SUNKEN AND SUBMERGED PLAN

Revision: 1

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ABBREVIATIONS

AOC	Areas of Concern
AUV	Autonomous Underwater Vehicles
CER	Canadian Energy Regulator
CSM	Conceptual Site Model
DFO	Department of Fisheries and Oceans
DGPS	Differential GPS
Dilbit(s)	Diluted Bitumen(s)
DQO	Data Quality Objectives
GAR	Geographic Area of Response
IAP	Incident Action Plan
IMP	Incident Management Plan
IMT	Incident Management Team
IOGP	International Association of Oil & Gas Producers
IOSC	International Oil Spill Conference
IPIECA	International Petroleum Industry Environmental Conservation Association
LAPIO	Low API oil
MSDS	Material Safety Data Sheet
NEBA	Net Environmental Benefit Analysis
NGP	Northern Gateway Pipeline
OMAs	Oil-suspended Particulate Matter Aggregates
OSRP	Oil Spill Response Plan
RO	Response Organization
SCAT	Shoreline Cleanup and Assessment Technique
SRP(s)	Strategic Response Plan(s)
SSO	Sunken and Submerged Oil
TC	Transport Canada
TMEP	Trans Mountain Expansion Project
TMPL	Trans Mountain Pipeline
TSD	Treatment, Storage and Disposal
UC	Unified Command
uSCAT	Underwater Shoreline Assessment
WCMRC	Western Canada Marine Response Corporation

STRATEGIC DOCUMENT CONNECTIVITY

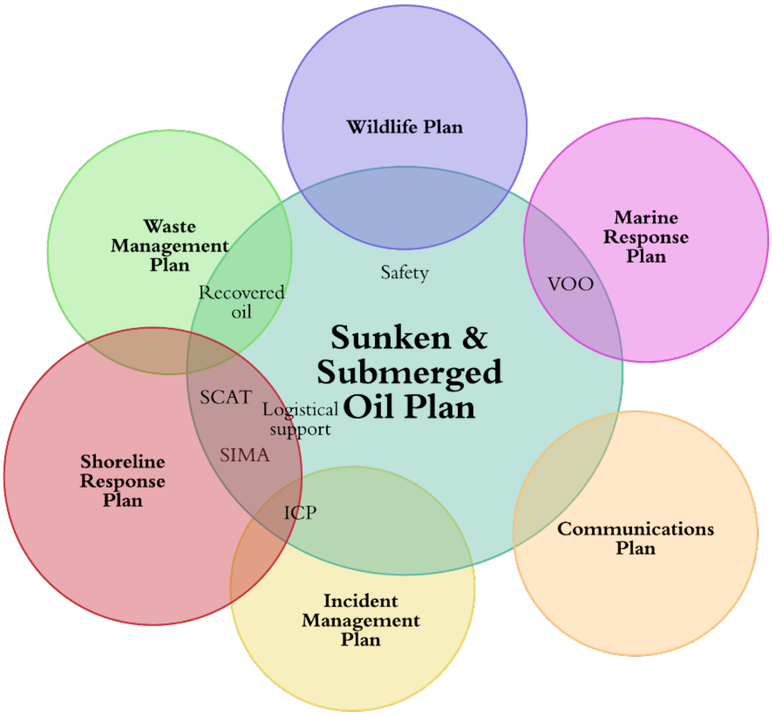

Figure 1 – Representation of the connections between strategic plans and their association to the central plan

TABLE OF CONTENTS

1. INTRODUCTION

This plan is one of multiple Strategic Response Plans (SRPs) which Western Canada Marine Response Corporation (WCMRC) has developed to support its operations, namely:

- Marine Response Plan
- Shoreline Response Plan
- Waste Management Plan
- Wildlife Response Plan
- Sunken & Submerged Oil Plan
- Communications Plan
- Surveillance Plan
- Alternative Countermeasures Plan
- Convergent Volunteer Plan
- Decontamination Plan
- Coastal Response Program
- Vessel of Opportunity Program
- Staging Area Program
- Tier 5 Operational Response Plan

These plans cover all major areas of response operations and aim to support WCMRC in identifying:

- The appropriate incident management structure and response organization for the applicable response strategy
- The likely resource requirements
- The likely logistical and support requirements.

