Plan

CDN/ID S4100AH717908

Offshore Victoria Operational and Scientific Monitoring Plan

Revision	Date	Reason for issue	Reviewer/s	Consolidator	Approver
0	19/06/2019	Issued for use	PW	GLE	TF

Review due	Review frequency
19/06/2020	1 year/s

THE THREE WHATS

What can go wrong?

What could cause it to go wrong?

What can I do to prevent it?

Offshore Victoria Operational and Scientific Monitoring Plan CDN/ID S4100AH717908

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1 Introduction

1.1 Purpose

This Offshore Victoria Operational and Scientific Monitoring Plan (OSMP) provides the framework for environmental monitoring response to Level 2 and Level 3 offshore hydrocarbon spills from petroleum activities undertaken by Beach Energy Ltd (Beach) in the Otway and Bass Basins.

The OSMP is a component of the environmental management framework, which also includes activity specific Environment Plans (EP), the Offshore Victoria – Otway Basin Oil Pollution Emergency Plan (OPEP) (CDN/ID S4100AH717907) and the BassGas Offshore OPEP (CDN/ID 3972816)

The OSMP has been developed to satisfy the requirements of Regulation 14(8AA) and 14(8D) of the Commonwealth *Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009* (OPGGS(E)R), Regulation 16 of the Victorian *Offshore Petroleum and Greenhouse Gas Storage Regulations 2011* (OPGGSR) and Regulation 19 of the Tasmanian *Petroleum (Submerged Lands) (Management of Environment) Regulations 2012* (P(SL)(ME)R).

The OSMP is to be read in conjunction with the relevant EP and OPEP when considering the existing environment, values and sensitivities, credible hydrocarbon spill risks and potential impacts, response activities and the decision processes that will apply in the event that a spill occurs. The relevant EP also describes any related performance standards, notification requirements and/or reporting compliance.

1.2 Scope

1.2.1 Activities

This OSMP is relevant to all Beach petroleum activities within the Otway and Bass Basins regulated under the Commonwealth OPGGS(E)R, Victorian OPGGSR and Tasmanian P(SL)(ME)R. This includes, but is not limited to the following activity types:

- Operation of a facility or pipeline
- Vessel activities
- Drilling.

1.2.2 Hydrocarbon type

Spill risks from the above activities that could result in a Level 2 or Level 3 spill event include two hydrocarbon types:

- Gas condensate
- Marine diesel.

This OSMP is relevant to all hydrocarbon types and states (i.e. fresh and weathered); and all distributions throughout the environment (e.g. surface, entrained, dissolved and shoreline).

1.2.3 Geographic extent

This OSMP is relevant and applicable to all Commonwealth and State marine and coastal areas that are potentially at risk of exposure to hydrocarbons in the event of a Level 2 or Level 3 spill resulting from Beach's petroleum activities within the Otway and Bass Basins.

The spatial extent of any particular operational or scientific monitoring study will depend on the actual and/or potential area exposed by an individual spill event. Therefore, monitoring extent would only be finalised once a spill event has occurred and be at a sufficient scale to meet monitoring objectives.

1.3 Responsibilities/Accountabilities

Beach is responsible for the implementation and adherence to the requirements of this OSMP for events where they are the Control Agency. Key roles and responsibilities are identified in Table 1.1

For hydrocarbon spill events where the Control Agency is not Beach (e.g. for spills impacting State waters, or vessel spills in Commonwealth waters), the relevant Control Agency would be responsible for the initiation and implementation of response phase (i.e. operational) monitoring requirements. It is noted that implementation may be delegated to another agency or company (including Beach) to provide services. The Control Agency (specifically the Incident Controller) is also responsible for initiating the recovery phase (i.e. scientific) monitoring, in conjunction with support agencies, local government and statutory authorities (AMSA 2019).

Table 1.1: Roles and responsibilities for OSMP implementation

Role	Timing	Responsibilities
Emergency Management Team (EMT) Leader	Emergency response	• Overall responsibility for implementation of this OSMP during an oil spill response • Equivalent to role of Incident Controller
Heath, Safety & Environment (HSE) Lead (or delegate)	Emergency response	• Interface between EMT and Environment SME • Responsible for ensuring safe operations during OSMP implementation • Provides operational monitoring data to EMT to support response planning • Initiation of operational and scientific monitoring studies • Termination of operational monitoring studies
Planning Lead (or delegate)	Emergency response	• Interface with Environment SME for OSMP implementation (as required)
Logistics Lead (or delegate)	Emergency response	• Interface with Environment SME for OSMP implementation • Support (as required) for implementing operational monitoring (e.g. site access etc.) • Support (as required) for mobilising plant and equipment (e.g. vessels, air support, vehicles etc.)
Emergency Management Liaison Officer	Emergency response	• Interface between Beach EMT and State Control Agency Incident Management Team (IMT)
Environment SME	Emergency response Ongoing	• Interface between HSE Lead and Monitoring Provider • Provide advice to HSE Lead on initiation of operational and scientific monitoring studies • Provide advice to HSE Lead on termination of operational monitoring studies • Termination of scientific monitoring studies

Role	Timing	Responsibilities
		• Day-to-day coordination of operational monitoring • Review and approval of operational monitoring plans and data reports • Day-to-day coordination of scientific monitoring • Review and approval of scientific monitoring plans and data reports • Interface with external agencies including NOPSEMA, DJPR and DPIPWE
Monitoring Provider – Study Lead	Emergency response Ongoing	• Interface with HSE Lead and Environment SME • Implementation of individual monitoring studies (as required) • Prepare monitoring plans and sampling procedures • Review and approve data reports • Ensure compliance with requirements of this OSMP
Monitoring Provider – Field Personnel	Emergency response Ongoing	• Undertake field sampling and observations • Ensure compliance with requirements of this OSMP
Monitoring Provider – Office Personnel	Emergency response Ongoing	• Prepare data reports • Ensure compliance with requirements of this OSMP

1.4 Definitions/Acronyms

Definitions of terms used in this plan:

Terms/acronym	Definition/expansion
AMSA	Australian Maritime Safety Authority
ANOVA	Analysis of variance
ANZECC	Australian and New Zealand Environment and Conservation Council
API	American Petroleum Institute
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
BACI	Before After Control Impact
Beach	Beach Energy Ltd
Control Agency	The Control Agency for an oil spill response is the government agency or company assigned by legislation, administrative arrangement or within the relevant contingency plan to control response activities to an oil spill
DJPR	(Victoria) Department of Jobs, Precincts and Regions
DPIPWE	(Tasmania) Department of Primary Industries, Parks, Water and Environment
EP	Environment Plan
EPBC Act	(Commonwealth) Environment Protection and Biodiversity Conservation Act 1999
EMT	Emergency Management Team
EUL	Environment Unit Lead
HSE	Heath, Safety and Environment
Incident Controller	The individual responsible for the management of all incident control activities across an incident (Note: for spill events where Beach is the Control Agency, this is the equivalent of the EMT Leader)

Terms/acronym	Definition/expansion
IMT	Incident Management Team
IvC	Impact versus Control
LCL	Lower control limit
LEL	Lower explosive limit
Level 2	Level 2 incidents are more complex in size, duration, resource management and risk and may require deployment of jurisdiction resources beyond the initial response (as per NatPlan)
Level 3	Level 3 incidents are generally characterised by a degree of complexity that requires the Incident Controller to delegate all incident management functions to focus on strategic leadership and response coordination and may be supported by national and international resources (as per NatPlan)
MBACI	Multiple Before After Control Impact
MNES	Matters of national environmental significance
Monitoring Provider	Service provider for environmental monitoring studies; may be one or multiple companies (as required)
NATA	National Association of Testing Authorities
NatPlan	National Plan for Maritime Environmental Emergencies
NOAA	(United States) National Oceanic and Atmospheric Administration
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
OPGGS(E)R	(Commonwealth) Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009
OPGGSR	(Victoria) Offshore Petroleum and Greenhouse Gas Storage Regulations 2011
OSMP	Operational and Scientific Monitoring Plan
OSRL	Oil Spill Response Limited
OPEP	Oil Pollution Emergency Plan
PAH	Polycyclic aromatic hydrocarbons
PERMANOVA	Permutational multivariate analysis of variance
PSD	Particle size distribution
P(SL)(ME)R	(Tasmania) Petroleum (Submerged Lands) (Management of Environment) Regulations 2012
Ramsar	Convention on wetlands of international importance
SAP	Sampling and Analysis Plan
SD	Standard deviation
SMART	Special Monitoring of Applied Response Technologies
SME	Subject Matter Expert
SQGV	Sediment quality guideline value
Statutory Authority	The Statutory Authority has the statutory responsibility for marine pollution incidents in their area of jurisdiction
TOC	Total organic carbon
TPH	Total petroleum hydrocarbon
UCL	Upper control limit
USEPA	United States Environment Protection Authority
VOC	Volatile organic compound

2 OSMP Framework

2.1 Objectives

The objectives of this OSMP are:

- Identify and describe the operational and scientific monitoring that may be implemented in the event of a Level 2 or Level 3 hydrocarbon spill to the marine or coastal environment
- Demonstrate an appropriate degree of readiness to implement this monitoring in the event of a hydrocarbon spill to the marine or coastal environment.

