waste streams/waste collection points (see Figure 2).
- Samples from unimpacted and impacted nearshore/shoreline/terrestrial/inland areas:
  - sediment and soil;
  - bedrock/boulders; and
  - biota.
- Samples of unimpacted and impacted human-made infrastructure (e.g. ports, fishery and aquaculture infrastructure, recreational and tourism areas, water intakes):
  - solid surfaces; and
  - water from intakes.
- Air quality samples:
  - air quality samples upwind from the slick;
  - atmosphere above and close to the spill; and
  - atmosphere near populated and environmentally sensitive areas.

Figure 2 Examples of oil spill surveillance tools that may be used in a response



Sampling of unimpacted areas (i.e. areas that are not anticipated to be impacted by the spill, but which are similar to impacted or potentially impacted areas) should be undertaken to collect ephemeral data that can be used to help define the baseline conditions prior to impacts from a spill. It may also be prudent to collect baseline data from potentially impacted areas (based on oil spill trajectory modelling) prior to any oiling taking place.

It should be noted that air quality M&S activities carried out to support responder and community health and safety during an oil spill incident are typically undertaken by the Health and Safety (H&S) Team under the guidance of the Safety Officer. Air quality M&S activities conducted as part of the environmental monitoring and sampling activities discussed in this document may be led either by the M&S Team or the H&S Team. In the latter case, the M&S Team/Environment Unit may be involved in managing the data flow or ensuring that the data are utilized effectively by the Planning Section which has overall responsibility for M&S activities.

A detailed summary of potential M&S locations, media types, objectives and methods can be found in Tables 7 to 11 on pages 33–37. Further guidance may be found in Kirby *et al.*, 2018.

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M&S preparedness

This section describes the preparatory steps that should be taken to ensure that a monitoring and sampling programme can be implemented efficiently if an oil spill should occur. It describes how an M&S Team is organized, and how the M&S activities are integrated into a typical incident management system.

OSRL

M&S preparedness

Several steps related to oil spill M&S activities may be pre-planned and performed before an incident occurs to assist in the fast and effective implementation of those activities if a spill should occur. The key steps that can be taken to ensure the efficient implementation of an M&S programme are discussed in this section and include the following:

- Step 1: Compiling information on regulatory agencies and external organizations.
- Step 2: Establishing a generic M&S Team structure.
- Step 3: Developing a generic M&S plan.
- Step 4: Acquiring and compiling baseline data.
- Step 5: Coordinating equipment, external resources and contracts.
- Step 6: Developing a generic data management system.
- Step 7: Developing a training and exercise programme.

STEP 1: COMPILING INFORMATION ON REGULATORY AGENCIES AND EXTERNAL ORGANIZATIONS

In any spill situation there will be various regulatory agencies and external organizations that need to be aware of, or involved in, the planning and implementation of an M&S programme.

The requirements of government agencies may influence the procedures used in an M&S programme, and can require specific monitoring or sampling activities to be performed. In addition, collaboration with authorities during the design of an M&S programme can help to reduce the duplication of effort and enable the sharing of resources. Collaboration also provides a common understanding of the approach and expected results, which can help to manage expectations and avoid potential misunderstandings concerning the data compiled and results obtained.

Information should also be compiled on external groups that may need to be contacted in relation to M&S activities. These include local community groups, indigenous groups, industry associations, animal welfare and rehabilitation organizations, and other non-governmental organizations. Unlike government agencies, there is typically no requirement to contact these groups; however, from a public relations and community health perspective, it is recommended that a proactive approach is taken to keep these groups abreast of M&S activities.

Table 2 on page 17 lists the government agency departments and regulatory requirements that may be relevant in the event of a spill. Full details of these agencies/requirements should be compiled as part of the preparedness activities for each location where a spill may occur.

STEP 2: ESTABLISHING A GENERIC M&S TEAM STRUCTURE

To ensure that relevant M&S activities begin as soon as possible after an incident occurs, it is important to identify individuals within, and external to, an operator's company who can form part of the M&S Team that operates under the authority of the Environment Unit within the Planning Section of the overall IMS. As with the IMS in general, the M&S Team structure should be scalable, as its members and roles would vary depending on the size and type of spill and the complexity of M&S requirements. However, the general organization of the M&S Team, their roles and responsibilities and how they would be integrated into the IMS can all be documented and communicated prior to a spill.

Figure 3 on page 17 provides an example of an IMS organization for a large spill, and shows how the M&S Team could fit into that structure. As most M&S activities support the Environment Unit within the IMS, it is most effective to have the M&S Team report to the Environment Unit Leader who, in turn, reports through the Planning Section to the Command function. However, it is important to note that M&S activities also support, or are supported by, other parts of the IMS as outlined in Table 3 on page 18.

Table 2 Government agency departments and regulatory requirements that may be relevant in the event of an oil spill

GOVERNMENT AGENCIES	REGULATORY REQUIREMENTS
Local government departments: • Public health • Community infrastructure (e.g. municipal drinking water agency)	Regulations and environmental criteria/exceedance levels for key petroleum components (i.e. concentrations of concern) in the following media: • Surface water • Groundwater • Sediment • Soil • Air
Regional government (state, province, regional area) departments: • Environment • Fisheries • Wildlife • Public health • Heritage and archaeological preservation	Information and regulations related to permits and licences required to perform M&S activities (e.g. biota collection, waste management, hazardous materials shipping)
National government departments: • Environment • Fisheries • Wildlife • Public health	Access agreements (both governmental and private) Any other applicable regulatory requirements

Figure 3 Example of M&S Team integration within the IMS

(adapted from IPIECA-IOGP, 2014)

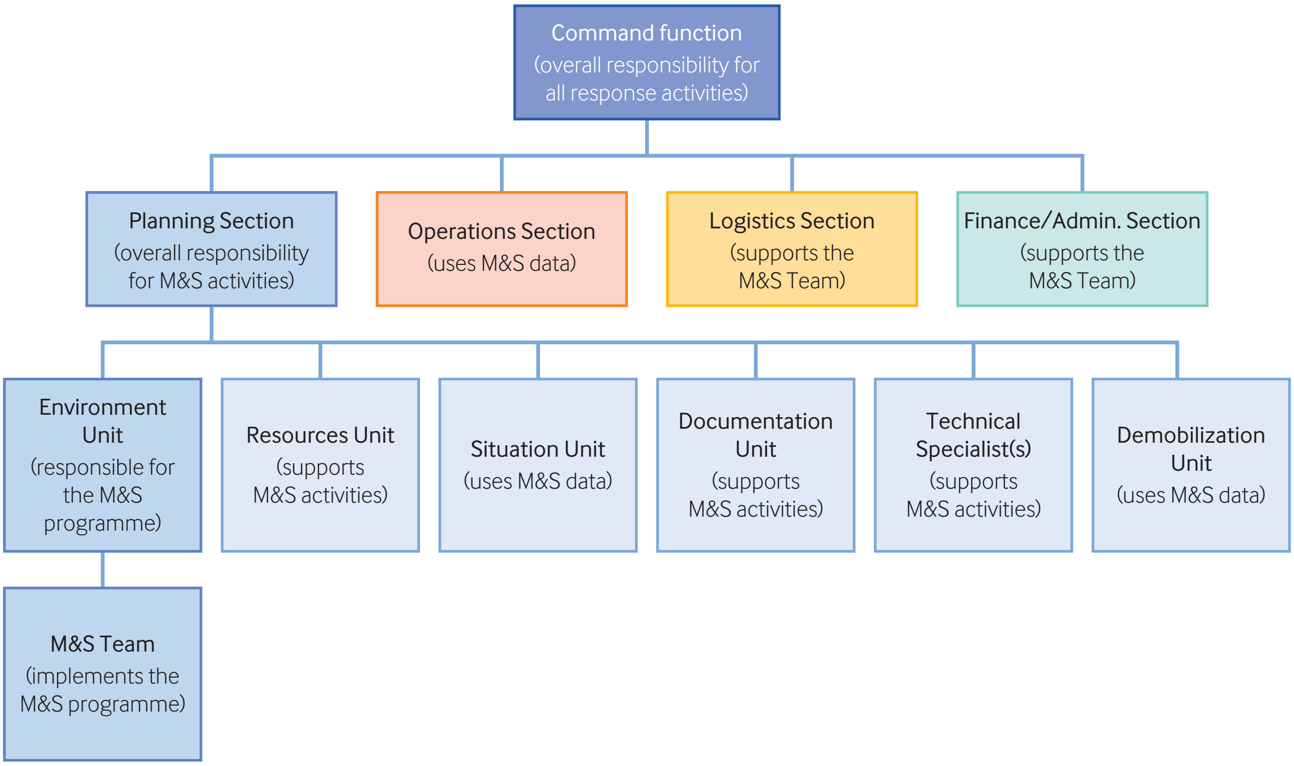

Table 3 IMS structure and linkage to M&S activities

IMS ELEMENT	GENERAL ROLE/RESPONSIBILITY	LINKAGE TO THE M&S TEAM
Command function	• Provides overall management and authority	Provides authority and objectives for M&S activities
Planning Section	• Prepares the Incident Action Plan • Maintains information on the status of resources and the overall status of the incident • Collects and evaluates operational information about the incident • Provides technical specialists	Incorporates M&S activities into the Incident Action Plan
Environment Unit	• Assesses potential environmental impacts of the incident • Establishes environmental priorities • Identifies ecological and socio-economic features at risk • Advises on oiled wildlife management and sampling activities • Formulates appropriate protection and mitigation strategies and treatment techniques • Evaluates SIMA or other impact assessment methodologies • Develops treatment target criteria	Responsible for the implementation of the M&S programme and the integration of M&S activities with other functions Responsible for the interpretation of sampling and monitoring results, and for developing advice based on this information in coordination with the M&S Team Leader
M&S Team	• Implements the M&S programme	Implements the M&S programme
Resources Unit	• Tracks all response resources including personnel, teams, equipment and facilities • Maintains an accurate and up-to-date record of the status of each resource to provide a complete picture for planning purposes	Supports M&S activities with resource planning
Situation Unit	• Collects and evaluates situational information for the response, including information on actions currently being undertaken, and forecasts of future incident management activities and information (weather, tides, oil trajectories, shoreline oiling reports, etc.)	Uses M&S data for situation tracking
Documentation Unit	• Manages the overall documentation for the response • Develops a complete overall administrative record, including logs, files, plans, maps and records for the response • Provides support to the Command function in the generation and preservation of response documents	Supports M&S data management and the M&S Team's Data Coordinator

continued ...

Table 3 IMS structure and linkage to M&S activities (continued)

IMS ELEMENT	GENERAL ROLE/RESPONSIBILITY	LINKAGE TO THE M&S TEAM
Technical Specialist(s)	• Provides support to response teams anywhere within the IMS organization depending on where their services are required	Supports M&S activities by providing additional technical expertise as required
Demobilization Unit	• Provides planning for the demobilization of personnel and response assets consistent with the needs of the overall response	Uses M&S data to determine when demobilization can start
Operations Section	• Directs the tactical operations throughout the incident	Uses M&S data to make operational decisions The M&S Team reports to the Operations Section with respect to field health and safety and operational decisions
Logistics Section	• Provides resources, services and support required by the incident	Supports the M&S Team by providing the resources, services and support required to implement the M&S programme
Finance/ Administration Section	• Responsible for financial controls, contracting and claims management	Supports the M&S Team by procuring resources and authorizing contracts required to implement the M&S programme

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Response personnel representing the various Sections, Units and Teams that operate within the IMS structure

In the case of smaller spills, the IMS would be simplified and there may not be a requirement for a full M&S Team. In this case one person may be responsible for M&S, or M&S would be merely a portion of an individual's overall responsibilities. As a result, the IMS structure would be simplified and M&S activities would likely be the responsibility of the Environment Unit within the Planning Section.

The key roles and responsibilities within the M&S Team are presented in Table 4. For a large spill, all roles identified in this table would likely be required and, in some cases, may be undertaken by more than one person. However, for a smaller spill, fewer resources would be required, and many of these roles could be combined and performed by a single person.

Table 4 M&S Team roles and responsibilities
(adapted from IPIECA-IOGP, 2014)

ROLE	RESPONSIBILITY
M&S Team Leader	• Oversees the development of the M&S plan and the implementation of the M&S programme • Reports on M&S activities to the Command function (through the Environment Unit/ Planning Section, as applicable) • Supports the Environment Unit Leader in the interpretation of sampling and monitoring results and the development of advice based on this information
Subject Matter Experts (SMEs)/ Technical Experts	• Provides independent advice on environmental matters relevant to M&S
Data Coordinator	• Establishes the M&S data management systems (including sample labelling and data compilation, storage and reporting) • Responsible for data visualization • Establishes the quality management system for the M&S programme
Health and Safety (H&S) Coordinator	• Reports to the Safety Officer and informs them of H&S issues and requirements as they relate to M&S activities • Communicates H&S requirements to the M&S Team • Monitors M&S activities to ensure that they are in compliance with H&S requirements
Sample Coordinator	• Coordinates the engagement of contractors and analytical laboratories • Manages sample receipt, storage and transport • Manages the interface between the field teams and laboratories
Field Operations Coordinator	• Develops the schedule and logistics associated with M&S activities • Identifies the equipment necessary for carrying out M&S activities • Identifies Field Team Leaders and field personnel for carrying out M&S activities • Mobilizes the M&S Field Team and equipment to the site
Field Team Leaders	• Coordinates and oversees M&S activities at specific field sites • Reviews site conditions, staff training requirements and pre-mobilization planning arrangements prior to mobilization to the assigned site
Field personnel	• Perform M&S activities in the field • Provide M&S data to the Field Team Leader

Figure 4 Example of M&S Team organization for a large spill

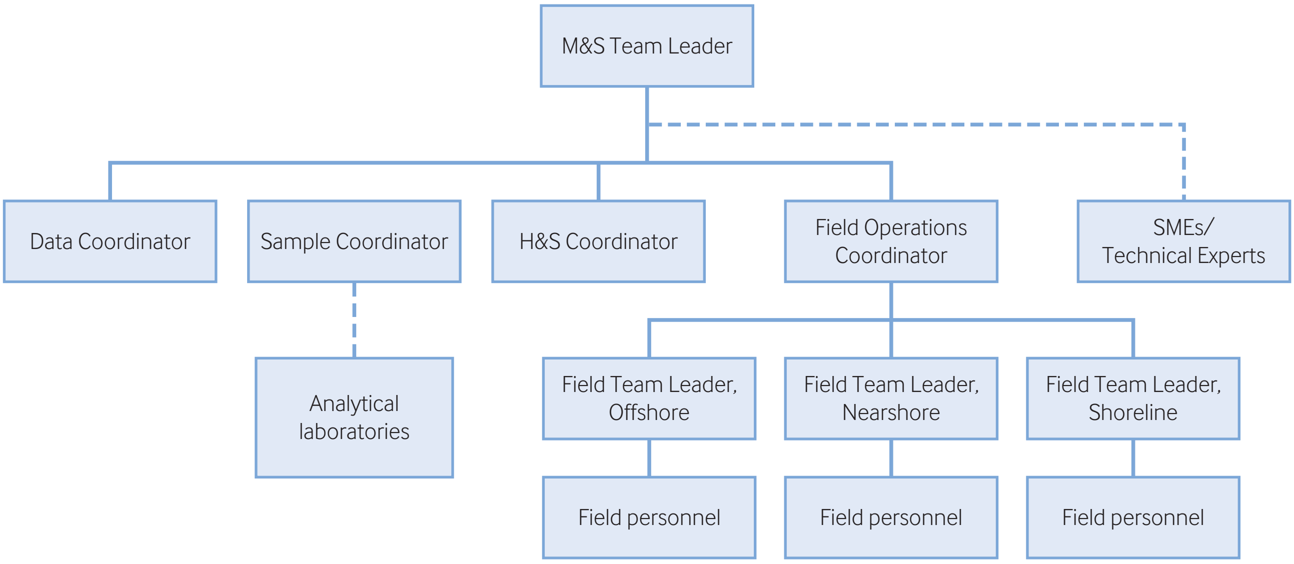


Figure 4 provides an example of an M&S Team organization for a large or complex M&S programme.

While the M&S Team within the IMS would typically consist primarily of personnel from the operator's company, external parties are also often engaged to provide specialized expertise. To facilitate this, planning should involve the identification of external technical specialists that may be required as part of the M&S Team; such expertise may include strategy advisors, field sampling contractors, analytical laboratories and data management specialists. As discussed under *Step 5: Coordinating equipment, external resources and contracts* on page 22, this planning work could involve identifying and, as required, making advance arrangements with individuals and service providers in these areas, and establishing standing agreements to allow these resources to be engaged quickly if an incident occurs. The planning activities associated with identifying the M&S Team should also include the development of a system to enable the rapid notification and activation of the M&S Team, as needed.

For additional information on the structure and organization of an IMS, see IPIECA-IOGP (2014), IMO (2012) and OSRL (2012).

STEP 3: DEVELOPING A GENERIC M&S PLAN

One way to ensure that M&S activities can be begin as soon as possible after a spill occurs is to have a generic M&S plan available that can easily be adapted to a variety of spill types and sizes, and which can be populated quickly if an incident occurs. For each phase of an M&S programme, an M&S plan should include information on:

- the aim and focus of the M&S programme;
- the activation process for the M&S Team/contractor(s);
- the types of media that need to be monitored and sampled;
- the locations that need to be monitored and sampled;
- how each M&S activity will be performed;
- how frequently each M&S activity will need to be undertaken;
- whether and how samples will be collected, preserved, transported and analysed;
- details of QA/QC procedures required to support the collected data; and
- the criteria that will be used to decide when to terminate an M&S activity.