2.2 Overview

This OSMP provides the framework for Beach's environmental monitoring response to Level 2 and Level 3 offshore hydrocarbon spills from their petroleum activities undertaken in the Otway and Bass Basins.

2.2.1 Types of monitoring

Oil spill monitoring has been divided into two types, operational and scientific, which are undertaken for two distinct, but closely related, purposes (NOPSEMA 2016).

Operational monitoring (also known as Type I or response phase monitoring) which collects information about the spill and associated response activities to aid planning and decision making during the response or clean-up operations. Operational monitoring may include both initial response phase monitoring (i.e. rapid qualitative and observational data gathering for situational awareness) and advanced response phase monitoring (i.e. quantitative measurement) (Hook et al. 2016). Operational monitoring typically finishes when the spill response is terminated.

Four operational monitoring studies have been identified (see Section 3):

- O1: Hydrocarbon in offshore waters
- O2: Hydrocarbon on shorelines
- O3: Oiled wildlife surveillance
- O4: Dispersant efficacy.

Operational monitoring studies complement the Monitoring and Evaluate response strategy described in the relevant OPEP. This response strategy may include spatial surveillance techniques and spill trajectory predictions. Operational monitoring (e.g. Study O4) can also be directly related to a particular response strategy (i.e. Chemical Dispersants) (see Section 2.2.2).

Scientific monitoring (also known as Type II or recovery phase monitoring) which is focussed on non-response objectives and evaluating environmental impact and recovery from the spill and response activities. Scientific monitoring may continue for extended periods after a spill response is terminated.

Six scientific monitoring studies have been identified (see Section 4):

- S1: Offshore waters impact assessment

- S2: Shoreline sediments impact assessment
- S3: Subtidal habitats impact assessment
- S4: Intertidal habitats impact assessment
- S5: Wildlife impact assessment
- S6: Commercial fisheries exposure assessment.

Operational and scientific monitoring studies may occur simultaneously (i.e. scientific monitoring can start before a response operation is completed). There may also be an information flow between studies, for example data from operational monitoring may be used to trigger the initiation of scientific studies.

Different oil types, spill locations, and volumes require different studies to form a fit–for–purpose operational and scientific monitoring program that is able to determine the extent, severity and persistence of environmental impacts from the oil spill.

2.2.2 Links to response options

The objective of individual operational monitoring studies are typically associated with one or more specific response strategies (Table 2.1).

Table 2.1: Operational monitoring and response strategies

Response strategy	Study O1 Hydrocarbon in offshore waters	Study O2 Hydrocarbon on shorelines	Study O3 Oiled wildlife surveillance	Study O4 Dispersant efficacy
Source control	✓			
Monitor and evaluate	✓	✓	✓	
Assisted natural dispersion	✓			
Chemical dispersants	✓			✓
Containment and recovery	✓			
Protection and deflection	✓	✓	✓	
Shoreline clean-up		✓	✓	
Oiled wildlife response		✓	✓	

2.2.3 Links to environmental values and sensitivities

The types of environmental values and sensitivities known to occur in the Otway and Bass Basins and the related operational and scientific monitoring studies area shown in Table 2.2.

Table 2.2: Environmental values and sensitivities and related operational and scientific monitoring studies

Environmental value and sensitivities	Matters of national environmental significance	Value or sensitivity present in region		Operational Monitoring				Scientific Monitoring					
		Otway Basin	Bass Basin	Study O1	Study O2	Study O3	Study O4	Study S1	Study S2	Study S3	Study S4	Study S5	Study S6
				Hydrocarbon in offshore waters	Hydrocarbon on shorelines	Oiled wildlife surveillance	Dispersant efficacy	Offshore waters impact assessment	Shoreline sediments impact assessment	Subtidal habitats impact assessment	Intertidal habitats impact assessment	Wildlife impact assessment	Commercial fisheries exposure assessment
Protected areas													
Australian Marine Parks	✓[1]	✓	✓	✓		✓		✓		✓		✓	
State marine protected areas		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	
State terrestrial protected areas		✓	✓		✓	✓			✓			✓	
Wetlands of international importance (Ramsar wetlands)	✓	✓	✓		✓	✓			✓		✓	✓	
Ecological features													
Key ecological features	[2]	✓	×	✓				✓		✓			
Threatened ecological communities	✓	✓	✓	✓						✓	✓		
Threatened and migratory species	✓	✓	✓			✓						✓	
Invertebrates		✓	✓									✓	✓
Fish		✓	✓									✓	✓
Sharks		✓	✓			✓						✓	

Environmental value and sensitivities	Matters of national environmental significance	Value or sensitivity present in region		Operational Monitoring				Scientific Monitoring					
		Otway Basin	Bass Basin	Study O1	Study O2	Study O3	Study O4	Study S1	Study S2	Study S3	Study S4	Study S5	Study S6
				Hydrocarbon in offshore waters	Hydrocarbon on shorelines	Oiled wildlife surveillance	Dispersant efficacy	Offshore waters impact assessment	Shoreline sediments impact assessment	Subtidal habitats impact assessment	Intertidal habitats impact assessment	Wildlife impact assessment	Commercial fisheries exposure assessment
Cetaceans		✓	✓			✓						✓	
Pinnipeds		✓	✓			✓						✓	
Turtles		✓	✓			✓						✓	
Birds		✓	✓			✓						✓	
Subtidal benthic habitats		✓	✓							✓			
Intertidal benthic habitats		✓	✓								✓		
Wetlands of national importance		✓	✓			✓					✓	✓	
Cultural and heritage features													
World Heritage properties	✓	×	×		✓				✓		✓		
Commonwealth Heritage places		×	✓		✓				✓		✓		
National Heritage places	✓	✓	✓		✓				✓		✓		
Indigenous Protected Areas		✓	✓		✓				✓		✓		
Areas of Aboriginal cultural heritage sensitivity		✓	✓		✓				✓		✓		
Shipwrecks		✓	✓	✓				✓		✓			

Environmental value and sensitivities	Matters of national environmental significance	Value or sensitivity present in region		Operational Monitoring				Scientific Monitoring					
		Otway Basin	Bass Basin	Study O1	Study O2	Study O3	Study O4	Study S1	Study S2	Study S3	Study S4	Study S5	Study S6
				Hydrocarbon in offshore waters	Hydrocarbon on shorelines	Oiled wildlife surveillance	Dispersant efficacy	Offshore waters impact assessment	Shoreline sediments impact assessment	Subtidal habitats impact assessment	Intertidal habitats impact assessment	Wildlife impact assessment	Commercial fisheries exposure assessment
Socioeconomic features													
Commercial fisheries		✓	✓										✓
Tourism and recreation		✓	✓		✓	✓			✓	✓	✓	✓	
Coastal settlements		✓	✓		✓	✓			✓		✓	✓	
Shipping		✓	✓	✓				✓					
Petroleum industry		✓	✓	✓				✓					

Notes:

1. Commonwealth marine areas are listed as a MNES under the EPBC Act. Marine protected areas are marine areas which are recognised to have high conservation value.
2. Key ecological features are not MNES and have no legal status in their own right; however, they may be considered as components of the Commonwealth marine area.

2.2.4 Implementation

This OSMP is supported by the Offshore Victoria – Otway Basin OPEP, the BassGas Offshore OPEP and the OSMP Implementation Guide and OSMP Resources and Capability.

The Implementation Guide is not a prescriptive set of procedures that must strictly be followed but has been prepared to provide Beach and their Monitoring Provider/s sufficient information to efficiently finalise a monitoring design of an appropriate nature and scale in the event of a hydrocarbon spill.

The Implementation Guide also includes draft Standard Operating Procedures. Where practicable, these operating procedures are aligned with existing standards and processes (see also Section 2.3).

It is expected that final sampling designs, monitoring plans and procedures would only be finalised once a spill event has occurred. This is essential to ensure the finalised monitoring plan/s are fit for purpose and tailored to the specific location, hydrocarbon type, environmental sensitivities, and the nature and scale of the individual spill.

2.3 Guidance and best practice

This OSMP incorporates regulatory guidance from the following documents:

- Guidance note – Oil pollution risk management (NOPSEMA 2018)
- Information paper – Operational and scientific monitoring programs (NOPSEMA 2016).

Where appropriate sampling design and procedures are aligned with existing standards or guidance notes. These include, but are not limited to:

- Oil Spill Monitoring Handbook (Hook et al. 2016)
- Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters Quality (ANZECC & ARMCANZ 2000)
- Parks Victoria Standard Operating Procedure for Biological Monitoring of Subtidal Reefs (Edmunds and Hart 2005)
- Parks Victoria Standard Operating Procedure for Biological Monitoring of Intertidal Reefs (Hart and Edmunds 2005)
- Industry Recommended Subsea Dispersant Monitoring Plan (American Petroleum Institute 2013)
- Dispersant Application Monitoring Field Guide Tier I Visual Observation (OSRL 2011)
- Special Monitoring of Applied Response Technologies (NOAA 2006).

2.4 Communication and Notification

Stakeholder (including regulators) consultation and external notification requirements are described in the activity-specific EPs. This includes the requirement to consult with:

- Department of Jobs, Precincts and Regions (Victoria) and/or Department of Primary Industries, Parks, Water and Environment (Tasmania), in the event that a hydrocarbon spill is likely to impact State waters.

- Department of the Environment and Energy (DoEE), in the event that a hydrocarbon spill is likely to impact matters of national environmental significance.

- Director of National Parks, in the event that a hydrocarbon spill and/or response activities are likely to impact an Australian Marine Park.

Consultation may also be undertaken with the above agencies in the event of a Level 2 or Level 3 hydrocarbon spill with respect to input and/or review of a spill-specific Sampling and Analysis Plan (SAP) for scientific monitoring studies.

2.5 Review and Revisions

This Offshore Victoria OSMP (and supporting guides and procedures) are subject to review, and revised if necessary, on an annual basis to incorporate the following:

- Significant change in the hydrocarbon spills risks associated with Beach activities and/or facilities within offshore Victorian waters

- Significant environmentally relevant changes (e.g. changes to relevant legislation, stakeholder information, MNES, State/Commonwealth management plans, or availability of new literature)

- Findings from internal or external audits or exercises

- Lessons learned following any actual spill event.

Review records will be detailed in Beach Document Information and History tables. Subsequent revisions to the OSMP (or supporting guides and procedures) will be actioned and closed-out as soon as practicable following the review.

As part an EP, Regulation 19 of the OPGGS(E)R also provides for the revision of the OSMP at least 14 days before the end of the period of five years from the most recent approval of an associated EP.

3 Operational Monitoring

The following sections outline the individual operational monitoring studies that may be implemented in the event of a Level 2 or Level 3 hydrocarbon spill to the marine or coastal environment. The tables describe the objective, initiation and termination criteria, implementation times, and provide a high-level description of monitoring, reporting, resources and competencies.

The studies are presented separately below; however, in practice they may be undertaken simultaneously.

These overviews are supported by the OSMP Implementation Plan, which has been prepared to provide Beach and their Monitoring Provider/s sufficient information to efficiently finalise a monitoring design of an appropriate nature and scale in the event of a hydrocarbon spill.

Four operational monitoring studies have been identified:

- O1: Hydrocarbon in offshore waters
- O2: Hydrocarbon on shorelines
- O3: Oiled wildlife surveillance
- O4: Dispersant efficacy.

The operational monitoring studies described in this OSMP complement the Monitor and Evaluate response strategy described in the OPEP in providing information to support decision-making around response activity.

Note: due to the rapid weathering characteristics of gas condensate and marine diesel, operational monitoring studies O1, O2 and O3 are not considered relevant for a pipeline rupture or vessel collision event where there is only a short period of hydrocarbon release. The time that would elapse between a spill occurring and monitoring personnel being on site would render the data collected unnecessary in informing response strategies. Studies O1, O2 and O3 are, therefore, only actioned (once initiation criteria are met) as a result of a loss of well control incident.

3.1 Study O1: Hydrocarbon in offshore waters

An overview of the key components of Study O1 is provided below:

Component	Description
Objective	Determine hydrocarbon concentrations in offshore marine waters
Initiation trigger	• The EMT Leader (or delegate) has confirmed that a Level 2 or Level 3 offshore hydrocarbon spill has occurred **or** • The EMT Leader (or delegate) advises that either full or partial implementation of the study is to commence
Termination trigger	• Any related scientific monitoring studies have been initiated by the HSE Lead (or delegate) **and** • The EMT Leader (or delegate) considers that continuation of monitoring under Study O1 will not result in a change to the scale or location of active response options **or** • The EMT Leader (or delegate) has advised that agreement has been reached with the Jurisdictional Authority relevant to the spill to terminate the response **or** • The HSE Lead (or delegate) has advised that continuation of monitoring under Study O1 may increase overall environmental impact
Timing	Study O1 is to be implemented[1] within 24 hours of the initiation criteria being met

Component	Description
Sampling	The following types of sampling may be implemented under Study O1: • Collection of an oil sample from water surface for physical and chemical characterisation • In-situ water quality data (e.g. water column profiles, TPH and/or physical characteristics) • Surface water sample collection for chemical analysis (e.g. TPH, PAH, heavy metals, dispersant) • Sub-surface water sample collection for chemical analysis (e.g. TPH, PAH, heavy metals, dispersant)
Reporting	• Results from in-situ sampling reported daily to the Environment SME • Results from laboratory sampling reported as available to Environment SME • Final report prepared within one-week of termination criteria being met and report provided to Environment SME
Key Resources	• Monitoring Provider • Vessels • Analytical laboratory services • *Refer to OSMP Resources & Capability for list of contact details for key resources*
Key Competencies	• Monitoring Provider – Study Lead ◦ Bachelor degree in environmental science/engineering from a recognised institution or equivalent tertiary study in technical area ◦ Familiarisation with relevant requirements of the OSMP and OPEP • Monitoring Provider – Field Personnel ◦ Familiarisation with oil and water sampling and recording techniques • Vessel provider ◦ Certificate of survey with appropriate service category • Analytical laboratory ◦ NATA accredited

Notes:

1. A study is considered implemented when Beach have (i) confirmed initiation criteria have been met, (ii) the Monitoring Provider/s have been notified, (iii) sampling and analysis plans (where required) have been completed, and (iv) mobilisation has commenced.

3.2 Study O2: Hydrocarbon on shorelines

An overview of the key components of Study O2 is provided below:

Component	Description
Objective	Determine hydrocarbon concentrations in shoreline sediments
Initiation trigger	• The EMT Leader (or delegate) has confirmed that a Level 2 or Level 3 offshore hydrocarbon spill has occurred **and** data from the OPEP Monitor and Evaluate response strategy indicates potential and/or actual shoreline contact **or** • The EMT Leader (or delegate) advises that either full or partial implementation of the study is to commence
Termination trigger	• Any related scientific monitoring studies have been initiated by the HSE Lead (or delegate) **and** • The EMT Leader (or delegate) considers that continuation of monitoring under Study O2 will not result in a change to the scale or location of active response options **or** • The EMT Leader (or delegate) has advised that agreement has been reached with the Jurisdictional Authority relevant to the spill to terminate the response **or** • The HSE Lead (or delegate) has advised that continuation of monitoring under Study O2 may increase overall environmental impact

Component	Description
Timing	Study O2 is to be implemented[1] within 36 hours of the initiation criteria being met
Sampling	The following types of sampling may be implemented under Study O2: • In-situ observations of oil coverage and characteristics • Surface sediment sample collection for chemical (e.g. TPH, PAH, heavy metals) and/or physical (e.g. PSD, TOC) analysis
Reporting	• Results from in-situ observations reported daily to the Environment SME • Results from laboratory sampling reported as available to Environment SME • Final report prepared within one-week of termination criteria being met and report provided to Environment SME
Key Resources	• Monitoring Provider • Vessels (island access) • Vehicles (mainland access) • Analytical laboratory services • *Refer to OSMP Resources & Capability for list of contact details for key resources*

Key Competencies	• Monitoring Provider – Study Lead
	  ◦ Bachelor degree in environmental science/engineering from a recognised institution or equivalent tertiary study in technical area
	  ◦ Familiarisation with relevant requirements of the OSMP and OPEP
	• Monitoring Provider – Field Personnel
	  ◦ Familiarisation with sediment sampling and recording techniques
	• Vessel provider
	  ◦ Certificate of survey with appropriate service category
	• Analytical laboratory
	  ◦ NATA accredited

Notes:

1. A study is considered implemented when Beach have (i) confirmed initiation criteria have been met, (ii) the Monitoring Provider/s have been notified, (iii) sampling and analysis plans (where required) have been completed, and (iv) mobilisation has commenced.