This guide describes the main elements that are recommended for inclusion in an M&S plan. Appendix 1 provides a series of good practice checklists that can be used to develop an M&S plan.

STEP 4: ACQUIRING AND COMPILING BASELINE DATA

In many cases, some of the media (e.g. sediment, shoreline materials, plants) that will be sampled during a spill incident may have been impacted by oil from a previous spill rather than the current spill source. For this reason, baseline data (if available) can be highly important during efforts to quantify the spatial and temporal impacts of the spill on natural resources; data on these impacts can be an important basis for determining the amount of restoration or monetary-based compensation required to offset spill-related effects. Specifically, baseline data can be used to:

- determine the environmental conditions that existed before the oil impacted the area;
- confirm whether contamination is from the current spill source; and
- determine spill response effectiveness and environmental impacts.

Common sources of baseline data for informing M&S activities in relation to environmental impacts include:

- local sensitivity maps/data for areas that are protected or have important biodiversity, sensitive ecosystems, critical habitats, endangered species and/or key natural resources;
- Environmental Impact Assessments (EIAs); and
- other environmental monitoring studies.

For more sources of baseline data see IPIECA/IMO/IOGP, 2012.

The compilation of baseline data and the use of existing sensitivity maps (or the development of new ones) for areas susceptible to spills and, in particular, for sensitive areas where spills would have potentially significant impacts should, ideally, include input from stakeholders in close proximity to the affected area, including the public, indigenous groups and businesses.

Because the availability of pre-spill baseline data is rare and, in some cases, may not be representative of the situation immediately prior to the current spill, it is typically recommended that, early in a spill, reference (or ephemeral) data are collected from areas that could potentially be impacted (based on spill trajectory modelling), and from unimpacted areas that are adjacent and/or similar to the areas anticipated to be impacted by the incident. M&S preparedness activities should therefore include the development of procedures that enable the effective collection of reference data early during an incident.

STEP 5: COORDINATING EQUIPMENT, EXTERNAL RESOURCES AND CONTRACTS

Operators can also enhance their M&S preparedness for an incident by identifying and, where feasible, making advance arrangements with companies and individuals that can provide the services and equipment required for an M&S programme (Table 5). Where these services are not available near the potential spill locations, operators could also choose to procure and maintain key M&S equipment, supplies and platforms and store these items at strategic locations. These arrangements will ensure that the equipment, resources and expertise can be quickly deployed early in an incident, thus saving time for the collection of information during this important period.

Table 5 Types of M&S service providers that could be identified prior to a spill

POTENTIAL M&S SERVICE PROVIDER
• Contractors providing field personnel and specialized expertise (e.g. subsurface sampling)
• Transportation companies to transport personnel to M&S sites, and for transporting samples (e.g. rental cars, helicopters, boats, etc.)
• Accredited analytical laboratories for undertaking the chemical and physical analyses of samples
• Couriers for transporting samples to analytical laboratories
• Companies specializing in the logistics and performance of aerial, surface, ground and subsea surveillance
• Companies that supply monitoring equipment (including subsurface sampling equipment, photographic equipment, remote sensing equipment, AUVs, ROVs, UAVs)
• Companies that are able to supply items of sampling equipment that will not be supplied by the contracted analytical laboratory (e.g. bags and other containers, disposable spatulas and tongs)
• Electronics companies for computers, tablets, global positioning systems (GPS), etc.
• Safety supply companies for personal protective equipment (PPE) and decontamination supplies
• Hardware stores for general M&S equipment such as coolers, waste bags (for investigation-derived waste), zip lock bags, electrical tape, etc.

STEP 6: DEVELOPING A GENERIC DATA MANAGEMENT SYSTEM

The M&S Team (and/or Environment Unit) are responsible for the management of data associated with the environmental monitoring and sampling activities discussed in this document. They are not responsible for the wider data management operation relating to the overall spill event.

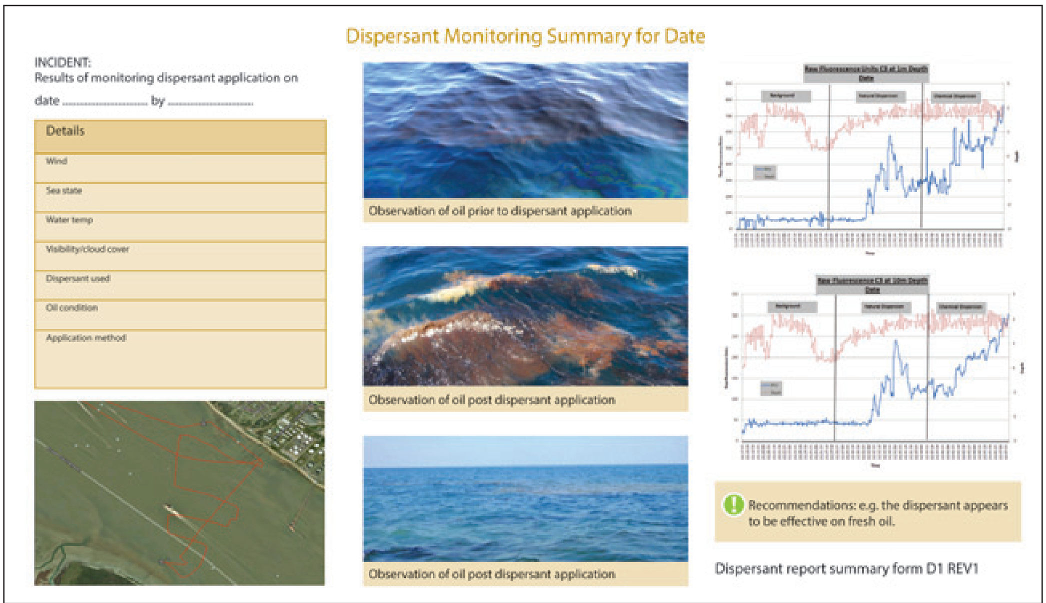
M&S programmes can generate a large amount of monitoring information and samples and, in turn, considerable amounts of data that need to be efficiently and effectively compiled, stored, managed, evaluated and extracted (Figure 5). These data need to be managed in a way that they can be effectively communicated, either within the IMS for decision-making purposes or to the public to provide updates on spill response status. Operators are therefore encouraged to include the development of an M&S data management system in their response planning activities. Such a system should be able to handle all forms of monitoring and sampling information, and should be capable of being implemented quickly during an incident.

Whenever M&S activities involve the collection of samples, it is important that systematic methods are in place to track these samples and the analytical data associated with them. Spill preparedness activities should therefore include the development of procedures related to the numbering and labelling of samples, and the recording of information on chain-of-custody (COC) forms that follow samples throughout the collection, transport, analysis and reporting steps.

One of the tools used by the Command function to communicate information related to a spill response, including the results of M&S activities, is the common operating picture (COP). The COP is defined as 'a computing platform based on geographic information system (GIS) technology, which provides a single source of data and information for situational awareness, coordination, communication and data archival to support emergency management and response personnel and other stakeholders involved in, or affected by, an incident' (IPIECA-IOGP, 2016b). Information obtained from M&S activities is an important component of the COP as it supports strategic and tactical decision-making within the IMS that is used to manage the response.

The key components of an M&S data management system that could be established prior to a spill are presented in Box 1 on page 24. Further details on the management and control of data quality and implementation of an M&S data management system, and specifics on numbering and labelling samples, can be found under *Step 6: Implementing a data management system* on page 47.

Figure 5 Example report summary form for recording dispersant monitoring data



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M&S activities can generate large amounts of data; an effective data management system will therefore need to be developed to ensure that these data can be efficiently and effectively compiled, stored, managed, evaluated and extracted as needed.

Box 1 The key components of an M&S data management system

An M&S data management system should include the components listed below:

- The ability to store a variety of data types, including the following:
  - M&S planning documents
  - GPS data
  - Air, ground and subsea surveillance photographic and remote sensing files
  - SCAT monitoring data
  - Field notes
  - Sample COC forms
  - Laboratory analytical reports
  - Other M&S reports
- A system or database to compile the following information on each piece of M&S data:
  - What was monitored or sampled
  - Why it was collected (e.g. for response information, spill impact information, reference data, etc.)
  - What types of data were acquired
  - Where the data were acquired (e.g. GPS data)
  - How the data were acquired
  - When the data were acquired (time and date)
  - Who obtained the data
  - In the case of a sample:
    - The unique sample label/number
    - Details of the holding time prior to analysis
    - Whether it is a quality assurance (QA) or quality control (QC) sample (i.e. duplicate, split, blank); (reference should be provided to the parent sample from which a QA/QC sample was derived)
    - Whether it is a split sample shared with regulatory authorities
    - What it was/will be analysed for
    - What the priority level was/is for analysis
    - Details of the turnaround time of the laboratory carrying out the analysis (results will likely be required in a rush; however, it should be noted that, in the event of a large spill, the rush turnaround capability of a laboratory may not always be achievable)
    - Where/to whom the results should be delivered
- A file naming system to enable different elements of M&S data to be distinguished so that specific tracked data can be easily located and used for decision-making
- A secure, shared file storage system
- A system to separate data that need to be reviewed from data that have been verified and validated
- A system (e.g. COP) that assists with the transmission and dissemination of data and information, as required, by the following personnel and organizations:
  - Those responsible for processing, compilation and validation
  - Other members of the IMS
  - Government, local stakeholders and indigenous groups

STEP 7: DEVELOPING A TRAINING AND EXERCISE PROGRAMME

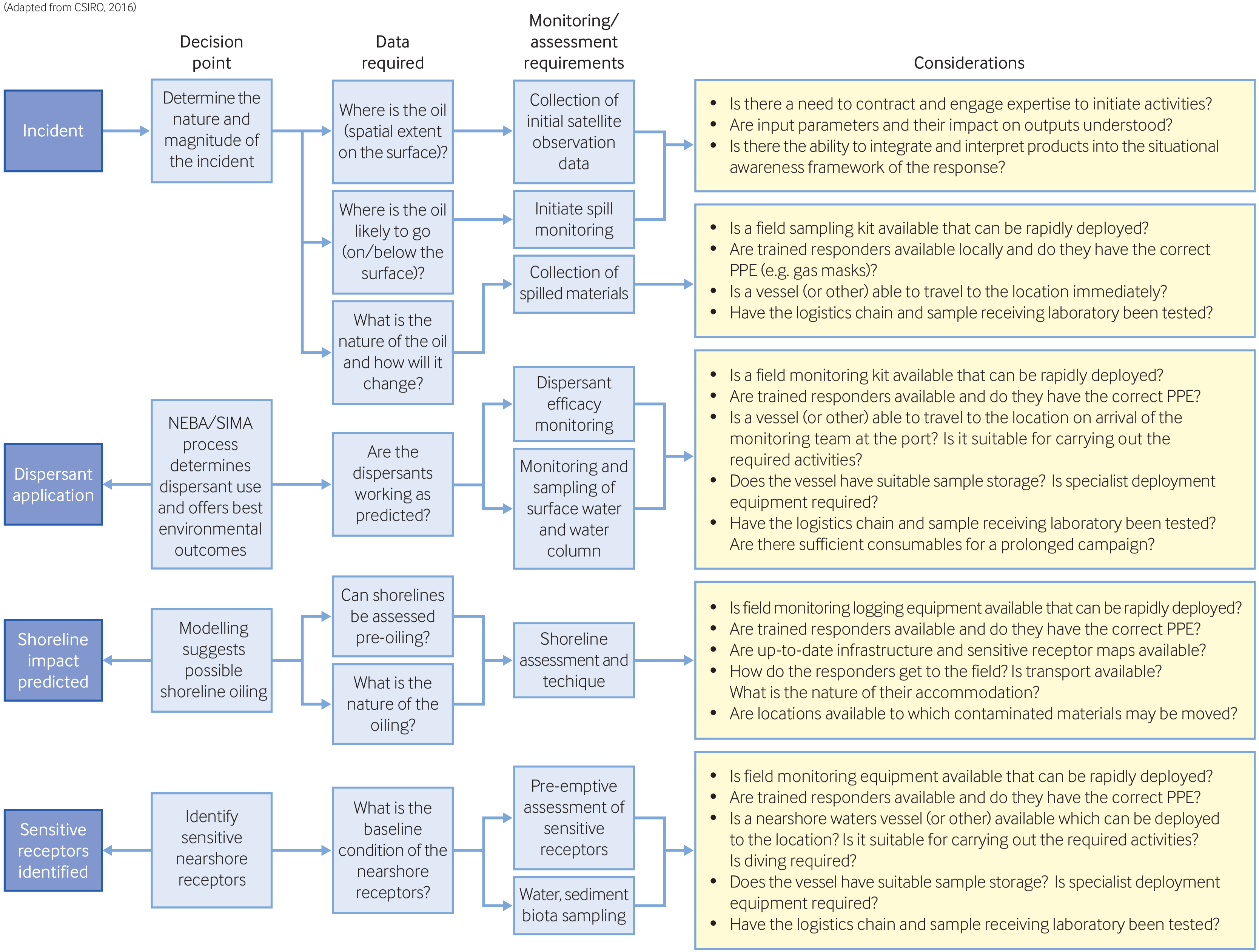
It is important that competent personnel are appointed to plan, oversee and implement M&S activities. Undertaking M&S activities can be physically challenging during a larger-scale response, and requires discipline-specific specialization to ensure accuracy and consistency. As part of the preparedness activities, the availability of key skills and knowledge, either internally or through the appointment of external SMEs, should be assessed so that gaps may be recognized, and any necessary training identified and implemented.

It is recommended that relevant training and exercises focus on the following areas:

- M&S plan development, including elements related to:
  - the phased approach to M&S planning;
  - establishing an M&S Team and its interaction with the IMS;
  - interaction with government agencies and regulatory bodies with respect to requirements and information/data sharing agreements;
  - the importance of collecting, compiling and using baseline data in M&S activities;
  - equipment, supplies and surveillance platform requirements for M&S activities;
  - health and safety requirements and procedures;
  - selecting the locations and media to be sampled;
  - the importance of collecting ephemeral data, which data tend to be ephemeral, and how to collect the data effectively; and
  - data management and reporting.
- Mobilizing a field team to collect and analyse environmental media samples.
- Testing the real-time provision of surveillance data to the Command function.
- Testing the receipt of electronic analytical data, verifying its QA/QC, and entering the data into the incident data management system.
- Monitoring, sampling and analytical methods related to key locations and media (see Tables 7 to 11 on pages 33–37), including:
  - source oil;
  - oil slick/sheen areas (pre- and post-response);
  - recovered oil from skimming or other recovery operations, and burn residue from in-situ burn operations;
  - water column from below slick/sheen areas and from unimpacted areas;
  - nearshore/shoreline/terrestrial/inland areas, including impacted and potentially impacted areas, and unimpacted areas that can be used as reference sites from which background data can be obtained (i.e. areas that are similar to impacted or potentially impacted areas);
  - human-made infrastructure, including impacted and potentially impacted areas, and unimpacted areas that can be used as reference sites from which background data can be obtained (i.e. areas that are similar to impacted or potentially impacted areas); and
  - air quality upwind from the slick, above and close to the spill, and near to populated and environmentally sensitive areas.

Operators should develop training materials and plan exercise scenarios to enable potential M&S Team members to understand the procedures and requirements related to M&S activities. Ideally, activation and management of the M&S plan should also be practised during response exercises so that capability may be assessed, and any improvements made based on feedback and review (e.g. lessons learned). Figure 6 on page 26 provides examples of decision points faced by an Environment Unit during a dispersant training exercise, the questions that had to be answered, the monitoring actions required to answer these questions, and several of the considerations associated with each monitoring action (CSIRO, 2016).