3.3 Study O3: Oiled wildlife surveillance

An overview of the key components of Study O3 is provided below:

Component	Description
Objective	Identify the presence and condition of oiled wildlife
Initiation trigger	• The EMT Leader (or delegate) has confirmed that a Level 2 or Level 3 offshore hydrocarbon spill has occurred **and** data from the OPEP Monitor and Evaluate response strategy indicates potential and/or actual shoreline contact **or** • The EMT Leader (or delegate) advises that either full or partial implementation of the study is to commence
Termination trigger	• Any related scientific monitoring studies have been initiated by the HSE Lead (or delegate) **and** • The EMT Leader (or delegate) considers that continuation of monitoring under Study O3 will not result in a change to the scale or location of active response options **or** • The EMT Leader (or delegate) has advised that agreement has been reached with the Jurisdictional Authority relevant to the spill to terminate the response **or**

Component	Description
	• The HSE Lead (or delegate) has advised that continuation of monitoring under Study O3 may increase overall environmental impact
Timing	Study O3 is to be implemented[1] within 24 hours of the initiation criteria being met
Surveillance	The following types of surveillance may be implemented under Study O3: • In-situ observations (vessel or aerial) to identify presence of oiled wildlife • Shoreline inspections to identify any oiled, injured or dead wildlife
Reporting	• Results from in-situ observations reported daily to the Environment SME • Final report prepared within one-week of termination criteria being met and report provided to Environment SME
Key Resources	• Monitoring Provider • Vessels • Aircraft • Vehicles • *Refer to OSMP Resources & Capability for list of contact details for key resources*
Key Competencies	• Monitoring Provider – Study Lead ◦ Bachelor degree in environmental science/engineering from a recognised institution or equivalent tertiary study in technical area ◦ Familiarisation with relevant requirements of the OSMP and OPEP • Monitoring Provider – Field Personnel ◦ Familiarisation with the fauna observation and recording techniques • Vessel provider ◦ Certificate of survey with appropriate service category • Aircraft ◦ Current registration with CASA • Analytical laboratory ◦ NATA accredited

Notes:

1. A study is considered implemented when Beach have (i) confirmed initiation criteria have been met, (ii) the Monitoring Provider/s have been notified, (iii) sampling and analysis plans (where required) have been completed, and (iv) mobilisation has commenced.

3.4 Study O4: Dispersant efficacy

An overview of the key components of Study O4 is provided below:

Component	Description
Objective	Determine the effectiveness of dispersant application
Initiation trigger	• The EMT Leader (or delegate) has confirmed that a Level 2 or Level 3 offshore hydrocarbon spill has occurred **and** the Chemical Dispersant response strategy from the OPEP has been selected for use
Termination trigger	• Any related scientific monitoring studies have been initiated by the HSE Lead (or delegate) **and** • The EMT Leader (or delegate) considers that continuation of monitoring under Study O4 will not result in a change to the scale or location of active response options **or** • The EMT Leader (or delegate) has advised that agreement has been reached with the Jurisdictional Authority relevant to the spill to terminate the response **or**

Component	Description
	• The HSE Lead (or delegate) has advised that continuation of monitoring under Study O4 may increase overall environmental impact
Timing	Study O4 is to be undertaken at the same time as the Chemical Dispersant response strategy
Sampling and Surveillance	The following types of sampling and surveillance may be implemented under Study O4: • In-situ observations (vessel or aerial) for dispersant efficacy • Air quality monitoring (e.g. VOCs and %LELs)
Reporting	• Results from in-situ observations reported daily to the Environment SME • Final report prepared within one-week of termination criteria being met and report provided to Environment SME
Key Resources	• Monitoring Provider • Vessels • Aircraft • *Refer to OSMP Resources & Capability for list of contact details for key resources*
Key Competencies	• Monitoring Provider – Study Lead ◦ Bachelor degree in environmental science/engineering from a recognised institution or equivalent tertiary study in technical area ◦ Familiarisation with relevant requirements of the OSMP and OPEP • Monitoring Provider – Field Personnel ◦ Familiarisation with vessel-based and/or aerial-based hydrocarbon spill monitoring ◦ Familiarisation with relevant sampling techniques (e.g. sub-surface video surveillance, use of fluorometer, water sample collection, air quality monitoring) • Vessel provider ◦ Certificate of survey with appropriate service category • Aircraft ◦ Current registration with CASA • Analytical laboratory ◦ NATA accredited

4 Scientific Monitoring

The following sections outline the individual scientific monitoring studies that may be implemented in the event of a Level 2 or Level 3 hydrocarbon spill to the marine or coastal environment. The sections describe the objective, initiation and termination criteria, implementation timing, and provide a high-level description of monitoring, reporting, resources and competencies.

The studies are presented separately below; however, in practice they may be undertaken simultaneously.

These overviews are supported by the OSMP Implementation Plan, which has been prepared to provide Beach and their Monitoring Provider/s sufficient information to efficiently finalise a monitoring design of an appropriate nature and scale in the event of a hydrocarbon spill.

Scientific monitoring generally has objectives relating to attributing cause-effect interactions of the spill with changes to the surrounding environment. Consequently, such studies are required to account for natural or sampling variation, and study designs must be robust and produce defensible data. Scientific monitoring is typically conducted over a wider study area, extending beyond the spill footprint, and a longer time period, extending beyond the spill response.

Six scientific monitoring studies have been identified:

- S1: Offshore waters impact assessment
- S2: Shoreline sediments impact assessment
- S3: Subtidal habitats impact assessment
- S4: Intertidal habitats impact assessment
- S5: Wildlife impact assessment
- S6: Commercial fisheries exposure assessment.

Guidance on various experimental monitoring approaches for scientific monitoring (e.g. use of baseline data in 'before versus after' analyses, and alternative approaches such as 'control versus impact' and 'gradient approach') is provided in Appendix B. Specific guidance and sampling approaches are described within the implementation guides for each scientific monitoring module.

Termination criteria for some of the scientific monitoring modules require the use of guidelines and/or benchmark values. Where available, Australian guidelines (e.g. ANZECC & ARMCANZ 2000) or regionally relevant data is used. Where these are unavailable for a selected parameter, toxicity screening benchmarks developed by the USEPA in response to the Deepwater Horizon incident (e.g. USEPA 2015), or other international guidelines (e.g. USEPA 2017) may be adopted.

4.1 Study S1: Offshore waters impact assessment

An overview of the key components of Study S1 is provided below:

Component	Description
Objective	Determine the impact to, and recovery of, offshore marine water quality from hydrocarbon exposure
Initiation trigger	• The EMT Leader (or delegate) has confirmed that a Level 2 or Level 3 offshore hydrocarbon spill has occurred **and** data from the Study O1 has confirmed exposure to offshore waters **or** • The EMT Leader (or delegate) advises that either full or partial implementation of the study is to commence
Termination trigger	• The Environment SME (or delegate) considers that: ◦ Hydrocarbon concentrations in offshore waters have returned to within the expected natural dynamics of baseline state and/or control sites **or** ◦ Hydrocarbon concentrations in offshore waters are below relevant ANZECC/ARMCANZ (2000) 99% species protection levels or other applicable benchmark values **or** ◦ There has been no demonstrable impact on offshore water quality from hydrocarbons **or** • Agreement has been reached with the Statutory Authority relevant to the spill to terminate the monitoring
Timing	• Study S1 is to be activated[1] within 24 hours of the initiation criteria being met • A draft SAP, prepared by the Monitoring Provider, to be available within 7 days of the study being activated • Consultation with relevant agencies to commence as soon as practicable after study being activated • Mobilisation and monitoring to commence as soon as practicable after SAP is finalised
Sampling	The following types of sampling may be implemented under Study S1: • Surface water sample collection for chemical analysis (e.g. TPH, PAH, heavy metals) • Sub-surface water sample collection for chemical analysis (e.g. TPH, PAH, heavy metals)
Reporting	• Data report to be provided to Environment SME following the completion of each field survey • Final impact assessment report to be provided to Environment SME following the termination criteria being met
Key Resources	• Monitoring Provider • Vessels • Analytical laboratory services • *Refer to OSMP Resources & Capability for list of contact details for key resources*
Key Competencies	• Monitoring Provider – Study Lead ◦ Bachelor degree in environmental science/engineering from a recognised institution or equivalent tertiary study in technical area ◦ Familiarisation with relevant requirements of the OSMP and OPEP • Monitoring Provider – Field Personnel ◦ Bachelor degree in environmental science/engineering from a recognised institution or equivalent tertiary study in technical area ◦ Experienced in the relevant sampling and/or recording techniques • Monitoring Provider – Office Personnel ◦ Bachelor degree in environmental science/engineering from a recognised institution or equivalent tertiary study in technical area ◦ Experience in water quality data analysis • Vessel provider ◦ Certificate of survey with appropriate service category

Component	Description
	• Analytical laboratory ◦ NATA accredited

Notes:

1. A study is considered activated when (i) Beach have confirmed initiation criteria have been met and (ii) the Monitoring Provider/s have been engaged.

4.2 Study S2: Shoreline sediments impact assessment

An overview of the key components of Study S2 is provided below:

Component	Description
Objective	Determine the impact to, and recovery of, shoreline sediment quality from hydrocarbon exposure
Initiation trigger	• The EMT Leader (or delegate) has confirmed that a Level 2 or Level 3 offshore hydrocarbon spill has occurred **and** data from the Study O2 has confirmed exposure to shoreline sediments **or** • The EMT Leader (or delegate) advises that either full or partial implementation of the study is to commence

Termination trigger	• The Environment SME (or delegate) considers that:
	  ◦ Hydrocarbon concentrations in shoreline sediments have returned to within the expected natural dynamics of baseline state and/or control sites **or**
	  ◦ Hydrocarbon concentrations in shoreline sediments are below relevant ANZECC/ARMCANZ SQGV (Simpson et al. 2013) other applicable benchmark values **or**
	  ◦ There has been no demonstrable impact on shoreline sediment quality from hydrocarbons **or**
	• Agreement has been reached with the Statutory Authority relevant to the spill to terminate the monitoring

Timing	• Study S2 is to be activated[1] within 24 hours of the initiation criteria being met • A draft SAP, prepared by the Monitoring Provider, to be available within 7 days of the study being activated • Consultation with relevant agencies to commence as soon as practicable after study being activated • Mobilisation and monitoring to commence as soon as practicable after SAP is finalised
Sampling	The following types of sampling may be implemented under Study S2: • Surface sediment sample collection for chemical (e.g. TPH, PAH, heavy metals) and/or physical (e.g. PSD, TOC) analysis
Reporting	• Data report to be provided to Environment SME following the completion of each field survey • Final impact assessment report to be provided to Environment SME following the termination criteria being met
Key Resources	• Monitoring Provider • Vessels (island access) • Vehicles (mainland access) • Analytical laboratory services • *Refer to OSMP Resources & Capability for list of contact details for key resources*

Key Competencies	• Monitoring Provider – Study Lead
	  ◦ Bachelor degree in environmental science/engineering from a recognised institution or equivalent tertiary study in technical area
	  ◦ Familiarisation with relevant requirements of the OSMP and OPEP
	• Monitoring Provider – Field Personnel

Component	Description
	◦ Bachelor degree in environmental science/engineering from a recognised institution or equivalent tertiary study in technical area ◦ Experienced in the relevant sampling and/or recording techniques • Monitoring Provider – Office Personnel ◦ Bachelor degree in environmental science/engineering from a recognised institution or equivalent tertiary study in technical area ◦ Experience in sediment quality data analysis • Vessel provider ◦ Certificate of survey with appropriate service category • Analytical laboratory ◦ NATA accredited

Notes:

1. A study is considered activated when (i) Beach have confirmed initiation criteria have been met and (ii) the Monitoring Provider/s have been engaged.

4.3 Study S3: Subtidal habitats impact assessment

An overview of the key components of Study S3 is provided below:

Component	Description
Objective	Determine the impact to, and recovery of, subtidal habitats from hydrocarbon exposure
Initiation trigger	• The EMT Leader (or delegate) has confirmed that a Level 2 or Level 3 offshore hydrocarbon spill has occurred **and** data from the OPEP Monitor and Evaluate response strategy indicates potential and/or actual exposure to near-bottom waters **or** • The EMT Leader (or delegate) advises that either full or partial implementation of the study is to commence
Termination trigger	• The Environment SME (or delegate) considers that: ◦ Disturbance parameters (e.g. species composition, percent cover) and health parameters (e.g. leaf condition) have returned to within the expected natural dynamics of baseline state and/or control sites **or** ◦ There has been no demonstrable impact on subtidal benthic habitats from hydrocarbons **or** • Agreement has been reached with the Statutory Authority relevant to the spill to terminate the monitoring
Timing	• Study S3 is to be activated[1] within 24 hours of the initiation criteria being met • A draft SAP, prepared by the Monitoring Provider, to be available within 7 days of the study being activated • Consultation with relevant agencies to commence as soon as practicable after study being activated • Mobilisation and monitoring to commence as soon as practicable after SAP is finalised
Sampling	The following types of sampling may be implemented under Study S3: • Diver surveys to record in situ observations (e.g. substrate type, abundance, percent cover) • ROV surveys to record benthic habitat type and state • Biological sample collection (e.g. for chemical analysis)
Reporting	• Data report to be provided to Environment SME following the completion of each field survey

Component	Description
	• Final impact assessment report to be provided to Environment SME following the termination criteria being met
Key Resources	• Monitoring Provider • Vessels • ROV • *Refer to OSMP Resources & Capability for list of contact details for key resources*
Key Competencies	• Monitoring Provider – Study Lead ◦ Bachelor degree in environmental science/engineering from a recognised institution or equivalent tertiary study in technical area ◦ Familiarisation with relevant requirements of the OSMP and OPEP • Monitoring Provider – Field Personnel ◦ Bachelor degree in environmental science/engineering from a recognised institution or equivalent tertiary study in technical area ◦ Commercial dive qualifications ◦ Experienced in the relevant sampling and/or recording techniques ◦ Experienced in commercial ROV operations • Monitoring Provider – Office Personnel ◦ Bachelor degree in environmental science/engineering from a recognised institution or equivalent tertiary study in technical area ◦ Experience in identification, analysis and interpretation of benthic habitat data • Vessel provider ◦ Certificate of survey with appropriate service category ◦ Suitable for commercial diving operations

Notes:

1. A study is considered activated when (i) Beach have confirmed initiation criteria have been met and (ii) the Monitoring Provider/s have been engaged.