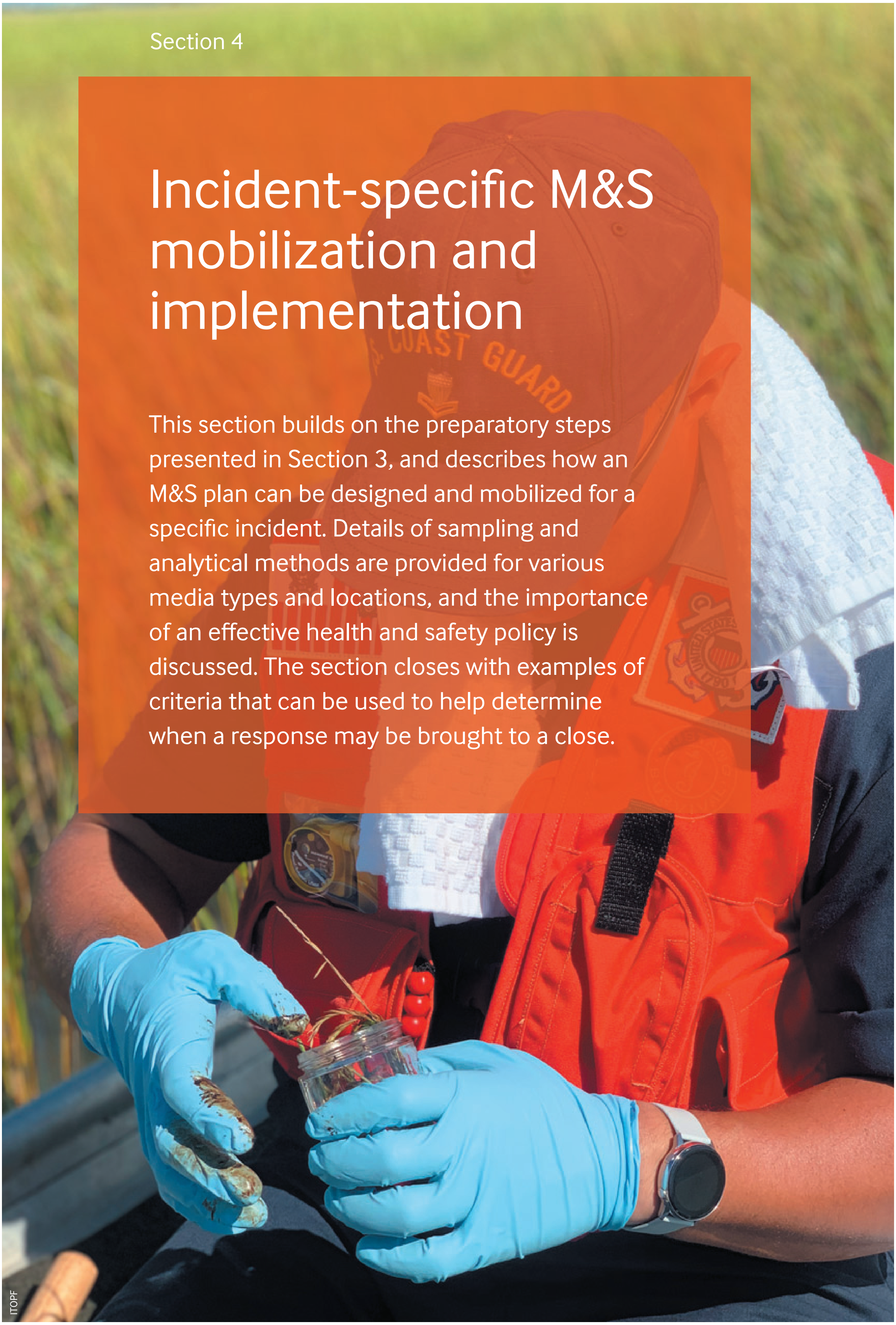
Figure 6 Example of monitoring requirements during an exercise using dispersant as a response technique
(Adapted from CSIRO, 2016)



Section 4

Incident-specific M&S mobilization and implementation

This section builds on the preparatory steps presented in Section 3, and describes how an M&S plan can be designed and mobilized for a specific incident. Details of sampling and analytical methods are provided for various media types and locations, and the importance of an effective health and safety policy is discussed. The section closes with examples of criteria that can be used to help determine when a response may be brought to a close.



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Incident-specific M&S mobilization and implementation

This section identifies and describes the key steps involved in developing and implementing a comprehensive M&S programme for a specific incident. These steps build on the preparedness steps introduced in Section 3, and include the following:

- Step 1: Coordinating and mobilizing the M&S programme.
- Step 2: Designing an M&S plan.
- Step 3: Selecting the locations and methods for undertaking M&S activities.
- Step 4: Monitoring the effectiveness of the selected response techniques.
- Step 5: Selecting the appropriate sampling and analytical methods.
- Step 6: Implementing a data management system.
- Step 7: Evaluating health, safety and logistical considerations relating to M&S activities.
- Step 8: Determining the criteria for termination of the M&S programme.

The extent to which the activities outlined in each step should be implemented is dependent upon the complexity of the M&S programme required for the response. Where possible, the phased approach to M&S is used to describe each of these steps.

STEP 1: COORDINATING AND MOBILIZING THE M&S PROGRAMME

In order for an M&S plan to be tailored to an incident and implemented as quickly and effectively as possible, a number of important mobilization activities will need to be undertaken. Many of these activities are extensions of the generic preparedness activities that should be performed by operators before an incident occurs (see Section 3) and are presented in Table 6 on page 29. These activities will generally take place in Phase 1 of the M&S programme and may be undertaken concurrently with initial M&S activities that are required early in the spill response (e.g. for situational analysis or the collection of ephemeral data). Figure 7 on page 30 presents the key steps associated with the coordination and mobilization of an M&S programme.

If a spill occurs, it is imperative that the M&S Team are notified and activated accordingly. The M&S Team will already have been established as part of the overall IMS (see *Step 2: Establishing a generic M&S Team structure* in Section 3). Based on the phased approach to M&S activities, for a small spill or in the early days of a larger spill, only a small team may be required with members that would perform more than one of the roles described in Table 4 (page 20). If required, the team can be expanded as the response evolves.

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Table 6 M&S mobilization steps

MOBILIZATION STEPS	RELEVANT SECTIONS IN THIS GUIDE
1. Notification and activation of the M&S Team	Establishing a generic M&S Team structure (page 16)
2. Situational awareness, and gathering critical information about the spill and the proposed response	Designing an M&S plan (page 30)
3. Obtain regulatory information on environmental criteria/exceedance levels and sampling requirements for key petroleum components	Compiling information on regulatory agencies and external organizations (page 16)
4. Review generic M&S planning information and adapt it as required by the spill situation	Developing a generic M&S plan (page 21)
5. Obtain permits and licences required for M&S activities	Compiling information on regulatory agencies and external organizations (page 16)
6. Brief the M&S Team and, as required, provide them with training on the situation and the proposed response	Developing a training and exercise programme (page 25)
7. Establish a data management system and communicate the quality management requirements	Developing a generic data management system (page 23)
8. Acquire and compile existing baseline data	Acquiring and compiling baseline data (page 22)
9. Arrange for other external resources and services and, as necessary, M&S equipment	Coordinating equipment, external resources and contracts (page 22)
10. Make transportation arrangements for personnel, equipment and samples	Coordinating equipment, external resources and contracts (page 22)
11. Contact and make arrangements or establish contracts with analytical laboratories	Coordinating equipment, external resources and contracts (page 22)

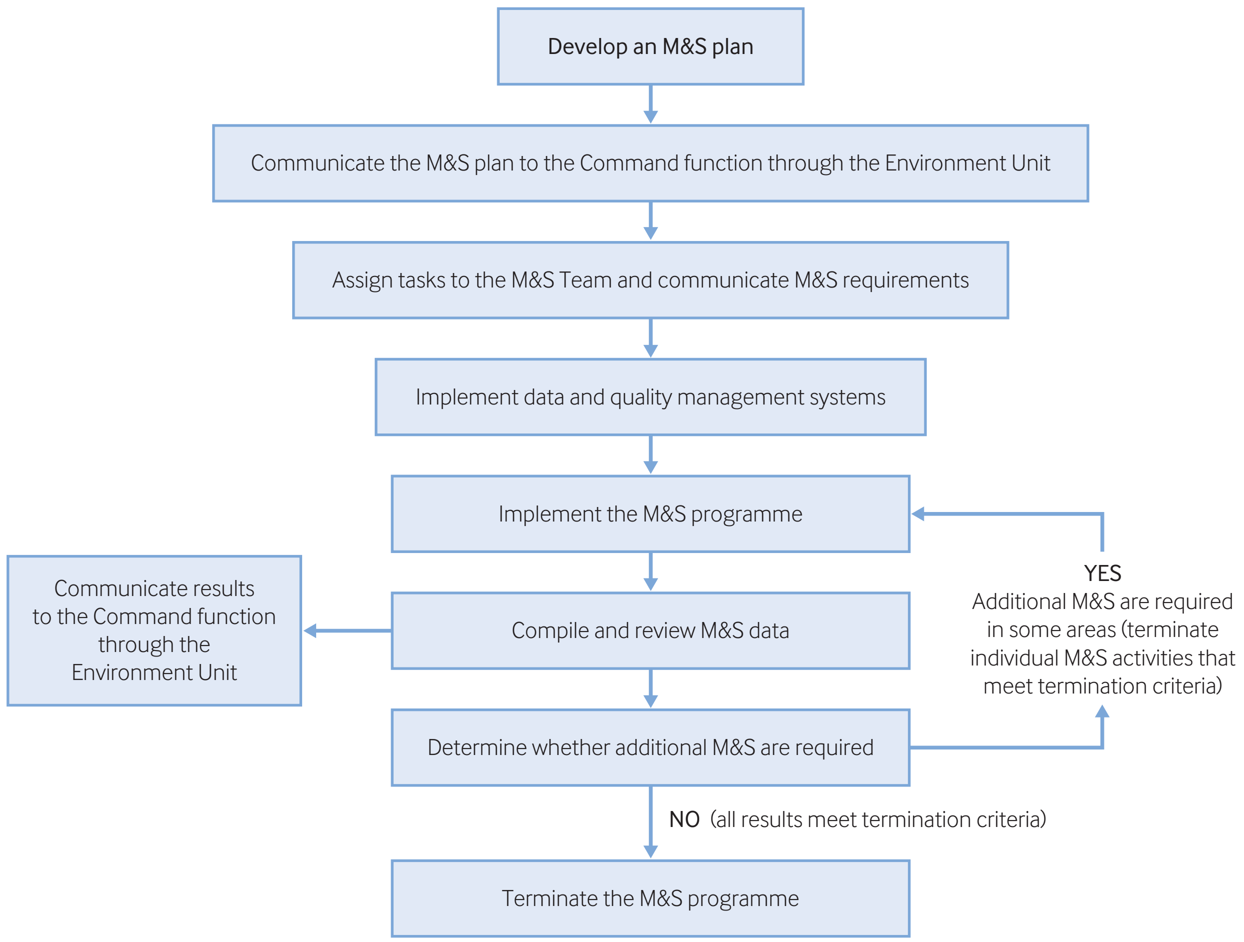
Regardless of the size of the team, the M&S Team Leader should work with the Environment Unit Leader and the IMS Command function (and, as applicable, other members of the IMS) to ensure that the roles and responsibilities of, and lines of reporting from, the M&S Team are clear and well defined. The M&S Team Leader, through the Environment Unit Leader, should also coordinate with the various other functions in the IMS to:

- ensure that M&S activities do not interfere with response operations;
- arrange for the sharing of resources (e.g. vessels, aircraft, ground transportation, etc.); and
- maintain M&S-related communications with the appropriate response-related personnel.

The health and safety of responders is of paramount importance, and the M&S Team Leader should coordinate with the Safety Officer to ensure that members of the M&S Team have had the necessary health and safety and M&S-specific training and/or certification required to perform the work they are assigned to undertake.

As the M&S programme evolves, any external experts and service providers that are needed should also be contacted and engaged to support the M&S Team. As discussed under *Step 2: Establishing a generic M&S Team structure* in Section 3, these external resources should have been identified and, as warranted, prearranged prior to the spill occurring.

Figure 7 Key steps in the coordination and mobilization of an M&S programme



STEP 2: DESIGNING AN M&S PLAN

In the early days of a spill, the M&S Team should have at least a basic plan and strategy in place prior to initiating the M&S programme. However, the development of this initial plan should not be allowed to interfere with opportunities to sample ephemeral data and meet any regulatory requirements associated with M&S activities. Some countries require that M&S activities begin within 24 hours of an incident. This further supports the requirement to develop a generic M&S plan prior to an incident, as outlined on page 21, that can easily be adapted to a variety of spill types and sizes, and which can then be populated quickly if an incident occurs.

Gathering as much critical information as possible about the spill situation is a key component in the effective design of an M&S plan. When compiling this information, it is also important to communicate and coordinate with other IMS groups to ensure that the M&S activities being planned align with, and are not precluded by, other response activities.

A combination of fixed sampling locations and adaptive monitoring should be considered as the event unfolds. This will allow a trend analysis to be produced for specific parameters, enable the M&S Team to document the efficacy of interventions, and will inform operational decision-making.

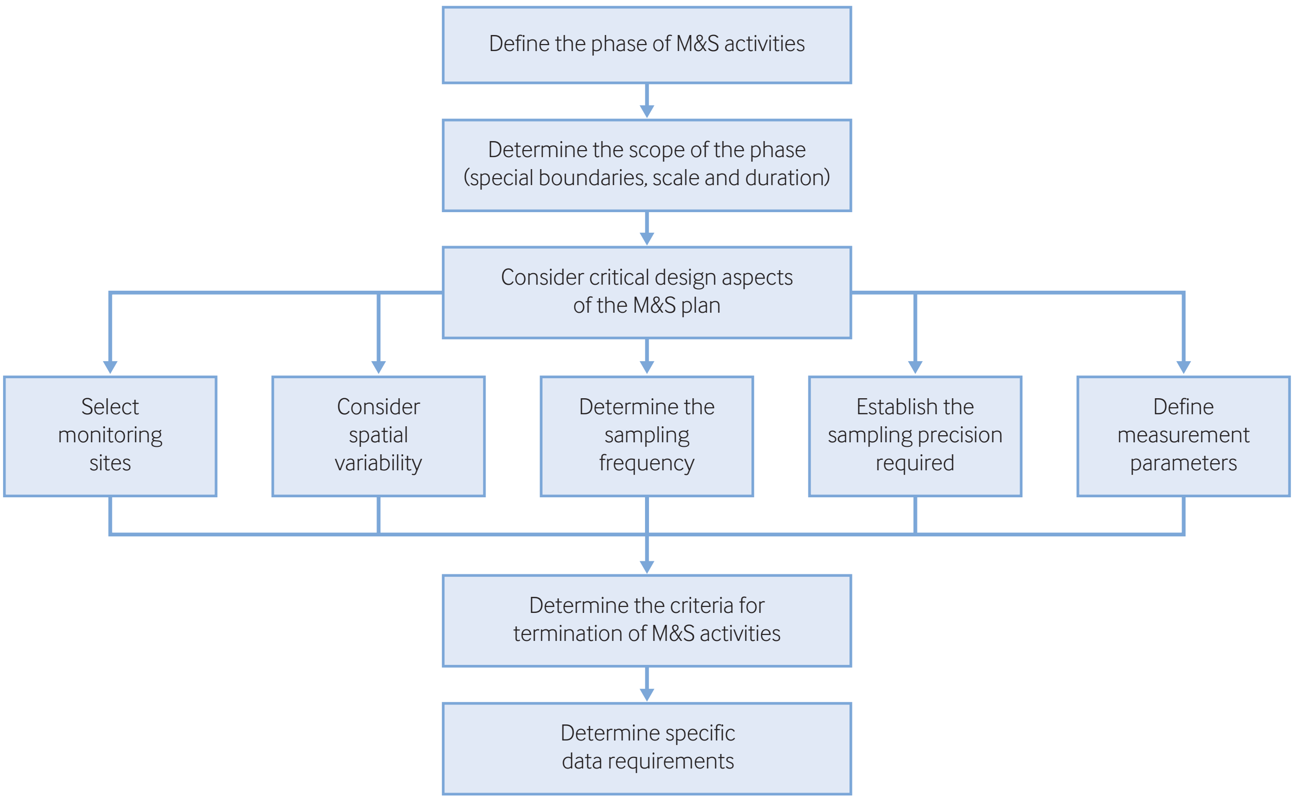
The key situational awareness information that should be acquired from the response team or others with knowledge of the spill situation as soon as possible after the spill includes:

- the source of the spill;
- the status of the release (continuing, slowing, stopped);
- the oil type/volume;
- spill trajectories;
- sea states;
- weather forecasts;
- existing baseline data compilations;
- location and sensitivity of resources at risk;
- location of communities and human-made infrastructure (e.g. water intakes, fishery facilities, aquaculture facilities, ports, industrial sites, recreation and tourism sites); and
- the most up-to-date response plan and spill objectives.

Figure 8 presents the key aspects that need to be addressed when determining the scale and scope of an M&S plan based on the M&S programme phase. Using the phased approach to the M&S programme, it is important that the elements of the plan outlined in Figure 8 are commensurate with the complexity of the M&S required (i.e. they should be aligned with the phases described in Section 2).

Many different factors will influence the continued presence of oil in various locations impacted by a spill, and it can be difficult to properly estimate the full extent of the M&S activities that will be required throughout the response. An M&S plan will therefore need to be adaptive and iterative so that it can be adjusted to take account of information that is acquired as the response evolves (ITOPF, 2012). The results of previous M&S activities should be used to define any additional M&S actions required, but also to help guide decisions on when to conclude specific aspects of the programme.

Figure 8 Key aspects that need to be considered when determining the scale and scope of an M&S plan
(adapted from CSIRO, 2016)



The key elements of an M&S plan are presented in the remainder of this section, as follows:

- Step 3: Selecting the locations and methods for undertaking M&S activities.
- Step 4: Monitoring the effectiveness of the selected response techniques.
- Step 5: Selecting the appropriate sampling and analytical methods.
- Step 6: Implementing a data management system.
- Step 7: Evaluating health, safety and logistical considerations relating to M&S activities.
- Step 8: Determining the criteria for termination of the M&S programme.

STEP 3: SELECTING THE LOCATIONS AND METHODS FOR UNDERTAKING M&S ACTIVITIES

The type and location of the initial (Phase 1) M&S activities required during the early days of a response are generally based on the analysis of information on the spill situation (see *Step 2: Designing an M&S plan* on page 30), the objectives set for the response by the Command function based on that information, and any regulatory requirements. For larger spills, as the response operations proceed, M&S activities will evolve (i.e. move into Phase 2) based on the results from the initial activities and the decisions that have been made in relation to the response. In cases where there are actual or expected impacts on resources at risk, additional M&S activities will be required to properly assess the impacts of the spill and to reach consensus on the eventual termination of the M&S programme (Phase 3).

To assist in the selection of the types and locations of M&S activities required during each of these phases, Tables 7 to 11 present a list of potential M&S locations and media types, along with the typical monitoring objectives and methods that could be used for each. These tables also recommend the typical phase during which each of these M&S activities would occur. It should be noted that the lists of typical locations and media presented in these tables are not exhaustive, as it is not possible to cover all spill situations in this document. The tables should therefore be used as a guide to help develop a spill-specific list of locations and media that may require M&S activities.