4.4 Study S4: Intertidal habitats impact assessment

An overview of the key components of Study S4 is provided below:

Component	Description
Objective	Determine the impact to, and recovery of, subtidal habitats from hydrocarbon exposure
Initiation trigger	• The EMT Leader (or delegate) has confirmed that a Level 2 or Level 3 offshore hydrocarbon spill has occurred **and** data from the Study O2 has confirmed exposure to shoreline sediments **or** • The EMT Leader (or delegate) advises that either full or partial implementation of the study is to commence
Termination trigger	• The Environment SME (or delegate) considers that: ◦ Disturbance parameters (e.g. species composition, percent cover) and health parameters (e.g. leaf condition) have returned to within the expected natural dynamics of baseline state and/or control sites **or** ◦ There has been no demonstrable impact on intertidal benthic habitats from hydrocarbons **or** • Agreement has been reached with the Statutory Authority relevant to the spill to terminate the monitoring

Component	Description
Timing	• Study S4 is to be activated[1] within 24 hours of the initiation criteria being met • A draft SAP, prepared by the Monitoring Provider, to be available within 7 days of the study being activated • Consultation with relevant agencies to commence as soon as practicable after study being activated • Mobilisation and monitoring to commence as soon as practicable after SAP is finalised
Sampling	The following types of sampling may be implemented under Study S4: • In situ observations (e.g. substrate type, abundance, percent cover) • Biological sample collection (e.g. for chemical analysis)
Reporting	• Data report to be provided to Environment SME following the completion of each field survey • Final impact assessment report to be provided to Environment SME following the termination criteria being met
Key Resources	• Monitoring Provider • Vessels (island access) • Vehicles (mainland access) • *Refer to OSMP Resources & Capability for list of contact details for key resources*
Key Competencies	• Monitoring Provider – Study Lead ◦ Bachelor degree in environmental science/engineering from a recognised institution or equivalent tertiary study in technical area ◦ Familiarisation with relevant requirements of the OSMP and OPEP • Monitoring Provider – Field Personnel ◦ Bachelor degree in environmental science/engineering from a recognised institution or equivalent tertiary study in technical area ◦ Experienced in the relevant sampling and/or recording techniques • Monitoring Provider – Office Personnel ◦ Bachelor degree in environmental science/engineering from a recognised institution or equivalent tertiary study in technical area ◦ Experience in identification, analysis and interpretation of benthic habitat data • Vessel provider ◦ Certificate of survey with appropriate service category

Notes:

1. A study is considered activated when (i) Beach have confirmed initiation criteria have been met and (ii) the Monitoring Provider/s have been engaged.

4.5 Study S5: Wildlife impact assessment

An overview of the key components of Study S5 is provided below:

Component	Description
Objective	Determine the impact to, and recovery of, wildlife from hydrocarbon exposure
Initiation trigger	• The EMT Leader (or delegate) has confirmed that a Level 2 or Level 3 offshore hydrocarbon spill has occurred **and** data from the Study O3 has confirmed exposure to wildlife **or** • The EMT Leader (or delegate) advises that either full or partial implementation of the study is to commence
Termination trigger	• The Environment SME (or delegate) considers that:

Component	Description
	◦ Disturbance parameters (e.g. population size, breeding success) have returned to within the expected natural dynamics of baseline state and/or control sites **or** ◦ There has been no demonstrable impact on wildlife from hydrocarbons **or** • Agreement has been reached with the Statutory Authority relevant to the spill to terminate the monitoring
Timing	• Study S5 is to be activated[1] within 24 hours of the initiation criteria being met • A draft SAP, prepared by the Monitoring Provider, to be available within 7 days of the study being activated • Consultation with relevant agencies to commence as soon as practicable after study being activated • Mobilisation and monitoring to commence as soon as practicable after SAP is finalised
Sampling	The following types of sampling may be implemented under Study S5: • In situ observations (e.g. counts) • Tissue sample collection and analysis
Reporting	• Data report to be provided to Environment SME following the completion of each field survey • Final impact assessment report to be provided to Environment SME following the termination criteria being met
Key Resources	• Monitoring Provider • Vessels (island access) • Vehicles (mainland access) • Analytical laboratory services • *Refer to OSMP Resources & Capability for list of contact details for key resources*
Key Competencies	• Monitoring Provider – Study Lead ◦ Bachelor degree in environmental science/engineering from a recognised institution or equivalent tertiary study in technical area ◦ Familiarisation with relevant requirements of the OSMP and OPEP • Monitoring Provider – Field Personnel ◦ Bachelor degree in environmental science/engineering from a recognised institution or equivalent tertiary study in technical area ◦ Experienced in the relevant sampling and/or recording techniques • Monitoring Provider – Office Personnel ◦ Bachelor degree in environmental science/engineering from a recognised institution or equivalent tertiary study in technical area ◦ Experience in identification, analysis and interpretation of biota data • Vessel provider ◦ Certificate of survey with appropriate service category • Analytical laboratory ◦ NATA accredited

Notes:

1. A study is considered activated when (i) Beach have confirmed initiation criteria have been met and (ii) the Monitoring Provider/s have been engaged.

4.6 Study S6: Commercial fisheries exposure assessment

An overview of the key components of Study S6 is provided below:

Component	Description
Objective	Determine the presence of, and recovery from, hydrocarbon taint in commercial fish species
Initiation trigger	• The EMT Leader (or delegate) has confirmed that a Level 2 or Level 3 offshore hydrocarbon spill has occurred **and** data from the Study O1 or Study S1 has confirmed exposure to offshore waters above the ANZECC/ARMCANZ (2000) 99% species protection levels **and** this exposure occurred in waters that intersect with active fisheries **or** • The EMT Leader (or delegate) advises that either full or partial implementation of the study is to commence
Termination trigger	• The Environment SME (or delegate) considers that: ◦ PAH levels in fish or shellfish show no presence of tissue taint (i.e. levels are below guidelines in ANZECC & ARMCANZ 2000) **or** ◦ PAH levels in fish and shellfish tissue have returned to within the expected natural dynamics of baseline state and/or control sites **or** ◦ PAH levels in fish and shellfish tissue are at or below levels of concern (USFDA 2010) or screening values (USEPA 2000) United States Food and Drug Administration (USFDA) **or** ◦ There has been no demonstrable impact on wildlife from hydrocarbons **or** • Agreement has been reached with the Statutory Authority relevant to the spill to terminate the monitoring
Timing	• Study S6 is to be activated[1] within 24 hours of the initiation criteria being met • A draft SAP, prepared by the Monitoring Provider, to be available within 7 days of the study being activated • Consultation with relevant agencies to commence as soon as practicable after study being activated • Mobilisation and monitoring to commence as soon as practicable after SAP is finalised
Sampling	The following types of sampling may be implemented under Study S6: • Tissue sample collection and chemical analysis (e.g. PAH) • Olfactory analysis
Reporting	• Data report to be provided to Environment SME following the completion of each field survey • Final impact assessment report to be provided to Environment SME following the termination criteria being met
Key Resources	• Monitoring Provider • Olfactory Analysis Panel • Vessels • Analytical laboratory services • *Refer to OSMP Resources & Capability for list of contact details for key resources*
Key Competencies	• Monitoring Provider – Study Lead ◦ Bachelor degree in environmental science/engineering from a recognised institution or equivalent tertiary study in technical area ◦ Familiarisation with relevant requirements of the OSMP and OPEP • Monitoring Provider – Field Personnel ◦ Bachelor degree in environmental science/engineering from a recognised institution or equivalent tertiary study in technical area ◦ Experienced in the relevant sampling and/or recording techniques • Monitoring Provider – Office Personnel

Component	Description
	◦ Bachelor degree in environmental science/engineering from a recognised institution or equivalent tertiary study in technical area ◦ Experience in analysis and interpretation of biota data • Olfactory Analysis Panel ◦ Experienced in olfactory analysis • Vessel provider ◦ Certificate of survey with appropriate service category • Analytical laboratory ◦ NATA accredited

Notes:

1. A study is considered activated when (i) Beach have confirmed initiation criteria have been met and (ii) the Monitoring Provider/s have been engaged.

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Appendix A Approaches for Scientific Monitoring Design

This appendix provides guidance (as provided in APPEA 2019) on survey design approaches that may be utilised for scientific monitoring:

- Impact versus Control (IvC)
- Gradient of Impacts
- Before-After-Control-Impact (BACI)
- Control Chart
- Lines of Evidence.

The design of monitoring studies should ensure, as far as possible, that the planned monitoring activities are practicable and that the objectives of the study will be met. The design must result in the collection of meaningful data and, where practicable, data that are sufficiently powerful to detect ecologically relevant changes.

The final survey design(s) can depend on a variety of factors, included but not limited to:

- Scale and pattern of potential effects of the spill
- Availability of baseline data and/or ability to rapidly obtain baseline data
- Time frame available to gather pre- and post-spill data
- Availability of operational monitoring data
- Availability of appropriate control sites
- Statistical approach proposed for data analysis
- Range of possible chronic and acute effects on the parameters of concern, based on the characteristics of the spill
- Monitoring frequency required to ensure short-and long-term impacts are detected
- Legislative requirements
- Available resources and equipment to conduct the work in terms of personnel, logistics, and access.

Note: data collection can depend on several constraints (as outlined above) and on access given logistical and safety constraints applicable to a spill event. Therefore, the survey designs recommended within the implementation guides for each scientific monitoring module, may not be able to be implemented exactly as intended. For example, there may be inadequate number of control sites because of the size of the spill and therefore data collected from an expected BACI design may need to be analysed as a gradient approach etc.

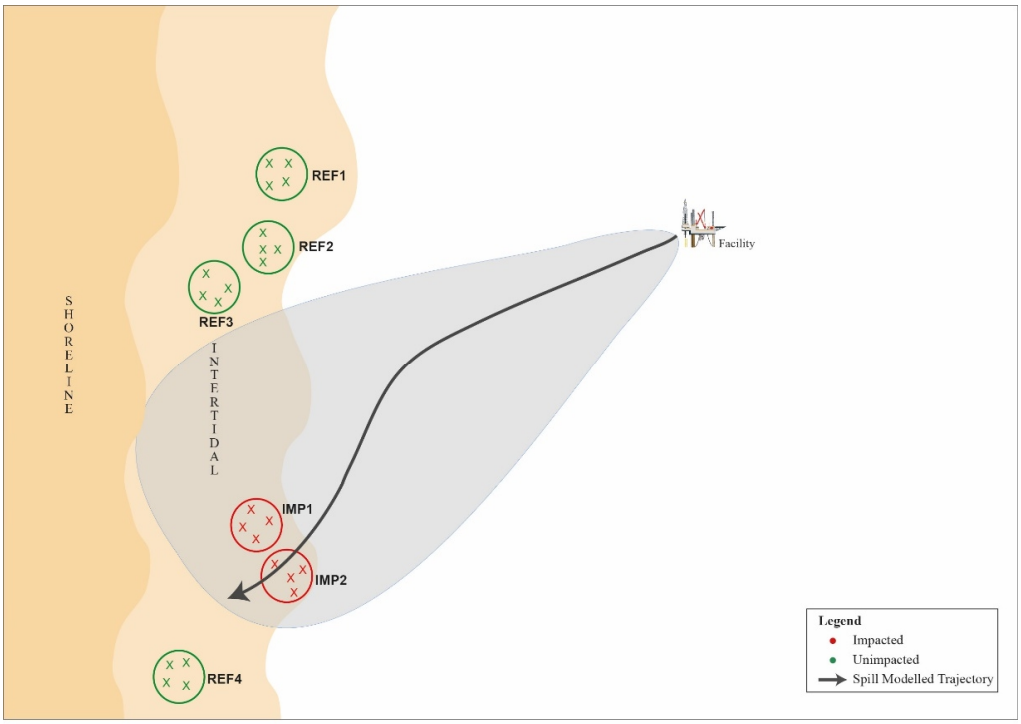
A. 1. Before-After-Control-Impact (BACI) approach

Where appropriate baseline data are available, consideration should be given to developing a beyond BACI monitoring program design (Underwood 1991; 1994) or similar extended BACI design (MBACI), which monitors a range of control and impact sites, and can do so over time (Figure A-1). Where robust, appropriate baseline data for exposure sites are not

available, pre-exposure sampling of locations that lie within the hydrocarbon spill trajectory should be prioritised to obtain baseline data prior to hydrocarbon exposure.

Exposure sites should be selected first, encompassing a representative selection of locations within the area affected by hydrocarbons. Where practicable, the monitoring program design may consider stratified sampling along environmental gradients (e.g. level of hydrocarbon exposure etc.). Comparable control sites beyond the area affected by hydrocarbons should then be selected, with monitoring conducted at all sites. Clearly obtaining control sites pre-exposure can be challenging and is heavily reliant on predicting the extent of hydrocarbon movement.

The suggested statistical analysis of data collected using the BACI approach includes a univariate or multi-factorial analysis of variance (ANOVA) and equivalent non-parametric tests, all of which will compare between treatment (impact versus reference) and time (before versus after). Components of variation may help partition a sum of squares into different sources and describe the importance of factors within tests.



(Source: APPEA 2019)

Notes:

1. A modification to the beyond BACI design, is known as an MBACI design. MBACI designs incorporate multiple impact locations, whereas beyond BACI designs include only one impact location.
2. The above design consists of four reference/control locations and two impact locations, with four nested sites in each. The number of replicates (e.g. quadrats or transects) per site should be set based on resourcing, and /or the results of the power analysis (if applicable).
3. The area affected by the spill is indicated by the grey shaded area, or the area of influence.
4. Design assumes the area of influence has been affected equally.

Figure A-1: Example of an MBACI design for shoreline and/or intertidal communities

A. 2. Impact versus Control (IvC) approach

For some locations and receptors, baseline data may not exist, may not be recent and applicable, or was collected using methods that are unrepeatable in the current study. If there is a lack of baseline information that can feed into a BACI design, an IvC approach can be used to assess impacts. However, due to the unknown status of the parameter before impact, there is a higher likelihood of encountering Type I error (falsely concluding that an impact has occurred) with this approach. For example, if the status of the parameter to be measured was already naturally lower at impact sites than control sites before the impact occurred, but this was not measured, a conclusion may be reached using the IvC approach that an impact has occurred when it may be natural variation. For this reason, sampling designs should always try to collect or use baseline data (i.e. aim for a BACI design), and if an IvC design is used, it is important to ensure that the control sites are comparable to the impact sites in every way possible except for the presence or absence of the studied effect (hydrocarbon). This may include, but not be limited to, site physical aspect, substrate, current regimes, and community composition.

Because of the higher likelihood of Type I error, it is also useful to collect additional data on relevant physical environmental parameters that are likely to be different at impact and control sites and may affect the conclusion of the assessment. Biological information may also be relevant, such as degree of sub-lethal and lethal impacts to populations. These parameters can be examined later for any potential co-variance with the observed changes in the parameter of interest, to understand whether hydrocarbons or natural variation affected the outcome. The physical and biological information can therefore augment and act as additional evidence to help interpret conclusions from any IvC analyses. As with the BACI approach, when using the IvC approach it is important to understand the scale of natural variation that may affect the outcome of the assessment by replicating sites within sampling locations and replicating samples within each site.

The suggested statistical approach for analysing the data collected using the IvC approach is a multi-factorial ANOVA (to account for nested data), including PERMANOVA and non-parametric tests, to test whether the level of variation among treatments (IvC) is greater than the level of variation within treatments. Components of variation may help partition variance into different sources and help infer whether the effect of hydrocarbons or spatial variation was responsible for any detected change in the receptors.

A. 3. Gradient approach

The gradient approach can be used in some instances where a lack of suitable control sites prohibits using a BACI or IvC approach. Sampling should be established along a gradient of predicted effect (based on input of data from operational monitoring, surveillance or modelling), with sites established at various distances from the source of impact or along a gradient of magnitudes of concentrations of hydrocarbons. The gradient approach can also be used in combination with a BACI or IvC approach to help infer the cause of a detected impact and describe thresholds of impacts at which a response appears to have occurred. The gradient approach also provides a 'line of evidence' that the source of potential impact (hydrocarbons) was responsible for the observed effect, rather than natural variation. However, care should be taken to ensure awareness of any natural gradients in the parameter measured and take these into account when interpreting the data.

When designing a study using a gradient approach, relevant operational and scientific monitoring data (e.g. water and sediment quality), and modelling should be considered. Prior knowledge or prediction of the likely gradient of effect will greatly improve the efficiency of the sampling design by minimising the collection of data points that provide no additional information in the analysis (e.g. data points showing similar or no effects that do not help to characterise the gradient of effect), though noting these may aid in statistical power of gradient description so shouldn't necessarily be discouraged.

Typically, the level of observed impact will decline at distance from the source of a hydrocarbon release, with this decline likely to be exponential (i.e. large changes close to a release that quickly decrease in severity); therefore, sampling effort can be distributed along the gradient of effect in a way that best characterises the changes in the parameter measured.

If possible, multiple (> two) sites could be sampled at each distance along the gradient (if logistics and time permit) to provide an understanding of small-scale variation. Sites should also be sampled at distances where no environmental effect is predicted or observed, if possible, to characterise the full extent of the effect's gradient.

The suggested statistical analysis for the gradient approach includes correlation analysis between impact (measurements of hydrocarbon/stress; x-axis) and measurement parameter (biological response; y-axis), and associated regression analyses, may include least-squares regression line and hypotheses testing to determine if the trend is significantly different from zero.