Table 7 Oil: potential locations, media types, objectives and methods for M&S activities

M&S LOCATION	MEDIA TYPE	M&S OBJECTIVE	M&S METHOD	TYPICAL PHASE
Source oil	Oil	Characterize the source/determine the chemical fingerprint to verify against impacted areas	Oil sampling and analysis for petroleum hydrocarbon composition	Phase 1
Oil slick/sheen areas—pre-response	Fresh and weathered/emulsified oil	Confirm the source of the slick/sheen	Oil sampling and analysis for baseline petroleum hydrocarbon composition	Phase 1
		Determine area, thickness, weathering and emulsification of the slick/sheen for response decision-making	Observations from satellites, aircraft, vessels using optical, infrared, radar, photo and video techniques, and trained observers; and/or oil sampling and analysis of the physical properties of the oil	Phase 2
Oil slick/sheen areas—post-response	Treated oil	Determine the area and thickness of the slick/sheen to evaluate response effectiveness		Phase 2
		Determine the post-response thickness, weathering and emulsification of unrecovered slick/sheen areas to provide an understanding of potential environmental impacts		Phase 3
Recovered oil/ oil residue	Oil recovered from skimming or other recovery operations	Determine effectiveness of recovery and/or ISB operations Determine waste disposal options	Oil sampling and analysis of the water content and petroleum hydrocarbon composition	Phase 2
	Burn residue from in-situ burning operations			
	Water run-off from waste streams			

Table 8 Water quality: potential locations, media types, objectives and methods for M&S activities

M&S LOCATION	MEDIA TYPE	M&S OBJECTIVE	M&S METHOD	TYPICAL PHASE
Water column from unimpacted areas	Water	Delineate slick/sheen areas; and determine baseline conditions for petroleum hydrocarbon levels in the water	Water sampling and analysis for background petroleum hydrocarbon concentration and composition	Phase 1
Water column below slick/sheen areas	Water	Determine the level of oil dispersion, either naturally or from the use of dispersants	Water sampling and analysis for petroleum hydrocarbon concentration and composition	Phase 2


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Table 9 Nearshore/shoreline/terrestrial/inland areas: potential locations, media types, objectives and methods for M&S activities

M&S LOCATION	MEDIA TYPE	M&S OBJECTIVE	M&S METHOD	TYPICAL PHASE
Unimpacted nearshore/shoreline/terrestrial/inland areas that can be used as reference sites from which background data can be obtained (i.e. areas that are similar to impacted or potentially impacted areas)	Sediment and soil	Determine baseline conditions for oil coverage levels	Visual observations using trained observers to estimate background oil coverage; and/or substrate sampling and analysis for background petroleum hydrocarbon concentration and composition	Phase 1
	Bedrock/ boulders		Visual observations using trained observers to estimate oil coverage; and/or sampling and analysis for background petroleum hydrocarbon concentration and composition	Phase 1
	Adjacent water		Sampling and analysis for background petroleum hydrocarbon concentration	Phase 1
	Biota	Determine baseline conditions for population, coverage and biomarker levels	Species surveys to estimate populations; and/or biomarker baseline analysis	Phase 1
Impacted nearshore/ shoreline/terrestrial/ inland areas, including run-off from waste streams	Sediment and soil	Verify the source of oil; determine the percentage oil coverage for response decision-making; determine the criteria for termination; and assess environmental impacts	Visual observations using trained observers to estimate oil coverage; and/or substrate sampling and analysis for petroleum hydrocarbon concentration and composition	Phase 3
	Bedrock/ boulders		Visual observations using trained observers to estimate oil coverage; and/or sampling and analysis for petroleum hydrocarbon concentration and composition	Phase 3
	Adjacent water		Sampling and analysis for background petroleum hydrocarbon concentration	Phase 3
	Biota		Species surveys to estimate populations, and visual observations of percentage oil coverage; and/or biomarker analysis to measure physiological changes	Phase 3

Table 10 Human-made infrastructure: potential locations, media types, objectives and methods for M&S activities

M&S LOCATION	MEDIA TYPE	M&S OBJECTIVE	M&S METHOD	TYPICAL PHASE
Unimpacted human-made infrastructure (e.g. ports, fishery and aquaculture infrastructure, recreational and tourism areas, water intakes) that can be used as reference sites from which background data can be obtained (i.e. areas that are similar to impacted or potentially impacted areas)	Solid surfaces	Determine baseline conditions for oil coverage levels	Visual observations using trained observers to estimate background oil coverage; and/or sampling and analysis for background petroleum hydrocarbon concentration and composition	Phase 1
	Water from intakes	Determine baseline conditions for petroleum hydrocarbon concentrations in intakes	Water sampling and analysis for background petroleum hydrocarbon concentration and composition	Phase 1
Impacted human-made infrastructure (e.g. ports, fishery/aquaculture infrastructure, recreational/tourism areas, water intakes)	Solid surfaces	Verify the source of the oil; determine the percentage oil coverage for response decision-making; determine termination criteria and assess impacts on, and damage to, the infrastructure	Visual observations using trained observers to estimate oil coverage; and/or sampling and analysis for petroleum hydrocarbon concentration and composition	Phase 3
	Water from intakes	Verify the source of the oil; determine petroleum hydrocarbon concentrations for response decision-making; determine termination criteria	Water sampling and analysis for petroleum hydrocarbon concentration and composition	Phase 3

Coastal aquaculture facilities are an important example of human-made infrastructure that would need to be a focus for M&S activities following an oil spill.

Table 11 Air quality: potential locations, media types, objectives and methods for M&S activities

M&S LOCATION	MEDIA TYPE	M&S OBJECTIVE	M&S METHOD	TYPICAL PHASE
Atmosphere upwind from the slick	Air	Determine background levels of volatile organic compounds (VOCs) and particulates	Use of air sampling instrumentation to perform analyses for VOC concentrations and particulate size and concentrations	Phase 1
Atmosphere above and close to the spill		Determine VOC and particulate levels to assess the safety of responders		Phases 1 and 2
Atmosphere near populated and environmentally sensitive areas		Determine VOC and particulate levels to assess the safety of the public and impacts on environmentally sensitive areas		Phases 1, 2 and 3


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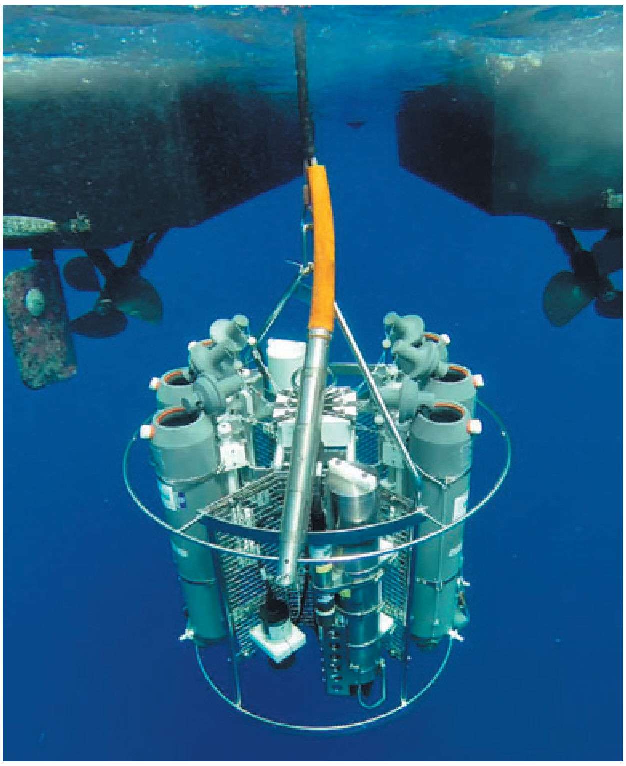
Air quality monitoring is essential following an oil spill in the vicinity of populated or environmentally sensitive areas.

STEP 4: MONITORING THE EFFECTIVENESS OF THE SELECTED RESPONSE TECHNIQUES

Key objectives of an oil spill M&S programme are to determine the effectiveness of response techniques and assess whether established M&S thresholds for the various media types have been met, as well as ensuring the safety of responders undertaking M&S activities. This can be achieved using visual techniques and, as required, through sampling and analysis, as shown in Tables 7 to 11 on pages 33 to 37.

The Special Monitoring of Applied Response Technologies (SMART) is a monitoring programme that has been established specifically for use when dispersants and in-situ burning are employed as oil spill response techniques (IPIECA-IOGP, 2016d, 2016e, 2016f; NOAA, 2006). The SMART programme involves the collection of real-time data using portable, rugged and easy-to-use instruments during dispersant and in-situ burning operations. The information obtained can be used to determine the effectiveness of the techniques and to ensure that they are being applied safely (API, 2020; IPIECA-IOGP, 2016b; IPIECA-IOGP, 2016c).


CSA Ocean Sciences

An example of water quality monitoring equipment

To monitor the efficacy of dispersant application, the SMART process recommends the following three levels of monitoring, starting with simple and quick monitoring to obtain rough data, and moving to more complex and detailed monitoring (NOAA, 2006):

Level 1: Visual observations, i.e. trained observers flying over the oil slick and using photographic job aids or advanced remote sensing instruments to assess the dispersant efficacy. This is typically the initial observation undertaken to determine whether the application of dispersant is effective, but does not enable quantification of how much oil is being dispersed.

Level 2: Use of monitoring instrumentation, i.e. collecting near real-time data from the treated slick using vessel-based instrumentation to continuously monitor for dispersed oil one metre beneath the dispersant-treated slick. These techniques are typically used to confirm the visual observations. If feasible, water samples should be collected to validate and quantify the data collected through the use of monitoring instrumentation.

Level 3: Expanded monitoring programme, i.e. using an expanded monitoring programme to gather additional information on where the dispersed oil is going and how effectively it is being dispersed. This level typically uses a wide range of vehicles and platforms as hosts for sensing systems in order to monitor the oil at various depths and locations in and around the slick. Analyses for physical and chemical parameters in water samples taken from the water column below the dispersed slick are typically performed in greater numbers than when undertaking Level 2 monitoring.

The American Petroleum Institute (API) has developed the *Industry Recommended Subsea Dispersant Monitoring Plan* (API, 2020; IPIECA-IOGP, 2016c) which is intended to supplement the SMART process specifically when using subsea dispersant application as a response technique (e.g. at a subsea well head). The API process presents a more detailed approach to dispersant M&S, which includes the rapid deployment of an initial monitoring programme to quickly provide dispersant efficacy information to operational decision-makers.

Subsequent steps involve more comprehensive monitoring tools that may assist oil spill responders in monitoring the dilution of dispersed oil and the oil's chemical fate. The three API steps are described as follows:

1. Confirmation of dispersant effectiveness near the discharge point and reduction in surface VOCs.
2. Characterization of dispersed oil concentrations at depths in the water column.
3. Detailed chemical characterization of water samples.

For in-situ burning operations, the SMART process involves deploying a monitoring team (or teams) downwind of the burn, specifically in populated or environmentally sensitive areas. Before the burn starts the team collects background data; then, after the burn begins, they continue sampling to assess trends in particulate concentrations. Both sets of data are recorded manually at fixed intervals, and automatically using a data logger (NOAA, 2006).

Table 12 summarizes the key aspects of an in-situ burn operation that need to be monitored. In particular, samples of the oil, both pre-burn and post-burn, should be targeted for collection and analysis (IPIECA-IOGP, 2016d). The collection and handling of the burn residue samples should follow the same general guidelines outlined for weathered oil. It should be noted that when oil burning takes place on water, the burn residue of floating oil may sink due to a loss of volatile compounds which increases the oil density. Residue samples from the burning of crude oil may resemble tar balls or heavy mousse, whereas a light product burn residue may be similar to a sheen.

STEP 5: SELECTING THE APPROPRIATE SAMPLING AND ANALYTICAL METHODS

In some cases, to verify monitoring information or to gather additional information related to response effectiveness, responder and public safety and/or environmental effects, sampling and analysis may be required. The selection of appropriate sampling and analytical methods for each selected media is dependent on the objectives defined in the M&S plan, and will evolve as the response progresses and as information is acquired. These activities typically do not occur in Phase 1 of an M&S programme.

General guidance on the methods of sampling and analysis is provided on pages 40–42, and is followed by more specific guidance relating to specific media types including oil, water, sediment and soil, solid surfaces (boulders and human-made infrastructure), biota and air. Further guidance on M&S activities related to specific media is presented in Appendix 3 which provides a list of selected references from a variety of jurisdictions.

It is preferable for the analysis of samples to be performed by a laboratory that is accredited for each required analysis in the jurisdiction responsible. The accredited analytical laboratory chosen to perform the analyses will be able to provide further direction on the volume, storage and handling of samples and on the type of analysis that should be undertaken to obtain the information required. Additional information on the QC associated with sampling and sample data management is provided under *Step 6: Implementing a data management system* on page 47.

Table 12 Monitoring an in-situ burn operation

ASPECT	TARGETS OF OBSERVATION	INTERPRETATION
Burn effectiveness	Oiled area ignited and burning over time	Efficiency of oil removal; volume of oil removal
Fire boom containment integrity (if used)	Loss of a boom's ability to contain the slick	Provide early warning to vessel operators and responders
Fire safety	Proximity of personnel to the burn	Danger to humans, infrastructure and amenities
	Fire control and movement	
Burn emissions	Particulates	Monitor human exposure

General sampling procedures

The determination of the locations where samples are to be taken, and the number of samples required from each location, is dependent upon the type and extent of contamination, the uniformity and size of the site, and the level/type of information desired. It may be more practical to describe conceptual sampling locations rather than actual geographic locations, as the spill trajectory may change and it is important to collect reference samples from where the oil is not present, as well as taking samples from where oil is already present.

Often, a combination of strategies is the best approach, using the following three sampling methods (US EPA, 1994):

- **Random sampling:** a collection of samples in a non-systematic fashion from the entire site or a specific portion of a site.
- **Systematic sampling:** a collection of samples based on a grid or a pattern which has been previously established.
- **Judgemental (judgement-based) sampling:** a collection of samples taken only from the portion(s) of the site most likely to be contaminated (US EPA, 1994).

The actual collection of samples generally falls into the following two categories (US EPA, 1994):

- **Grab samples:** a grab sample is a discrete aliquot representative of a specific location at a given point in time. The sample is collected all at once at one point in the sample medium. The representativeness of such samples is defined by the nature of the materials being sampled. In general, as sources vary over time and distance, the representativeness of grab samples will decrease.
- **Composite samples:** a composite sample is a non-discrete sample composed of more than one specific aliquot collected at various sampling locations and/or different points in time. Analysis of this type of sample produces an average value and can in certain instances be used as an alternative to analysing a number of individual grab samples and calculating an average value. It should be noted, however, that compositing can mask problems by diluting isolated concentrations of some hazardous compounds below detection limits.

For QC purposes, the sampling plan should consider collecting the following additional types of samples (ITOPF, 2012):

- **Field duplicate/replicate samples:** two or more samples that should be identical, taken using the same device and procedure at the same location. Such samples are used to test sample variance, and their identity may not always be made known to the laboratory.
- **Split sample:** a fully-homogenized sample which is divided after being collected so that it can be analysed independently by two or more parties.
- **Laboratory duplicate:** a single sample which is split into two or more samples that are then used to check the precision of a laboratory analysis. The splitting of samples is typically done by the laboratory performing the analysis.

Table 13 on page 41 provides an indication of the quantities of samples that are typically required, by media type (ITOPF, 2012). As an aid to ensuring the quality of the samples and the data obtained from them, Table 14 (page 41) provides general guidelines that should be used to avoid cross-contamination or damage to samples when collecting, transporting and storing samples (ITOPF, 2012). Note that, when collecting samples, it is advisable to avoid free water in oil samples and free oil in water samples.

As outlined under *Step 6: Developing a generic data management system* on page 23, samples taken as part of an M&S programme should be numbered and labelled, and recorded on a COC form that accompanies the sample throughout the collection, transport, analysis and reporting steps. If multiple teams are collecting samples simultaneously, it is extremely important that a numerical coding scheme is planned ahead of time so that each sample can be assigned a unique identification number; any changes to the sample numbering or labelling requirements should be coordinated by the data management team. In the case of spill situations with a large number of samples coming from various sources, a central sample intake area and role should be established to ensure compliance and accurate sample labelling.

Table 13 General quantities of samples required for analysis

DESCRIPTION	INDICATION OF MINIMUM REQUIRED QUANTITY (PER SAMPLE)
Pure oil source sample	30–50 ml
Contaminated oil (e.g. emulsified oil, oil from the sea or shore, sandy tar ball, etc.)	10–20 g
Debris with oil, oil-stained sand	Sufficient quantity that oil content is approximately 10 g
Oiled feather	5–10 feathers depending on oil quantity present
Fish, shellfish (fresh and organs)	Multiple individuals of the same species totalling 30 g
Water sample with visible oil	1 litre
Water sample with no visible oil	3–5 litres

Table 14 General guidelines for sample collection, transportation and storage

SAMPLE TYPE	GUIDELINES
Fluid samples (general)	• Use laboratory-supplied clean jars/lids. • Use amber bottles or keep samples in the dark during transfer and storage.
Fluid oil samples	• Fluid source oils may be collected in stainless steel containers. • Use 30 ml or larger sample jars for pure oil and oiled sediments.
Water samples	• Protect against photo-oxidation and degradation by keeping samples cool and in the dark. • Wide necks and screw caps are recommended. • Avoid using narrow-mouthed or thin glass sample jars as these are harder to fill and may break during transport. • When filling sample jars with liquid or oily debris, allow some space for thermal expansion, especially if there is a risk of freezing.
Solid or semi-solid samples	• Transfer the samples with an unused lollipop stick or wooden tongue depressor. • Use a new sampling stick for handling each sample.
General	• Avoid the use of plastic containers; these can contaminate the sample and should be avoided. • Use clean nitrile gloves (if available) to avoid the risk of contamination by trace oils from skin during handling. • Sample jars should be correctly labelled with a unique reference number, location, time and date, type of sample and other relevant information (e.g. the depth at which the sample was obtained). • Standard labels should be prepared with as much information as possible just before taking the sample. Use a permanent pen, and cover the label with clear tape to maintain its legibility (do this after sealing the container, so that the SVOCs/VOCs in the glue do not contaminate the sample). • Secure the lids of containers to avoid spillage and to ensure that no tampering can take place along the COC. • Use tape to ensure that the lids remain secure. • Avoid contamination. • Clean sampling devices between samples using appropriate procedures. Avoid smoking! Keep samples and sampling devices away from vessel exhaust or similar.