A. 4. Control chart approach

The control chart approach is applicable in the following circumstances:

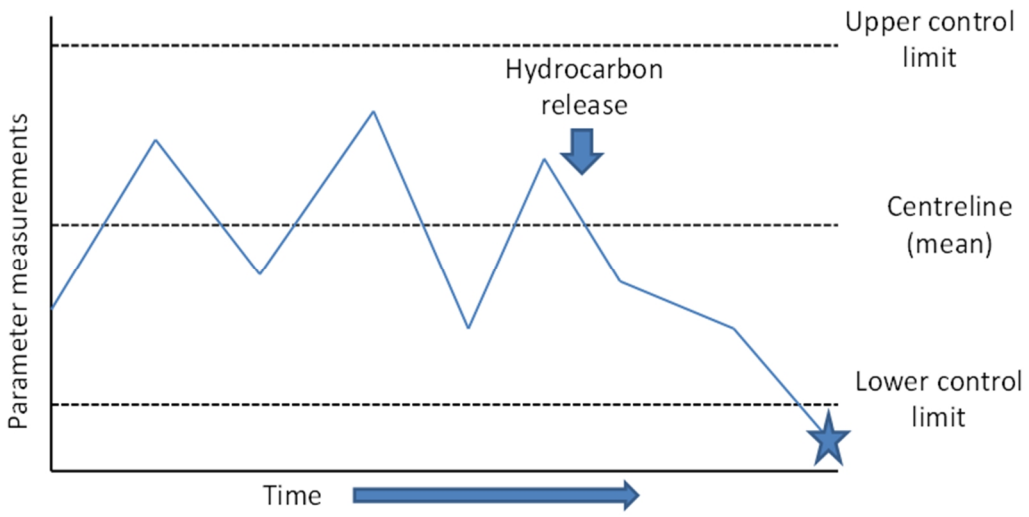
- When long-term (multi-year) datasets exist for the measured parameter;
- When a large amount of natural variation exists in the measured parameter;
- When predicting the expected range of outcomes from an impact.

One of the causal criteria described in the lines of evidence approach is 'strength of association' (Hill 1965), exemplified by a 'larger decline in individuals in areas affected by hydrocarbon than in control areas'. The control chart approach takes this causal criterion a step further and uses rules to establish whether a detected change in a parameter at impact sites is outside what would be expected to occur naturally. This technique requires tracking a parameter over time and determining whether an observed change is within the bounds of what has been observed to occur naturally at that impact site or at control sites.

A control chart has a central line for the mean, an upper control limit (UCL; e.g. typically 3 standard deviations [SD] above the mean), and a lower control limit (LCL; e.g. typically 3SD below the mean), which are typically all determined from historical data (Gotelli and Ellison 2004). The mean line can be constructed using data from i) historical data of an impact site prior to it being affected by hydrocarbons (i.e. what the mean used to be), or ii) control locations, whereby either historical or recent data is used for comparison to other sites (i.e. a control site historical data compared to impact site). The approach is then based on calculating the mean (ongoing) for an impact site to compare against the control chart. Any observations outside the UCL and LCL suggest that increased variation has been observed that are inconsistent with other data and may post a simple way to detect change in a system (Figure A-2).

In addition, if ongoing data collection is possible following a potential impact, the control chart approach can be used to examine the direction of change and whether this is consistent or inconsistent with other data. These data and interpretation may provide a weight of evidence of a directional change in a given parameter.

The control chart approach is only useful if there is an adequate knowledge of natural variability in a given parameter whether from historical sources or similar sites/locations. Control chart approaches can be a powerful tool for detecting impacts for systems that are naturally highly variable.



(Source: APPEA 2019)

Note: The star represents a measurement beyond the likely anticipated variation, which needs to be investigated.

Figure A-2: Example Control Chart showing Centreline (mean), Upper Control Limit (3 SD above mean), Lower Control Limit (3 SD below mean), and Measurements

A. 5. Lines of evidence approach

The lines of evidence approach is applicable in the following circumstances:

- Can be combined with any of the above monitoring designs to provide inferential evidence of an effect;
- Are useful to support evidence of effect if there are limited (or only one) impact locations;
- Are useful to support evidence of effect if the effect radiates outward from source;
- Are useful to infer cause of change if limited or no baseline data exist;
- Are useful to infer cause of change if limited or no control sites exist.

When a sampling design is suboptimal, or if conclusions from more formal tests are inconclusive, a lines of evidence approach can be used to help infer the cause of an observed change (i.e. attribute change to the hydrocarbon release or to other causes, such as natural variation). Within the lines of evidence approach, inference is developed based on carefully structured arguments. A weakness of this method is that the evidence may be largely circumstantial because it is based on correlations (Downes et al. 2002), which does not necessarily imply causation. Each causal argument may be weak when considered independently but combined they may provide strong circumstantial evidence and support for a conclusion (Downes et al. 2002).

This approach was originally developed in medicine (Hill 1965) but has been used more recently in ecological studies (e.g. Downes et al. 2002; McArdle 1996; Suter 1996; Beyers 1998; Fabricius 2004). Causal criteria have been developed for categorizing arguments from studies on disease on humans (Hill 1965), and these can be applied to ecological arguments (Hill 1965). With lines of evidence, there is a need to seek evidence not only to support the impact prediction, but evidence to rule out plausible alternative predictions, such as that the observed difference was due to natural processes (Downes et al. 2002; Beyers 1998).

In the lines of evidence approach, a set of descriptions should be developed for all or some of the causal criteria listed in Table A-1 before the survey is undertaken (see Downes et al. 2002 for further criteria and examples). Data would then be collected that allows each line of evidence to be tested or objectively questioned. The final assessment of whether an impact is likely to have occurred should be based on the 'weight of evidence' from examining multiple lines of evidence.

Example generalised lines of evidence descriptions are provided in Table A-2. These should be modified and tailored to individual scientific monitoring module, as required and each parameter investigated.

Table A-1: Causal criteria and description in the context of ecological impact Assessment

(Source: Hills 1965, in APPEA 2019)

Causal criterion	Description
Strength of association	A large proportion of individuals are affected in the impact area relative to control areas
Consistency of association	The association was observed by other investigators at other times and places
Specificity of association	The effect is diagnostic of exposure
Temporality	Exposure must precede the effect in time
Biological gradient	The risk of effect is a function of magnitude of exposure
Biological plausibility	A plausible mechanism of action links cause and effect
Experimental evidence	A valid experiment provides strong evidence of causation
Coherence	Similar stressors cause similar effects
Analogy	The causal hypothesis does not conflict with existing knowledge of natural history and biology

Table A-2: Causal criteria and example lines of evidence descriptions that could be used to assess whether a change in a measured parameter was due to the effects of a hydrocarbon release

(Source: APPEA 2019)

Causal criterion	Evidence supportive of a hydrocarbon release impact	Evidence unsupportive of a hydrocarbon release impact
Strength of association	Larger decline in individuals in areas affected by hydrocarbon than in control areas	Similar declines in individuals in areas affected by hydrocarbon and control areas
Consistency of association	Consistent finding of declines in a range of biota in areas affected by hydrocarbon	Inconsistent declines in biota in areas affected by hydrocarbon (e.g. declines in one species but not in other similar species)
Specificity of association	Number of individuals affected correlates with hydrocarbon concentrations	No correlation between number of individuals affected and hydrocarbon concentration
Temporality	Decline in individuals immediately preceded by contact with hydrocarbon	Decline in individuals occurred before or long after hydrocarbon contact

Causal criterion	Evidence supportive of a hydrocarbon release impact	Evidence unsupportive of a hydrocarbon release impact
Biological gradient	Changes in individuals aligned with exposure to hydrocarbon spills or concentrations	Decline in individuals occurs with increasing distance from a hydrocarbon spill or hydrocarbon concentrations
Biological plausibility	Evidence from literature of sensitivity to detected hydrocarbon concentration for species where declines are observed	Evidence from literature suggests lack of sensitivity to detected hydrocarbon concentration for species where declines are observed
Experimental evidence	A valid experiment provides strong evidence of causation	Not applicable (N/A)
Coherence	Evidence of a decline in species abundance, habitat, and food source with increasing hydrocarbon exposure	Evidence of a decline in species abundance, but no other evidence of expected declines associated with exposure
Analogy	Apparent declines in hatchling numbers despite no apparent decline in numbers of adults	Apparent declines in hatchling numbers associated with decreased numbers of adults