ITOPF

Key items to remember when numbering, labelling and recording samples are listed below (NOAA, 2014):

- Labels should be secured to the sampling container and be long-lasting.
- Label numbering should be clear, legible, accurate and unique.
- When labelling jars, the sample number should be recorded on both the label and lid, and a protective layer of clear tape wrapped around the entire circumference of the container to secure the label and protect the writing.
- The sample number should be recorded on the COC form and checked against the sample number on the container to ensure that they are the same.
- For samples placed in bags, a sturdy waterproof paper label written in indelible ink should be placed into the bag, and an additional copy of the label attached to the outside of the bag.
- For each sampling area, a field sketch should be created and attached to the COC form showing the location where samples were taken, identified by sample number, and including a scale, north arrow, location of the transects, description of the area and any visible oil locations. Sampling locations should also be geo-referenced and recorded.

The following shipping requirements should also be considered when handling hazardous samples in the field (NOAA, 2014):

- It is important to ensure compliance with hazardous materials regulations, which typically pertain to sample preservatives and other materials (e.g. formalin, alcohols, solvents, some cleaning agents, etc.).
- The shipment of hazardous materials may be subject to legislation on the transportation of dangerous goods, and may require the use of special packaging (e.g. primary container, watertight secondary container, absorbent material between the primary and secondary containers, and sturdy outer packaging).
- Hazardous materials may need to be shipped to sampling locations via cargo or charter aircraft, and will need proper documentation and shipping containers to comply with transportation regulations. Shipment by air is more strictly regulated than ground shipment and, in the case of source oil, there will be a limit on the volume of oil that can be transported.
- It should be borne in mind that some of these shipping requirements may delay the shipment of equipment and other materials to field study areas.

Oil sampling and analysis

Oil sampling requires a variety of procedures and equipment, the selection of which are determined by site-specific conditions and the type of oil. As outlined in Table 7 on page 33, different types of oil samples are required to characterize an oil spill, select appropriate response techniques and determine the effectiveness of the chosen response plan. Typical oil sample types are listed below:

- Source oil (also called product or 'neat' oil): For baseline information and to verify the source of potential impacts, samples of the spilled oil which has not had contact with the environment should be taken. These samples should be collected directly from the source when possible and as soon as possible. It is of critical importance that all sources of spilled oil are identified and sampled to enable forensic analyses and toxicity testing as well as to enable comparison with the oil that may be detected in samples collected from various media.
- Oil slick/sheen: To learn about the spill and its behaviour, and make decisions related to response options and response efficiency, samples of the slick/sheen should be taken over time. Early in the spill, both fresh and weathered samples should be collected. To properly document the degradation of the oil over time, repeated samples of weathered oil are usually needed. Weathered oil samples may consist of floating oil, mousse or tar balls. This information will assist in determining response options. Once a response option is chosen, samples of the slick/sheen should be collected both before and after the response operation (e.g. skimming, in-situ burning, dispersants) takes place, so that the effectiveness of the response can be determined.
- **Recovered oil/oil residue:** Samples should be taken from oil that has been collected through recovery operations (e.g. skimming) and/or oil that has been treated either with physical or chemical response techniques (e.g. high-pressure washing, burning, herding agents, dispersants, etc.). These samples may be used to determine the effectiveness of the response techniques, as well as determining waste disposal options, and can be analysed for water content and/or chemical composition.

If the slick is thick enough, samples of it can be taken from the water surface using sampling jars or sorbent pads (ITOPF, 2012). If access is restricted, samples may be collected using a bucket on a rope or by using extension poles. If samples are taken from the bow of a boat, care should be taken to avoid sheens from the sampling vessel's hull or engine exhaust. For thin sheens, specialized, fine-mesh sampling nets can be used. For quality control, unused sampling nets or sorbent pads should be provided to the laboratory as references for analysis alongside the sample. As it is difficult to collect a sample of pure oil from a spill site, samples may include a small amount of water and/or sediment, which will need to be considered during analyses.

Whenever possible, oil samples should be placed into amber glass containers, and duplicate samples taken in case of breakage. For pure oil source samples, approximately 30–50 ml should be taken, and for oil samples collected from water (including weathered and emulsified oil), between 10 and 20 g should be collected (ITOPF, 2012). Oil samples should be kept and shipped separately from all other environmental samples to avoid cross-contamination. It is important to remember that oil samples and any samples containing oil should be collected in vials with hard caps only. Soft septum caps should not be used as the oil may leak and could compromise all samples in the same shipping container. It should also be noted that off-the-shelf sampling kits are available that can save costs and simplify the selection of techniques and equipment required.

Water sampling and analysis

As outlined in Table 8 on page 34, samples should be taken from the water column below slick/sheen areas to determine the level of oil dispersion that is taking place either naturally or due to the use of dispersants. Samples should also be taken from unimpacted areas to delineate slick/sheen areas and determine baseline conditions for petroleum hydrocarbon levels in the water. The type of surface water body, the sampling depth and the sample location's distance from the shore can all influence the methods used to sample and analyse oil in water. For shallow depth water sampling, a manual grab sampler such as a bailer, hand-held bottle or even a bucket can be used (ADEC, 2019).

Other surface water sampling devices may include a dip sampler to obtain samples from an outfall pipe or from areas difficult to access.

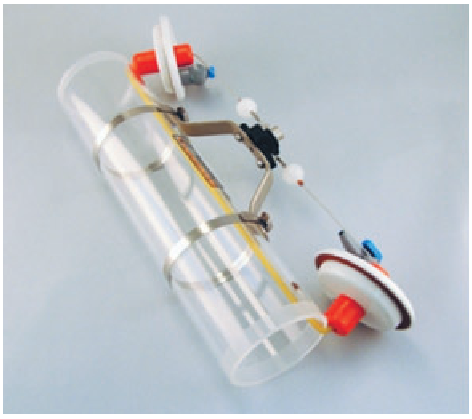
For sampling at deeper depths, automatic samplers can be used which are deployed to collect either grab or composite samples at specific depths, flow rates or points in time, using an intermediary disposable collection container, messenger-activated sampler or a peristaltic pump. Examples of water sample collection equipment include the Van Dorn sampler, the Kemmerer Bottle, the Nansen or Niskin bottle and other samplers capable of sampling at specific depths (ADEC, 2019). Wildco®, in conjunction with the United States Geological Survey (USGS), have also developed a sampler that is specifically designed for collecting VOCs from flowing water. Examples of some of these water sampling devices are shown in Figure 9.

When oil is visible in the water, a sample amounting to approximately one litre should be taken from each sampling location; and for water without visible oil, a three- to five-litre sample should be taken (ITOPF, 2012). For each sample taken, data such as temperature, dissolved oxygen content, pH and water hardness may also be measured and recorded (ADEC, 2019). These in-situ parameters can provide important information related to the fate and behaviour of oil in water and the selection and effectiveness of response techniques. They are typically measured using multi-parameter probes/direct-read instruments that are appropriately calibrated for each parameter being measured.

The results obtained from water sample analyses may be compared with background values and with jurisdictional water quality petroleum hydrocarbon criteria, if available.

Figure 9 Examples of water sampling devices

ADEC, 2019

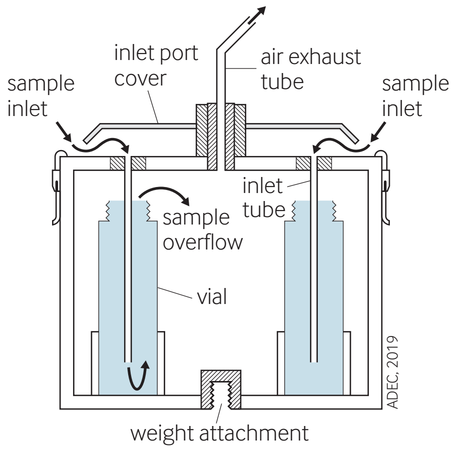


ADEC, 2019

Left: examples of messenger-activated samplers—the Van Dorn sampler (far left) and the Kemmerer Bottle (near left). When using these types of sampler, a metal weight referred to as a 'messenger' is dropped down a line connected to the sampler and triggers the closure of the device which can then be retrieved with the desired sample of water being uncontaminated by other water.

Laboratory Analysis Limited
http://www.laboratoryanalysis.co.uk/products/water-and-soil-testing-

Manual sampling method.



ADEC, 2019

Wildco® sampling device for collecting VOCs in water.

Sediment and soil sampling and analysis

As outlined in Table 9 on page 35, sediment and soil samples should be taken from both unimpacted and impacted areas to determine background petroleum hydrocarbon types and levels, and actual petroleum hydrocarbon impacts from the spill. Typically, equipment and sampling procedures used for sediment and soil samples vary depending on the location, logistics, safety considerations, site-specific conditions (e.g. substrate, habitat) and sampling plan objectives. The depth from which sediment or soil samples should be collected is determined by the chemical and/or toxicological analysis objectives for each sample.

For shoreline samples, tar balls, oiled debris, oil-stained sand and other sediments, etc. should be collected so that the oil content collected is approximately 10 g for each sample (ITOPF, 2012). Larger volumes may need to be collected for additional analysis, e.g. for grain size and TOC.

The results obtained from sediment and soil sample analyses may be compared with background values and also with jurisdictional sediment and soil quality petroleum hydrocarbon criteria, if available.

Bedrock, boulder and solid infrastructure sampling and analysis

When sampling for oil impacts on solid surfaces such as boulders, bedrock (see Table 9) and human-made infrastructure (see Table 10 on page 36), a pre-survey or detailed walk of the area should be undertaken to select appropriate areas for taking samples, focusing on sheltered areas being that these are where oiling is likely to occur and persist (NOAA, 2014).

Areas known or assumed to be impacted by the spill should be observed visually using trained observers to estimate oil coverage, and/or sampled for analysis for petroleum hydrocarbon concentration and composition.

Areas that are known to be unimpacted by the spill source should also be observed to estimate baseline conditions for oil coverage, and/or should be sampled for analysis for background petroleum hydrocarbon concentration and composition.

When sampling oiled areas, a clean sampling scoop or wooden spatula can be used to scrape oil off the surface. In some cases, a sorbent pad of known weight can be used.

Biota sampling and analysis

Biota (i.e. plant and animal) tissue samples can be collected during an incident to evaluate the extent of contamination or for biomarker analysis (e.g. to measure physiological changes in an organism that has been exposed to oil) (CSIRO, 2016).

Tissue sampling requires a variety of procedures and instruments depending on the species selected for sampling. The selection of target organisms is incident-specific, but commonly includes birds, fish, crustaceans and/or molluscs.

When sampling small species (e.g. molluscs), samples for tissue analysis should include the whole animal. For larger species, a smaller sample of tissue is typically taken. As an example, in the case of oiled birds, 5 to 10 feathers depending on oil quantity present should be collected. For fish and shellfish (fresh and organs), single or multiple individuals of the same species should be collected such that the total sample is 30 g (ITOPF, 2012).

For plant analyses, the whole plant should be collected and placed in an airtight bag or container. Further guidance on collecting plant tissue samples can be found in the Canadian Council of Ministers of the Environment's *Protocols Manual for Water Quality Sampling in Canada* (CCME, 2011b).

Air sampling and analysis

Air quality monitoring during an oil spill incident is typically performed to support responder and community health and safety but may also be conducted by the M&S Team for monitoring purposes. Air quality is generally monitored for VOCs and particulates, using either direct-reading instruments or by laboratory analysis of collected samples. Real-time measurements provide immediate information for responder and community exposure scenarios and, with the use of appropriate site safety measures, can help to prevent overexposures. Real-time air monitoring can also be used during response operations (e.g. in-situ burning) to ensure that the response technique is performing as expected and is being undertaken in a safe manner. However, real-time samples do not necessarily represent conditions experienced throughout the work period and can substantially underestimate or overestimate exposures potentially experienced by responders and the public.

Table 15 Recommended instruments and their applications for the real-time monitoring of air quality

INSTRUMENT	HAZARD BEING MONITORED	APPLICATION
Combustible gas indicator (CGI)	Combustible gases and vapours (e.g. hydrogen sulphide, sulphur dioxide, benzene, methyl tertiary-butyl ether (MTBE)	Measures the concentration of a combustible gas or vapour.
Flame ionization detector (FID) with gas chromatography option	Many organic gases and vapours (e.g. VOCs, hydrogen sulphide, benzene)	In survey mode, detects the total concentration of many organic gases and vapours. In gas chromatography mode, identifies and measures specific compounds.
Portable infrared (IR) spectrophotometer	Many gases and vapours	Measures the concentration of many gases and vapours in air. Designed to quantify one- or two-component mixtures.
Ultraviolet (UV) photoionization detector (PID)	Many organic and some inorganic gases and vapours (e.g. VOCs, hydrogen sulphide, benzene)	Detects total concentrations of many organic and some inorganic gases and vapours. Some identification of compounds is possible if more than one probe is used.

Table 15 lists several air quality monitoring instruments recommended for the real-time monitoring of various hazardous compounds that may be of concern following a petroleum release.

The analysis of air samples may be conducted for the purpose of collecting data that represents concentrations of contaminants over a specified period of time. The results of these samples can be compared to occupational health and safety requirements established for the jurisdiction in which the work is being performed.

Monitoring air quality in the vicinity of a spill.

OSRL

STEP 6: IMPLEMENTING A DATA MANAGEMENT SYSTEM

As discussed on pages 23–24, the development of an M&S data management system should be undertaken as part of the organization's spill preparedness activities; the key components of such a system are presented in Box 1 on page 24. If a spill incident should occur, it is essential that this system is implemented effectively to enable the efficient and secure collection, storage and transfer of the data received from the M&S programme. The system also needs to be able to generate reports, so that data and results can be quickly and clearly communicated to other IMS functions and, as required, to regulatory authorities and other stakeholders.

The level of data management activities required can generally be aligned with the phases associated with the M&S activities presented in Section 2. Table 16 (below) describes the link between these phases and the types of data management activities generally performed within each phase. As shown in Figure 4 on page 21, in the case of larger spills, the M&S Team should include a Data Coordinator responsible for the compilation, storage and dissemination of the data collected.

The data management system should also include the following key quality management elements (ITOPF, 2012):

- Quality assurance (QA) to ensure that processes and procedures are in place to check that the various aspects of the monitoring plan, such as sampling and analysis, are being carried out in the correct manner (an audit of the process).
- Quality control (QC) to ensure that the monitoring plan delivers the planned objectives (a check of the product).

These quality management elements can be incorporated into a data management system by taking the following steps (NOPSEMA, 2016):

- Establishing clear chain of custody, roles, and lines of responsibility and processes for sampling, data collection, data entry/management, statistical analyses and interpretation.
- Maintaining systems to ensure that those responsible for packages of work are appropriately trained and qualified to manage the data.
- Establishing a review function for all data and reports generated.
- Regularly reviewing the processes to ensure quality, and implementing changes as required.

Table 16 The phased approach to data management

PHASE	DATA MANAGEMENT DESCRIPTION
Phase 1: Situational analysis/ initial response decision-making	• Individuals or field teams arrive on-site and begin data collection. • These first observations and surveys often involve ephemeral data that need to be systematically recorded to avoid data being lost as the spill response progresses or personnel and resources are demobilized.
Phase 2: Selection and effectiveness of response options	• The spill is of sufficient size or importance that one or more field teams are called upon to assist. • A Data Coordinator should be designated as part of the M&S Team and be responsible for data management and QA to centralize information about the data collected and to integrate all previously recorded information.
Phase 3: Impact assessment and termination of M&S activities	• Involves extensive utilization of computer-based databases, entry forms, and reports linked to spatial data in a GIS format to enable maps of various aspects of the spill (e.g. site maps, oiling trajectory and extent maps, shoreline maps, etc.) to be produced on demand using the information contained in the database. • Each field M&S Team should designate an individual to be responsible for their team's data management, QA/QC and dissemination of information to the Data Coordinator.

STEP 7: EVALUATING HEALTH, SAFETY AND LOGISTICAL CONSIDERATIONS RELATING TO M&S ACTIVITIES

In conjunction with the Safety Officer, the M&S Team Leader should ensure that health and safety policies and procedures are in place in relation to M&S-specific activities, in the areas of:

- training (including hazard identification (HAZID)/Hazardous Waste Operations and Emergency Response (HAZWOPER) training or similar programmes);
- personal protective equipment (PPE);
- chemical handling;
- personnel tracking;
- operation of monitoring equipment (e.g. UAVs, ROVs, air sampling equipment, subsea monitoring equipment); and
- transportation (including approval of contractor vessels).

The Safety Officer and associated personnel would be responsible for determining the conditions under which M&S Team members should or should not be performing their work; however, in some cases, data obtained by the M&S Team may be used to determine whether conditions have become unsafe for their activities.

M&S Team members also need to be aware of health and safety information and requirements related to the handling and shipping of samples that would be considered hazardous materials (NOAA, 2014). M&S Team members should therefore have access to safety data sheets (SDS) that provide recommendations for the handling of hazardous materials and the types of PPE required.

When selecting a location for M&S activities, there are logistical and health and safety considerations that need to be considered, particularly if the activities require personnel to work in remote areas or on an aircraft (fixed-wing, helicopter) or vessel. Questions related to working in remote areas are presented Box 2, and those related to M&S activities that require the transportation of personnel via aircraft or vessels are presented in Box 3 on page 49 (IPIECA, 2019).

Box 2 Planning for M&S activities in remote areas

The following questions should be asked when M&S activities require travel to remote areas requiring overnight stays:

- Can the site be accessed?
  - By car? What are the road conditions like?
  - By boat? Is there a docking site?
  - What are the tidal conditions?
  - By air? Is there an airstrip?
  - Is access to the site by air likely to be restricted, for example due to the proximity of the site to airports or defence facilities?
  - Can fuel be obtained?
- Can the site accommodate the response team?
  - Is accommodation available?
  - Are catering facilities and a water supply available?
  - Are decontamination or washing facilities available?
  - Are shade or rest areas provided?
  - Is there access to on-site medical resources and/or first-aid supplies/capabilities?
- Can the necessary monitoring and sampling equipment be stored and transported?
  - Is there a way to keep samples collected at the proper temperatures?
  - Where will samples and equipment be stored and maintained?
- Are there environmental, cultural or social considerations?
  - Is the area of indigenous cultural significance?
  - Are there vegetation, corals or other significant habitats?
  - Is there a waste management plan?
  - Can hazardous waste be shipped off-site?
  - Are there likely to be gender or other inequalities that need to be considered by the M&S Team?
- Are there any health and safety considerations?
  - Does the site have any inherent hazards?
  - Is there a communications plan?
  - Are there any quarantine requirements?
  - Is there a first-aid or medical evacuation plan?
  - Are sufficient people trained in first aid?

Box 3 Planning for M&S activities requiring the transportation of personnel by aircraft or vessel

The following questions should be asked when M&S activities require the transportation of personnel by an aircraft or vessel:

- Can the vessel accommodate the required M&S Team members?
- Can the necessary monitoring and response equipment be accommodated?
- Does the aircraft/vessel have a power supply? If so, what is the voltage/frequency?
- Is there a winch, crane or other means of securing/deploying equipment?
- Is there a water supply or other means of decontaminating equipment?
- What working area is available?
- Is there enough space for the team to operate their equipment?
- Is there a dry workspace for laptops?
- Can cases for laptops and other equipment be stored dry?
- What storage is available?
- Can samples be stored at the appropriate temperatures?
- Is storage available for any chemicals that may be required?
- Is storage available for any waste that may be generated?
- Are berths provided, or will the team be deployed for daytime or local work only?
- Are catering facilities and a water supply available?
- Are decontamination or washing facilities available?
- Are shade or rest areas provided?
- Are toilets available?
- Where will equipment be stored and maintained?
- Is there a communications plan?

Health, safety and logistical considerations are paramount when planning for M&S activities requiring transport by aircraft or vessel.

STEP 8: DETERMINING THE CRITERIA FOR TERMINATION OF THE M&S PROGRAMME

Specific M&S activities may be terminated when the objective for that activity has been met. The decision to recommend the termination of M&S activities is made by the M&S Team Leader, along with the IMS Command function (and, as applicable, the supervisory roles that sit between the M&S Team Leader and the Command function). It is important that government agencies, local stakeholder interests and indigenous groups are also consulted to ensure that all parties understand any needs for continued sampling and analysis, and to reach consensus on the eventual reduction of M&S effort and the demobilization of resources. Examples of termination criteria that could be used for specific M&S activities are provided in Table 17.

In the case of larger spills or spills where there are significant impacts on sensitive areas, a response M&S programme would be terminated at the point where a recovery or rehabilitation M&S programme has been prepared and initiated. Details of any ongoing scientific M&S activities, including management responsibilities and reporting lines, should be incorporated into the recovery M&S plan.

Table 17 Examples of criteria for termination of M&S activities

M&S ACTIVITY	EXAMPLE TERMINATION CRITERIA
Oil chemical composition for fingerprinting	The source has been confirmed
Air quality monitoring during in-situ burning	Jurisdictional air quality guidelines have been met
Biota presence, general density, welfare, mortality	Environmental effects have been documented and assessed
Oil coverage on bedrock, boulders	Oil coverage is at, or below, pre-spill baseline levels or meets 'no-further-treatment' criteria
Oil concentration in water, sediment or soil samples	Oil concentrations in samples are at, or below, pre-spill baseline levels or jurisdictional environmental quality guidelines

Appendices

Appendix 1: M&S preparedness—good practice checklists

The key steps related to M&S preparedness activities as described in Section 3 of this guide are summarized below. Good practice checklists for each step are provided on pages 53–58 as a guide and a reminder of the various aspects that should be considered when preparing an M&S programme.

It should be noted that, while each item in the checklists represents current good practice, not every item listed will necessarily be applicable in all spill situations or in all phases of an M&S programme.

M&S PREPAREDNESS CHECKLISTS

M&S PREPAREDNESS

STEP 1: Compiling information on regulatory agencies and external organizations

As applicable, consider collecting contact and other information from relevant government/regulatory agencies and other organizations within jurisdictions that may be affected by spills, and compile details of the regulatory requirements for those jurisdictions. For further guidance see page 16.

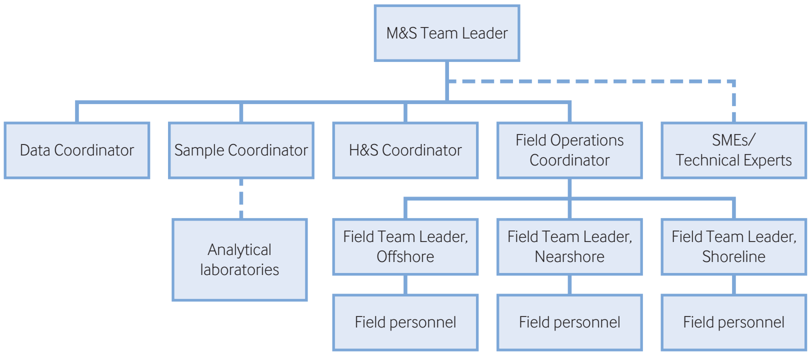
Government agencies	
☐	Local government departments: ☐ Public health ☐ Community infrastructure (e.g. municipal drinking water agency)
☐	Regional government (state, province, regional area) departments: ☐ Environment ☐ Fisheries ☐ Wildlife ☐ Public health ☐ Heritage and archaeological preservation
☐	National government departments: ☐ Environment ☐ Fisheries ☐ Wildlife ☐ Public health

Regulatory requirements	
☐	Regulations and environmental criteria/exceedance levels for key petroleum components (i.e. concentrations of concern) in the following media: ☐ Surface water ☐ Groundwater ☐ Sediment ☐ Soil ☐ Air
☐	Information and regulations related to permits and licences required to perform M&S activities (e.g. biota collection, waste management, hazardous materials shipping)
☐	Access agreements (both governmental and private)
☐	Any other applicable regulatory requirements

M&S PREPAREDNESS

STEP 2: Establishing a generic M&S Team structure

The example organizational chart on the right and the checklist below can be used to identify the roles and structure of a potential M&S Team and, where possible, to help identify individuals to take on those roles. For further guidance see page 16.



	Role	Responsibilities
☐	M&S Team Leader	■ Oversees the development of the M&S plan and the implementation of the M&S programme ■ Reports on M&S activities to Command function (through the Environment Unit/ Planning Section, as applicable) ■ Supports the Environment Unit Leader in the interpretation of sampling and monitoring results and the development of advice based on this information
☐	Subject Matter Experts (SMEs)/ Technical Experts	■ Provides independent advice on environmental matters relevant to M&S
☐	Data Coordinator	■ Establishes the M&S data management systems (including sample labelling and data compilation, storage and reporting) ■ Responsible for data visualization ■ Establishes the quality management system for the M&S programme
☐	Health and Safety (H&S) Coordinator	■ Reports to the Safety Officer, and provides details of H&S issues and requirements as they relate to M&S activities ■ Communicates H&S requirements to the M&S Team ■ Monitors M&S activities to ensure that they are in compliance with H&S requirements
☐	Sample Coordinator	■ Coordinates the engagement of contractors and analytical laboratories ■ Manages sample receipt, storage and transport ■ Manages the interface between the field teams and laboratories
☐	Field Operations Coordinator	■ Develops the schedule and logistics associated with M&S activities ■ Identifies the equipment necessary for carrying out M&S activities ■ Identifies Field Team Leaders and field personnel to carry out M&S activities ■ Mobilizes the M&S Field Team and equipment to the site
☐	Field Team Leaders	■ Coordinates and oversees M&S activities at specific field sites ■ Reviews site conditions, staff training requirements and pre-mobilization planning arrangements prior to mobilization to the assigned site
☐	Field personnel	■ Perform M&S activities in the field ■ Provide M&S data to the Field Team Leader

M&S PREPAREDNESS

STEP 3: Developing a generic M&S plan

As part of the spill preparation activities, it is recommended that a generic M&S plan is developed that can be quickly adapted and applied to a specific spill situation. The plan should be developed based on the phased approach and should consider requirements that need to be implemented in each phase. For each phase of the M&S programme, the M&S plan should include the elements outlined in the checklist below. For further guidance see page 21.

	Information to be included in a generic M&S plan, for each phase of the M&S programme
☐	Aim and focus of the M&S programme
☐	Activation process for the M&S Team/contractor(s)
☐	Details of the types of media that need to be monitored and sampled
☐	Details of the locations that need to be monitored and sampled
☐	How each M&S activity will be performed
☐	How frequently each monitoring and sampling activity needs to be undertaken
☐	If and how samples are to be collected, preserved, transported and analysed
☐	Details of QA/QC procedures required to support the collected data
☐	The criteria that will be used to terminate a monitoring and sampling activity

M&S PREPAREDNESS

STEP 4: Acquiring and compiling baseline data

Where available, baseline data should be collected, and procedures should be developed for the collection of reference data during a spill. For further guidance see page 22.

	Potential sources of baseline data
☐	Sensitivity maps/data
☐	Environmental Impact Assessments (EIAs)
☐	Other targeted studies where sampling and analyses were performed prior to a spill
☐	Information from stakeholders, such as the public, indigenous groups and businesses in close proximity to the area
☐	Local universities

	Reference data procedures
☐	Develop procedures to collect, early in a spill, reference (or ephemeral) data from potentially impacted areas (based on spill trajectory modelling) and unimpacted areas that are adjacent and/or similar to the area anticipated to be impacted by the incident.

M&S PREPAREDNESS

STEP 5: Coordinating equipment, external resources and contracts

It is important to identify a variety of potential M&S service providers and, where feasible, prearrange the use of their services during an incident. For further guidance see page 22.

Potential M&S-related service providers	
☐	Contractors providing field personnel and specialized expertise (e.g. subsurface sampling)
☐	Transportation companies to transport personnel to M&S sites and transport samples (e.g. rental cars, helicopters, boats, etc.)
☐	Accredited analytical laboratories for undertaking the chemical and physical analyses of samples
☐	Couriers for transporting samples to analytical laboratories
☐	Companies specializing in the logistics and performance of aerial, surface, ground and subsea surveillance
☐	Companies that supply monitoring equipment (including subsurface sampling equipment, photographic equipment, remote sensing equipment, AUVs, ROVs, UAVs)
☐	Companies that are able to supply items of sampling equipment that will not be supplied by the contracted analytical laboratory (e.g. bags and other containers, disposable spatulas and tongs)
☐	Electronics companies for computers, tablets, GPS systems, etc.
☐	Safety supply companies for personal protective equipment (PPE) and decontamination supplies
☐	Hardware stores for general M&S equipment such as coolers, waste bags (for waste derived from M&S activities), zip lock bags, electrical tape, etc.

M&S PREPAREDNESS

STEP 6: Developing a generic data management system

A generic data management system should be developed that includes the following key elements.
For further guidance see page 23.

	Key elements of an M&S data management system
☐	The ability to store a variety of data types, including the following: ☐ M&S planning documents ☐ GPS data ☐ Air, ground and subsea surveillance photographic and remote sensing files ☐ SCAT monitoring data ☐ Field notes ☐ Sample COC forms ☐ Laboratory analytical reports ☐ Other M&S reports
☐	A system or database to compile the following information on each piece of M&S data: ☐ What was monitored or sampled ☐ Why it was collected (response information, spill impact information, reference data, etc.) ☐ What types of data were acquired ☐ Where the data were acquired (i.e. GPS data) ☐ How the data were acquired ☐ When the data were acquired (time and date) ☐ Who obtained the data ☐ In the case of a sample: ■ The unique sample label/number ■ Details of the holding time prior to analyses ■ Whether it is a quality assurance (QA) or quality control (QC) sample (i.e. duplicate, split, blank) (reference should be provided to the parent sample from which a QA/QC sample was derived) ■ Whether it is a split sample shared with regulatory authorities ■ What it was/will be analysed for ■ What the priority level was/is for analysis ■ Details of the turnaround time of the laboratory carrying out the analysis ■ Where/to whom the results should be delivered
☐	A file naming system to enable different elements of M&S data to be distinguished and tracked so that it can be easily located and used for decision-making
☐	A secure, shared file storage system
☐	A system to separate data that need to be reviewed from data that have been verified and validated
☐	A system (e.g. COP) that assists with the transmission and dissemination of data and information, as required, by: ■ those responsible for processing, compilation, validation ■ other members of the IMS ■ government, local stakeholders, indigenous groups

M&S PREPAREDNESS

STEP 7: Developing a training and exercise programme

The availability of key skills and knowledge, either internally or provided by external SMEs, should be assessed so that gaps may be recognized, and any necessary training identified and implemented. It is recommended that relevant training and exercises focus on the areas listed below. For further guidance see page 25.

Areas of focus for a training and exercises programme

M&S plan development, including elements related to the following areas:

- ☐ The phased approach to M&S planning
- ☐ Establishing an M&S Team and its interaction with the incident management system (IMS)
- ☐ Interaction with government agencies and regulatory bodies with respect to requirements and information/data sharing agreements
- ☐ The importance of collecting, compiling and using baseline data in M&S activities
- ☐ Equipment, supplies and surveillance platform requirements for M&S activities
- ☐ Health and safety requirements and procedures
- ☐ Selecting the locations and media to be sampled
- ☐ The importance of collecting ephemeral data, which data tend to be ephemeral, and how to collect the data effectively
- ☐ Data management and reporting
- ☐ Mobilizing a field team to collect and analyse environmental media samples
- ☐ Testing the real-time provision of surveillance data to the Command function
- ☐ Testing the receipt of electronic analytical data, its QA/QC and entry into the incident data management system

Monitoring, sampling and analytical methods related to key locations and media as listed below (see M&S programme implementation Step 3, *Selecting the locations and methods for undertaking M&S activities,* on pages 32–37):

- ☐ Source oil
- ☐ Oil slick/sheen areas (pre- and post-response)
- ☐ Recovered oil from skimming or other recovery operations
- ☐ Burn residue from in-situ burn operations
- ☐ Water column from:
  - below slick/sheen areas
  - unimpacted areas
- ☐ Nearshore/shoreline/terrestrial/inland areas, including:
  - impacted areas
  - potentially impacted areas
  - unimpacted areas that can be used as reference sites from which background data can be obtained (i.e. areas that are similar to impacted or potentially impacted areas)
- ☐ Human-made infrastructure, including:
  - impacted areas
  - potentially impacted areas
  - unimpacted areas that can be used as reference sites from which background data can be obtained (i.e. areas that are similar to impacted or potentially impacted areas)
- ☐ Air quality upwind from the slick, above and close to the spill, and near populated and environmentally sensitive areas

Appendix 2: M&S programme implementation—good practice checklists

The key steps related to M&S programme implementation activities as described in Section 4 of this guide are summarized below. Good practice checklists for each step are provided on pages 60–75 as a guide and a reminder of the various aspects that should be considered when implementing an M&S programme.

It should be noted that, while each item in the checklists represents current good practice, not every item listed will necessarily be applicable in all spill situations or in all phases of an M&S programme.

M&S PROGRAMME IMPLEMENTATION CHECKLISTS

M&S PROGRAMME IMPLEMENTATION

STEP 1: Coordinating and mobilizing the M&S Programme

The following steps should be performed to mobilize the M&S Team. These mobilization activities will generally be undertaken in Phase 1 of the M&S programme and take place concurrently with initial M&S activities that are required early in the spill response (e.g. for situational analysis or the collection of ephemeral data). For further guidance see page 28.

Pre-mobilization steps	
☐	Notification and activation of the M&S Team
☐	Situational awareness, and gathering critical information about the spill and the proposed response as listed below: ☐ Source of the spill ☐ Status of the release (continuing, slowing, stopped) ☐ Oil type/volume ☐ Spill trajectories ☐ Sea states ☐ Weather forecasts ☐ Existing baseline data compilations ☐ Location and sensitivity of resources at risk ☐ Location of communities and human-made infrastructure (e.g. water intakes, fishery facilities, aquaculture facilities, ports, industrial sites, recreation and tourism sites) ☐ The most up-to-date response plan and spill objectives
☐	Obtain regulatory information on environmental criteria/exceedance levels and sampling requirements for key petroleum components
☐	Review generic M&S planning information and adapt it as required by the spill situation
☐	Obtain permits and licences required for M&S activities
☐	Brief the M&S Team and, as required, provide them with training on the situation and the proposed response
☐	Establish a data management system and communicate the quality management requirements
☐	Acquire and compile existing baseline data
☐	Arrange for other external resources and services and, as necessary, M&S equipment
☐	Make transportation arrangements for personnel, equipment and samples
☐	Contact and make arrangements or establish contracts with analytical laboratories

M&S PROGRAMME IMPLEMENTATION

STEP 2: Designing an M&S plan

To design an effective M&S plan it is essential to establish the objectives for each phase of the M&S programme. The following table can be used as a checklist to determine the general objectives and M&S activities that are typically required in each phase of the M&S programme. Based on this information further details could then be compiled in Step 3 (see pages 62–67). For further guidance on designing an M&S plan see page 30.

Phase of M&S activities			Objectives of M&S activities
Phase 1: Situational analysis/ initial response decision-making	Increase in complexity of M&S activities ▼	Initial few days of the response	Objectives of M&S activities performed during the early stages of a spill: ☐ Characterize the source of the oil ☐ Confirm the source of slick areas ☐ Delineate slick areas ☐ Understand the properties of the oil slicks ☐ Determine background concentrations of petroleum hydrocarbons ☐ Ensure the safety of responders and the public
Phase 2: Selection and effectiveness of response options			Objectives of M&S activities associated with response selection and operations: ☐ Determine the properties of the oil slicks to aid response decision-making, and to evaluate response effectiveness and determine termination criteria ☐ Determine waste disposal options for recovered oil and burn residues ☐ Ensure the safety of responders and the public
Phase 3: Impact assessment and termination of M&S activities		Response termination	Objectives of M&S activities associated with understanding the impacts of the spill: ☐ Determine environmental impacts on nearshore/shoreline/ terrestrial/inland areas and biota, and on human-made infrastructure ☐ Select response options for the above areas and determine the criteria for termination ☐ Ensure the safety of responders and the public

M&S PROGRAMME IMPLEMENTATION

STEP 3: Selecting the locations and methods for undertaking M&S activities

The checklists on pages 63–67 can be used to identify the specific locations, media types, objectives and methods for the M&S activities required in each phase of the M&S programme. Separate checklists are provided for each of the following potential M&S locations/media types:

Additional details will be required on the methods to be used for each identified M&S activity.

It should be noted that the lists of typical locations and media presented in these checklists are not exhaustive, as it is not possible to cover all spill situations in this document. The checklists should therefore be used as a guide to help develop a spill-specific list of locations and media that may require M&S activities.

For further guidance on selecting the locations and methods for undertaking M&S activities see page 32.

M&S PROGRAMME IMPLEMENTATION

STEP 3: Selecting the locations and methods for undertaking M&S activities (continued)

(a) Oil: potential locations, media types, objectives and methods for M&S activities

M&S location	Media type	M&S objective	M&S method	Typical phase
☐ Source oil	☐ Oil	Characterize the source/ determine the chemical fingerprint to verify against impacted areas	Oil sampling and analysis for petroleum hydrocarbon composition	Phase 1
☐ Oil slick/sheen areas—pre-response	☐ Fresh and weathered emulsified oil	Confirm the source of the slick/sheen	Oil sampling and analysis for baseline petroleum hydrocarbon composition	Phase 1
		Determine the area, thickness, weathering and emulsification of the slick/sheen for response decision-making	Observations from satellites, aircraft, vessels using optical, infrared, radar, photo and video techniques, and trained observers; and/or oil sampling and analysis of the physical properties of the oil	Phase 2
☐ Oil slick/ sheen areas—post-response	☐ Treated oil	Determine the area and thickness of the slick/sheen to evaluate response effectiveness		Phase 2
		Determine the post-response thickness, weathering and emulsification of unrecovered slick/sheen areas to provide an understanding of potential environmental impacts		Phase 3
☐ Recovered oil/oil residue	☐ Oil recovered from skimming or other recovery operations	Determine effectiveness of recovery and/or ISB operations Determine waste disposal options	Oil sampling and analysis of the water content and petroleum hydrocarbon composition	Phase 2
	☐ Burn residue from in-situ burn operations			
	☐ Water run-off from waste streams			

continued ...

M&S PROGRAMME IMPLEMENTATION

STEP 3: Selecting the locations and methods for undertaking M&S activities (continued)

(b) Water quality: potential locations, media types, objectives and methods for M&S activities

M&S location	Media type	M&S objective	M&S method	Typical phase
☐ Water column from unimpacted areas	☐ Water	Delineate slick/sheen areas; and determine baseline conditions for petroleum hydrocarbon levels in the water	Water sampling and analysis for background petroleum hydrocarbon concentration and composition	Phase 1
☐ Water column below slick/sheen areas	☐ Water	Determine the level of oil dispersion, either naturally or from the use of dispersants	Water sampling and analysis for petroleum hydrocarbon concentration and composition	Phase 2

continued ...

M&S PROGRAMME IMPLEMENTATION

STEP 3: Selecting the locations and methods for undertaking M&S activities (continued)

(c) Nearshore/shoreline/terrestrial/inland areas: potential locations, media types, objectives and methods for M&S activities

M&S location	Media type	M&S objective	M&S method	Typical phase
☐ Unimpacted nearshore/shoreline/terrestrial/inland areas that can be used as reference sites from which background data can be obtained (i.e. areas that are similar to impacted or potentially impacted areas)	☐ Sediment and soil	Determine baseline conditions for oil coverage levels	Visual observations using trained observers to estimate background oil coverage; and/or substrate sampling and analysis for background petroleum hydrocarbon concentration and composition	Phase 1
	☐ Bedrock/ boulders		Visual observations using trained observers to estimate oil coverage; and/or sampling and analysis for background petroleum hydrocarbon concentration and composition	Phase 1
	☐ Adjacent water		Sampling and analysis for background petroleum hydrocarbon concentration	Phase 1
	☐ Biota	Determine baseline conditions for population, coverage and biomarker levels	Species surveys to estimate populations; and/or biomarker baseline analysis	Phase 1
☐ Impacted nearshore/ shoreline/terrestrial/ inland areas, including run-off from waste streams	☐ Sediment and soil	Verify the source of the oil; determine the percentage oil coverage for response decision-making; determine the criteria for termination; and assess environmental impacts	Visual observations using trained observers to estimate oil coverage; and/or substrate sampling and analysis for petroleum hydrocarbon concentration and composition	Phase 3
	☐ Bedrock/ boulders		Visual observations using trained observers to estimate oil coverage; and/or sampling and analysis for petroleum hydrocarbon concentration and composition	Phase 3
	☐ Adjacent water		Sampling and analysis for background petroleum hydrocarbon concentration	Phase 3
	☐ Biota		Species surveys to estimate populations, and visual observations of the percentage oil coverage; and/or biomarker analysis to measure physiological changes	Phase 3

continued ...

M&S PROGRAMME IMPLEMENTATION

STEP 3: Selecting the locations and methods for undertaking M&S activities (continued)

(d) Human-made infrastructure: potential locations, media types, objectives and methods for M&S activities

M&S location	Media type	M&S objective	M&S method	Typical phase
☐ Unimpacted human-made infrastructure (e.g. ports, fishery and aquaculture infrastructure, recreational and tourism areas, water intakes) that can be used as reference sites from which background data can be obtained (i.e. areas that are similar to impacted or potentially impacted areas)	☐ Solid surfaces	Determine baseline conditions for oil coverage levels	Visual observations using trained observers to estimate background oil coverage; and/or sampling and analysis for background petroleum hydrocarbon concentration and composition	Phase 1
	☐ Water from intakes	Determine baseline conditions for petroleum hydrocarbon concentrations in intakes	Water sampling and analysis for background petroleum hydrocarbon concentration and composition	Phase 1
☐ Impacted human-made infrastructure (e.g. ports, fishery and aquaculture infrastructure, recreational/tourism areas, water intakes)	☐ Solid surfaces	Verify the source of the oil; determine the percentage oil coverage for response decision-making; determine termination criteria and assess impacts on, and damage to, the infrastructure	Visual observations using trained observers to estimate oil coverage; and/or sampling and analysis for petroleum hydrocarbon concentration and composition	Phase 3
	☐ Water from intakes	Verify the source of petroleum hydrocarbon concentrations; determine petroleum hydrocarbon concentrations for response decision-making; determine termination criteria	Water sampling and analysis for petroleum hydrocarbon concentration and composition	Phase 3

continued ...

M&S PROGRAMME IMPLEMENTATION

STEP 3: Selecting the locations and methods for undertaking M&S activities (continued)

(e) Air quality: potential locations, media types, objectives and methods for M&S activities

M&S location	Media type	M&S objective	M&S method	Typical phase
☐ Atmosphere upwind from the slick	☐ Air	Determine background VOC and particulate levels	Use of air sampling instrumentation to perform analyses for VOC concentrations, and particulate size and concentrations	Phase 1
☐ Atmosphere above and close to the spill		Determine VOC and particulate levels to assess the safety of responders		Phases 1 and 2
☐ Atmosphere near populated and environmentally sensitive areas		Determine VOC and particulate levels to assess the safety of the public and impacts on environmentally sensitive areas		Phases 1, 2 and 3

M&S PROGRAMME IMPLEMENTATION

STEP 4: Monitoring the effectiveness of the selected response techniques

The following checklist can be used to help develop a process for determining the effectiveness of the selected response techniques and whether the established M&S thresholds for the various media types have been met. For further guidance see page 38.

Dispersant monitoring
☐ Visual observations—trained observers flying over the oil slick and using photographic job aids or advanced remote sensing instruments to assess the dispersant efficacy. assess the dispersant efficacy. This is typically the initial observation undertaken to determine whether the application of dispersant is effective, but does not enable quantification of how much oil is being dispersed.
☐ Use of monitoring instrumentation—collecting near real-time data from the treated slick using vessel-based instrumentation to continuously monitor for dispersed oil one metre beneath the dispersant-treated slick. These techniques are typically used to confirm the visual observations. If feasible, water samples should be collected to validate and quantify the data collected through the use of monitoring instrumentation.
☐ Expanded monitoring programme—using an expanded monitoring programme to gather additional information on where the dispersed oil is going and how effectively it is being dispersed. This level typically uses a wide range of vehicles and platforms as hosts for sensing systems in order to monitor the oil at various depths and locations in and around the slick. Analyses for physical and chemical parameters in water samples taken from the water column below the dispersed slick are typically performed in greater numbers than when using monitoring instrumentation as described above.
In-situ burning monitoring
☐ Burn effectiveness—measuring the oiled area ignited and burning over time to determine the efficiency of oil removal and the volume of oil removal
☐ Fire boom containment integrity (if used)—measuring the loss of a boom's ability to contain the slick to provide an early warning to vessel operators and responders
☐ Fire safety—monitoring fire behaviour and movement, determining the proximity of personnel to the burn, and identifying potential dangers to people, infrastructure and amenities
☐ Burn emissions—measuring burn emissions and particulates, and comparing the results with air quality thresholds.
Other response technique ______________________________ *(e.g. for oil-on-water, oiled shorelines, etc. — add rows below as necessary depending on the technique)*
☐ Visual determination of oil removal by comparing oil levels before and after the response
☐ Oil fingerprinting to determine the source of the oil
☐ Sampling to determine oil properties for response decision-making

M&S PROGRAMME IMPLEMENTATION

STEP 5: Selecting the appropriate sampling and analytical methods

For each set of samples taken, the following checklist can be used to ensure that samples are properly acquired, labelled, stored and transported. For further guidance see page 39.

Description of sample set

- ☐ Location ____________________
- ☐ Media type ____________________
- ☐ Sampling objective ____________________
- ☐ Sampling method description ____________________
  - ☐ Additional details on the sampling method:
    - ☐ Random sampling
    - ☐ Systematic sampling
    - ☐ Judgemental sampling
    - ☐ Grab samples
    - ☐ Composite samples
  - ☐ Quality control samples:
    - ☐ Field duplicate/replicate samples
    - ☐ Split samples
    - ☐ Laboratory duplicate

Sample numbering, labelling and recording

- ☐ Labels should be secured to the sampling container and be long-lasting.
- ☐ Labelling and numbering should be clear, legible, accurate and unique.
- ☐ When labelling jars, record the sample number on both the label and lid, and use a protective layer of clear tape wrapped around the entire circumference of the container to secure the label and protect the writing.
- ☐ Record the sample number on the chain of custody form and ensure that the sample number and the number on the corresponding form are the same.
- ☐ For samples placed in bags, place a sturdy waterproof paper label written in indelible ink into the bag and repeat the label on the outside.
- ☐ For each sampling area, a field sketch should be created and attached to the chain of custody form, showing the location where samples were taken, identified by sample number as well as a scale, north arrow, location of the transects, description of the area and any visible oil locations. Sampling locations should also be geo-referenced and recorded.

Handling of hazardous samples in the field

- ☐ Hazardous materials regulations typically pertain to sample preservatives and other materials (e.g. formalin, alcohols, solvents, some cleaning agents, etc.).
- ☐ The shipment of hazardous materials may be subject to legislation on the transportation of dangerous goods, and may require the use of special packaging (e.g. primary container, watertight secondary container, absorbent material between the primary and secondary containers, and sturdy outer packaging).

continued ...

M&S PROGRAMME IMPLEMENTATION

STEP 5: Selecting the appropriate sampling and analytical methods (continued)

Note: when collecting samples, it is advisable to avoid free water in oil samples and free oil in water samples.

Handling of hazardous samples in the field (continued)

- ☐ Hazardous materials may need to be shipped to sampling locations via cargo or charter aircraft, and will need proper documentation and shipping containers to comply with transportation regulations. Shipment by air is more strictly regulated than ground shipment and, in the case of source oil, there will be a limit on the volume of oil that can be transported.
- ☐ Some of these shipping requirements may delay the shipment of equipment to field study areas.

Sample handling and transportation

- ☐ Fluid samples (general)
  - ☐ Use laboratory-supplied clean jars/lids.
  - ☐ Use amber bottles or keep samples in the dark during transfer and storage.
- ☐ Fluid oil samples
  - ☐ Fluid source oils may be collected in stainless steel containers.
  - ☐ Use 30 ml or larger sample jars for pure oil and oiled sediments.
- ☐ Water samples
  - ☐ Protect against photo-oxidation and degradation by keeping samples cool and in the dark.
  - ☐ Wide necks and screw caps are recommended.
  - ☐ Avoid using narrow-mouthed or thin glass sample jars as these are harder to fill and may break during transport.
  - ☐ Do not fill the sample jars fully with liquid or oily debris unless instructed by the analytical laboratory. Allow some space for thermal expansion, especially if there is a risk of freezing.
- ☐ Solid or semi-solid samples
  - ☐ Transfer the samples with an unused lollipop stick or wooden tongue depressor.
  - ☐ Use a new sampling stick for handling each sample.
- ☐ General
  - ☐ Avoid the use of plastic containers; these can contaminate the sample and should be avoided.
  - ☐ Use clean nitrile gloves (if available) to avoid the risk of contamination by trace oils from skin during handling.
  - ☐ Sample jars should be correctly labelled with a unique reference number, location, time and date, type of sample and other relevant information (e.g. the depth at which the sample was obtained).
  - ☐ Standard labels should be prepared with as much information as possible just before taking the sample. Use a permanent pen, and cover the label with clear tape to maintain its legibility (do this after sealing the container, so that the SVOCs/VOCs in the glue do not contaminate the sample).
  - ☐ Secure the lids of containers to avoid spillage and to ensure that no tampering can take place along the chain of custody.
  - ☐ Use tape to ensure that the lids remains secure.
  - ☐ Avoid contamination.
  - ☐ Clean sampling devices between samples using appropriate procedures. Avoid smoking! Keep samples and sampling devices away from vessel exhaust or similar.

M&S PROGRAMME IMPLEMENTATION

STEP 6: Implementing a data management system

This checklist can assist with implementing the aspects of the data management system developed in M&S preparedness Step 6, and ensuring that these align with the phase of the M&S programme. For further guidance see page 47.

Phase	Data management aspects to be implemented (as required)
☐ Phase 1: Situational analysis/initial response decision-making	☐ Send individuals or field teams to the respective locations to begin data collection. ☐ Collect spill situation data and ephemeral data.
☐ Phase 2: Selection and effectiveness of response options	☐ Increase the number of field teams. ☐ Designate a Data Coordinator responsible for data management and quality assurance.
☐ Phase 3: Impact assessment and termination of M&S activities	☐ Make use of the following: ☐ Computer-based databases ☐ Entry forms ☐ Reports linked to spatial data in a geographic information system (GIS) ☐ On-demand maps of various aspects of the spill, such as site maps, oiling trajectory and extent maps, shoreline maps, etc. ☐ Each field M&S Team should designate an individual to be responsible for their team's data management, QA/QC and dissemination of information to the Data Coordinator.

Implement quality management processes and procedures
☐ Establish clear chains of custody, roles and lines of responsibility and processes for sampling, data collection, data entry/management, statistical analyses and interpretation.
☐ Maintain systems to ensure that those responsible for packages of work are appropriately trained and qualified to manage the data.
☐ Establish a review function for all data and reports generated.
☐ Regularly review the processes to ensure quality and implement changes as required.

M&S PROGRAMME IMPLEMENTATION

STEP 7: Evaluating health, safety and logistical considerations relating to M&S activities

The checklists on pages 72–74 can be used to verify the general health and safety of M&S activities. The health and safety checklist (below) can help to ensure that H&S policies and procedures are in place as they relate to M&S-specific activities. The logistics checklists on pages 73 and 74 present important questions to be asked in relation to M&S activities carried out at remote locations or which require the transportation of personnel by aircraft or vessel. For further guidance see page 48.

(a) Health and safety checklist

	Health and safety aspects to be considered
☐	Training (including HAZID/HAZWOPER training or similar programmes)
☐	Personal protective equipment
☐	Chemical handling
☐	Personnel tracking
☐	Operation of monitoring equipment (e.g. UAVs, ROVs, air sampling equipment, subsea monitoring equipment)
☐	Transportation (including approval of contractor vessels).

continued ...

M&S PROGRAMME IMPLEMENTATION

STEP 7: Evaluating health, safety and logistical considerations relating to M&S activities (continued)

(b) Logistics checklist: travel to remote areas requiring overnight stays

Aspects to be considered when M&S activities require travel to remote areas requiring overnight stays	
☐	Can the site be accessed? ☐ By car? What are the road conditions like? ☐ By boat? Is there a docking site? ☐ What are the tidal conditions? ☐ By air? Is there an airstrip? ☐ Is access to the site by air likely to be restricted, for example due to the proximity of the site to airports or defence facilities? ☐ Can fuel be obtained?
☐	Can the site accommodate the response team? ☐ Is accommodation available? ☐ Are catering facilities and a water supply available? ☐ Are decontamination or washing facilities available? ☐ Are shade or rest areas provided? ☐ Is there access to on-site medical resources and/or first-aid supplies/capabilities?
☐	Can the necessary monitoring & sampling equipment be stored and transported? ☐ Is there a way to keep samples collected at the proper temperatures? ☐ Where will samples and equipment be stored and maintained?
☐	Are there environmental, cultural or social considerations? ☐ Is the area of indigenous cultural significance? ☐ Are there vegetation, corals or other significant habitats? ☐ Is there a waste management plan? ☐ Can hazardous waste be shipped off-site? ☐ Are there likely to be gender or other inequalities that need to be considered by the M&S Team?
☐	Are there any health and safety considerations? ☐ Does the site have any inherent hazards? ☐ Is there a communications plan? ☐ Are there any quarantine requirements? ☐ Is there a first-aid or medical evacuation plan? ☐ Are sufficient people trained in first aid?

continued ...

M&S PROGRAMME IMPLEMENTATION

STEP 7: Evaluating health, safety and logistical considerations relating to M&S activities (continued)

(c) Logistics checklist: transportation of personnel by aircraft or vessel

Aspects to be considered when M&S activities require the transportation of personnel by aircraft or vessel	
☐	Can the vessel accommodate the required M&S Team members?
☐	Can the necessary monitoring and response equipment be accommodated?
☐	Does the aircraft/vessel have a power supply? If so, what is the voltage/frequency?
☐	Is there a winch, crane or other means of securing/deploying equipment?
☐	Is there a water supply or other means of decontaminating equipment?
☐	What working area is available?
☐	Is there enough space for the team to operate their equipment?
☐	Is there a dry workspace for laptops?
☐	Can cases for laptops and other equipment be stored dry?
☐	What storage is available?
☐	Can samples be stored at the appropriate temperatures?
☐	Is storage available for any chemicals that may be required?
☐	Is storage available for any waste that may be generated?
☐	Are berths provided, or will the team be deployed for daytime or local work only?
☐	Are catering facilities and a water supply available?
☐	Are decontamination or washing facilities available?
☐	Are shade or rest areas provided?
☐	Are toilets available?
☐	Where will equipment be stored and maintained?
☐	Is there a communications plan?

M&S PROGRAMME IMPLEMENTATION

STEP 8: Determining the criteria for termination of the M&S programme

The following checklist indicates the types of criteria that could be used to determine when an M&S activity can be terminated. For further guidance see page 50.

M&S activity	Example termination criteria
☐ Oil chemical composition for fingerprinting	The source has been confirmed.
☐ Air quality monitoring during in-situ burning	Jurisdictional air quality guidelines have been met.
☐ Biota presence, general density, welfare, mortality	Environmental effects have been documented and assessed.
☐ Oil coverage on bedrock, boulders	Oil coverage is at, or below, pre-spill baseline levels or meets 'no-further-treatment' criteria.
☐ Oil concentration in water, sediment or soil samples	Oil concentrations in samples are at, or below, pre-spill baseline levels or jurisdictional environmental quality guidelines.

Appendix 3: Selected references for M&S procedures for various media types

OIL	ISO (2004). *ISO 3170:2004. Petroleum liquids – Manual sampling.* CSIRO (2016). See Appendix D: *Standard operating procedure for shipboard collection of surface oil using Teflon® nets.* NOAA (2014). See page 15: *Guidelines For Collecting Ephemeral Data In The Arctic: Source Oil.* Stout, S. A. and Wang, Z. (2016). *Standard Handbook Oil Spill Environmental Forensics. Fingerprinting and Source Identification.*
OIL SLICK/SHEEN	CSIRO (2016). See Appendix D: *Standard operating procedure for shipboard collection of surface oil using Teflon® nets.* CSIRO (2016). See Appendix E: *Standard operating procedure for the collection of thin sheens using slick samplers.* CSIRO (2016). See Appendix F: *Use of sensors for oil spill monitoring.* CSIRO (2016). See Appendix W: *Standard operating procedure for requesting oil spill trajectory modelling.* NOAA (2014). See page 38: *Guidelines For Collecting Ephemeral Data In The Arctic: Sheen*
BURN RESIDUE	NOAA (2006). *Special Monitoring of Applied Response Technologies.* IPIECA-IOGP (2016d). *Controlled in-situ burning of spilled oil.*
WATER COLUMN BELOW SLICK/ SUBSEA	CSIRO (2016). See Appendix B: *Standard operating procedure for Niskin bottle collection at depth of waters for dissolved hydrocarbon analysis.* CEN (2006). *Oil spill identification - Waterborne petroleum and petroleum products - Part 1: Sampling.* CCME (2011b). *Protocols Manual for Water Quality Sampling in Canada.* US EPA (2016a). *Surface Water Sampling* (operating procedure). NOAA (2014). See page 48: *Guidelines For Collecting Ephemeral Data In The Arctic: Water.*
DISPERSANT OR OTHER AGENTS	CSIRO (2016). See Appendix X: *Standard operating procedure for testing incident-specific field oil spill dispersant effectiveness.* API (2020). *Industry Recommended Subsea Dispersant Monitoring Plan* NOAA (2006). *Special Monitoring of Applied Response Technologies.*

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SEDIMENT AND SOIL	CSIRO (2016). See Appendix G: *Standard operating procedure for grab sample collection of sediments for PAH, biomarker and TOC analyses.* CSIRO (2016). See Appendix H: *Standard operating procedure for collection of overlying waters plus sediment from corers for PAH and biomarker analyses.* CSIRO (2016). See Appendix I: *Standard operating procedure for shoreline sediment sampling with a manual push corer.* CSIRO (2016). See Appendix K: *Standard operating procedure for the collection of sediments for molecular microbial analysis.* ECCC (2018). *Shoreline Cleanup Assessment Technique (SCAT) Manual. Third Edition.* NOAA (2014). See page 72: *Guidelines For Collecting Ephemeral Data In The Arctic: Intertidal Sediments.* NOAA (2014). See page 87: *Guidelines For Collecting Ephemeral Data In The Arctic: Subtidal Sediments.* NOAA (2014). See page 25: *Guidelines For Collecting Ephemeral Data In The Arctic: Stranded Oil Surveys.* NOAA (2014). See page 114: *Guidelines For Collecting Ephemeral Data In The Arctic: Sand Beach And Tidal Flat Infauna.* NOAA (2014). See page 129: *Guidelines For Collecting Ephemeral Data In The Arctic: Gravel Beach Intertidal Communities.* NOAA (2014). See page 145: *Guidelines For Collecting Ephemeral Data In The Arctic: Rocky Intertidal Habitats.* US EPA (2014). *Soil Sampling* (operating procedure).
BIOTA	ARCOPOL (2013). *Determination of acute and chronic toxicity of priority HNS upon representatives of different marine plant and animal taxa.* CSIRO (2016). See Appendix L: *Standard operating procedure for the collection of seafood samples for the analysis of taint.* CSIRO (2016). See Appendix O: *Collecting samples for sediment infaunal analysis.* CSIRO (2016). See Appendix P: *Standard operating procedure for sampling intertidal and subtidal areas for community composition.* CSIRO (2016). See Appendix Q: *Standard operating procedure for surveying the impacts of oil spills on bird populations.* CSIRO (2016). See Appendix R: *Standard operating procedure for surveying impacts of oil spills on non-avian marine wildlife.* NOPSEMA (2016). See Appendix 5: *Monitoring techniques. Addresses techniques for seabed flora and fauna, fish and fisheries, and wildlife.*

continued ...

BIOTA *(continued)*	IPIECA-IOGP (2017). See pages 35–40: *Capture of live oiled animals* and *Collection/evaluation of dead oiled animals.* Environment Agency (2014). *Infaunal quality index: Water Framework Directive classification scheme for marine benthic invertebrates.* NOAA (2014). See page 100: *Guidelines For Collecting Ephemeral Data In The Arctic: Shellfish Tissues.* NOAA (2014). See page 233: *Guidelines For Collecting Ephemeral Data In The Arctic: Fish.* NOAA (2014). See page 173: *Guidelines For Collecting Ephemeral Data In The Arctic: Vegetated Habitats.* NOAA (2014). See page 188: *Guidelines For Collecting Ephemeral Data In The Arctic: Eelgrass Habitats.* NOAA (2014). See page 205: *Guidelines For Collecting Ephemeral Data In The Arctic: Kelp-Boulder Field Habitats.*
AIR	CCME (2011a). *Ambient Air Monitoring Protocol for PM2.5 and Ozone. Canada-wide Standards for Particulate Matter and Ozone.* US EPA (1999). *Determination of Volatile Organic Compounds (VOCs) in Air Collected in Specially-Prepared Canisters and Analyzed by Gas Chromatography/Mass Spectrometry (GC/MS).* (Method TO-15). US EPA (2016b). *Reference Method for the Determination of Fine Particulate Matter as* $PM_{2.5}$ *in the Atmosphere.* Title 40, Code of Federal Regulations, Part 50 (40 CFR 50).

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CCME (2011b). *Protocols Manual for Water Quality Sampling in Canada*. Canadian Council of Ministers of the Environment. Document ref. PN 1461, ISBN 978-1-896997-7-0 PDF. http://protocols.ccme.ca/

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Environment Agency (2014). *Infaunal quality index: Water Framework Directive classification scheme for marine benthic invertebrates*. Report: SC080016. assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/314673/Water_Framework_Directive_classification_scheme_for_marine_benthic_invertebrates_-_report.pdf

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Glossary of terms

Glossary of terms

Autonomous surface vehicle (ASV)	Vehicle that operates on the surface of the water, without a crew, in full autonomy.
Autonomous underwater vehicle (AUV)	Vehicle that operates underwater, without a crew, in full autonomy.
Background (concentration)	Petroleum concentration levels in samples from a site (i.e. reference site) that is outside the area impacted by an oil spill but is similar to the impacted area. In particular, background petroleum concentration data should be obtained from water and sediment samples taken from reference sites that are known or suspected to be affected by other natural or anthropogenic sources of contamination (e.g. oil seeps, coal, peat, mining, combustion engines).
Baseline conditions	The conditions of an area prior to the point at which it was impacted by oil.
Benthic	Of or pertaining to the surface and subsurface of the seafloor.
Chain of custody (COC)	The movement and transfer of samples or other evidence or data collected in the field, and the supporting documentation that accompanies them.
Common operating picture (COP)	A computing platform based on geographic information system (GIS) technology, which provides a single source of data and information for situational awareness, coordination, communication and data archival to support emergency management and response personnel and other stakeholders involved in, or affected by, an incident.
Composite samples	Non-discrete samples composed of more than one specific aliquot collected at various sampling locations and/or at different points in time. Analysis of this type of sample produces an average value.
Dispersant	Blends of surfactants and solvents used as a response technique during oil spills to reduce the interfacial tension between oil and water so that the oil slick breaks apart and mixes into the water column. Dispersant can be applied by aircraft or vessel, or injected at a subsea oil release (e.g. at a leaking subsea well head).
Ephemeral (data)	Time-sensitive data collected during the early hours/days of an incident that are used to document pre-spill conditions at location(s) prior to spill-related effects. In the early days of a spill it is important to collect ephemeral data related to the spill and its impacts in order to document conditions that change rapidly over time.
Field duplicate/ replicate samples	Two or more samples that should be identical which are taken using the same device and procedure at the same location. Such samples are used to test sample variance, and their identity may not always be made known to the laboratory.
Grab sample	A discrete aliquot representative of a specific location at a given point in time. The sample is collected all at once at one particular point in the sample medium.

In-situ burning	Response technique used during oil spills involving the ignition and burning of oil to rapidly reduce the volume of spilled oil.
Incident Management System (IMS)	System that provides standardized structures and processes to manage an incident.
Judgemental sampling	A non-probability sampling technique where the sampler selects units to be sampled based on their knowledge and best professional judgement. It may be directed at either contaminated or unaffected locations.
Laboratory duplicate	The splitting of a single sample into two or more samples used to check the precision of a laboratory analysis. The splitting of samples is typically carried out by the laboratory performing the analysis.
Monitoring	For the purposes of this document, 'monitoring' refers to techniques that generally use surveillance data to observe changes over time.
Quality assurance (QA)	The assurance that processes and procedures are in place to check that the aspects of a process (e.g. an M&S plan or programme) are being carried out in the correct manner (an audit of the process).
Quality control (QC)	The act of ensuring that the process (e.g. an M&S plan or programme) delivers the planned objectives (i.e. a check of the product).
Random sampling	The collection of samples in a non-systematic fashion from the entire site or from a specific portion of a site.
Reference sites	Areas outside the area impacted by an oil spill that are similar to the impacted areas with respect to elements such as geological characteristics, species of fish and shellfish present, plant types and coverage, etc. These sites can be used to collect information, samples and data to provide an understanding of the conditions of the area before the incident occurred.
Remotely operated vehicle (ROV)	An unmanned vehicle operated by personnel either aboard a vessel/floating platform or on land.
Remote sensing	The acquisition of data on an object or phenomenon without making physical contact with it, e.g. by using satellites, aircraft, electromagnetic radiation, etc.
Sampling	For the purposes of this document, 'sampling' refers to the collection of data from specific types of media, including the collection of physical material during an oil spill response operation (e.g. oil, water, sediment, biota, air, etc.). Collected samples are often (if not always) provided to an analytical laboratory for chemical, physical or biological analyses.
Spill Impact Mitigation Assessment (SIMA)	A process used to inform decision-making with respect to the selection of response options for minimizing the ecological, socio-economic and cultural impacts of an oil spill.
Split samples	A fully-homogenized sample which is divided after being collected so that it can be analysed independently by two or more parties.

Systematic sampling	The collection of samples based on a grid or a pattern which has been previously established.
Unimpacted areas	Areas that have not been impacted, and are not anticipated to be impacted by the spill. Unimpacted areas that are adjacent and/or similar to impacted or potentially impacted areas can be used as reference sites from which background data and samples can be obtained to provide an understanding of the conditions of the area before the incident occurred.
Unmanned aerial vehicle	An unmanned aircraft which is operated remotely.
Unmanned surface vessel	An unmanned vessel that operates on the surface of the water and is controlled remotely.
Unmanned underwater vehicle	An unmanned vessel that operates underwater and is controlled remotely.
Weathered oil	Oil which has spilled from the source into the environment (aquatic or terrestrial) and has remained in the environment long enough to have been affected by weathering (e.g. dissolution, evaporation, photodegradation, biodegradation). Oil weathers over time; therefore, 'weathered oil' is a generic term used to describe many stages of degradation.

List of acronyms

List of acronyms

API	American Petroleum Institute
ASV	Autonomous surface vehicle
AUV	Autonomous underwater vehicle
CGI	Combustible gas indicator
COC	Chain of custody
COP	Common operating picture
EIA	Environmental Impact Assessment
FID	Flame ionization detector
GIS	Geographic information system
GPS	Global positioning system
H&S	Health and safety
HAZID	Hazard identification
HAZWOPER	Hazardous Waste Operations and Emergency Response
IMS	Incident Management System
IR	Infrared
ITOPF	International Tanker Owners Pollution Federation Ltd
M&S	Monitoring and sampling
MTBE	Methyl tertiary-butyl ether
OSRL	Oil Spill Response Limited
PID	Photoionization detector
PPE	Personal protective equipment
QA	Quality assurance
QC	Quality control
ROV	Remotely operated vehicle
SDS	Safety data sheet(s)
SIMA	Spill impact mitigation assessment
SMART	Special Monitoring of Applied Response Technologies
SME	Subject matter expert
UAV	Unmanned aerial vehicle
USGS	United States Geological Survey
USV	Unmanned surface vessel
UUV	Unmanned underwater vehicle
UV	Ultraviolet
VOC	Volatile organic compound

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IPIECA is the global oil and gas industry association for advancing environmental and social performance. IPIECA convenes a significant portion of the oil and gas industry across the value chain, bringing together the expertise of companies and associations to develop, share and promote good practice and knowledge.

IPIECA is the industry's principal channel of engagement with the United Nations. Its unique position enables its members to support the energy transition and contribute to sustainable development.

International Association of Oil & Gas Producers

IOGP represents the upstream oil and gas industry before international organizations including the International Maritime Organization, the United Nations Environment Programme (UNEP) Regional Seas Conventions and other groups under the UN umbrella. At the regional level, IOGP is the industry representative to the European Commission and Parliament and the OSPAR Commission for the North East Atlantic. Equally important is IOGP's role in promulgating best practices, particularly in the areas of health, safety, the environment and social responsibility.

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