As illustrated by Figure 2, all SRPs listed above are underpinned by the principles and response methodology outlined in the WCMRC Incident Management Plan (IMP) and wider response fundamentals outlined in the WCMRC Oil Spill Response Plan (OSRP).

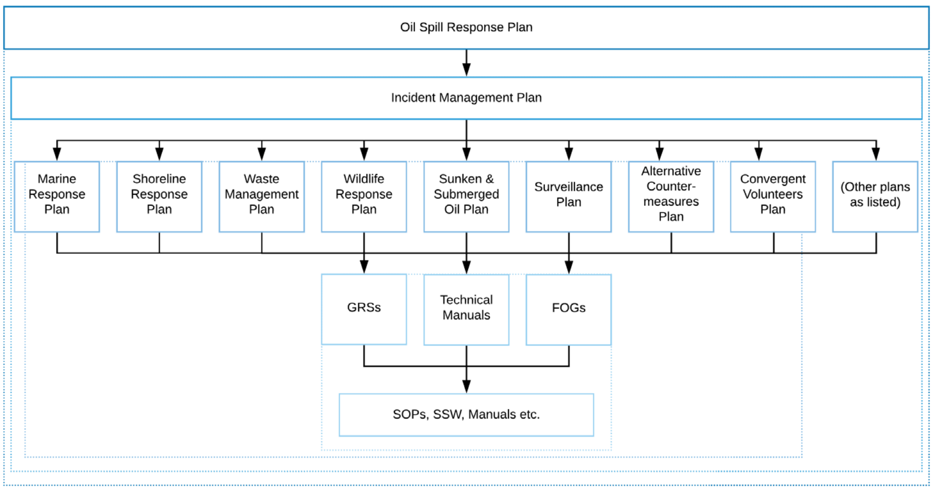

Figure 2 – WCMRC response documentation framework and hierarchical plan linkage

There are also several technical manuals in place which assist with implementing the strategies outlined in each SRP. The following technical manuals are relevant to this SRP and are used by WCMRC to enact the measures outlined in this plan:

- At Sea Containment and Recovery
- Underwater Shoreline Assessment (uSCAT)
- Dispersants and In-Situ Burning (strategy not currently undertaken by WCMRC).

Additional technical manuals which may be referred to in support of operations are:

- Wildlife Response
- Waste management
- Spill Impact Mitigation Assessment [SIMA] (previously Net Environmental Benefit Analysis (NEBA))
- Logistics.

1.1 PURPOSE

While WCMRC's primary mission is the containment, recovery and disposal of surface oil slicks, this document recognizes there is potential to encounter submerged or sunken oils during an oil spill response. Early awareness of this contingent situation will improve the response performance. It is nevertheless important to recognize that in the case of oil that has submerged or sunk, no detection and recovery methods have proven to be universally effective or efficient (Owens, 2013).

The purpose of this document is to demonstrate WCMRC's level of capability by:

- Describing the resources required for different response strategies for sunken and submerged oil (SSO)
- Describing how WCMRC will implement those response strategies (thereby demonstrating a response capability which meets Canadian Energy Regulator [CER] and Transport Canada [TC] requirements)
- Describing the framework WCMRC will establish to manage SSO response operations.

1.2 USE

This plan should be used by WCMRC personnel to, as effectively and efficiently as possible, establish and enact SSO identification strategies appropriate to the requirements of the incident and in line with CER requirements. It provides a clear guidance on choosing response organization structure and response techniques but can also be used as a reference tool for assessing how likely oil is to sink/submerge as a result of a release. This plan is an operational document and as such acts as a guide to establishing SSO response activities in the 24-48 hours which follow initial notification of an incident, particularly when escalating to a Level 2/3 response (see Section 3). This plan does cover specific tasks and arrangements required during the SSO response operations nor does it cover operations as they move into the 'project phase' as sites become established for long term recovery.

This SRP is applicable to all WCMRC response personnel at strategic level and above and is shared internally as 'required reading'. This ensures all response personnel are aware of the procedures and guidance which have been put in place to ensure any response is conducted in accordance with that described in the OSRP.

1.3 BACKGROUND

In the event of an oil spill, the pollutant often remains on the surface of the water and requires established on-water containment and recovery and shoreline response operations to mitigate its effects. There are, however, instances where oil will not float on the surface and enter the water column by various means (as outlined in Section 2.3).

It may be that the material released is 'heavier than water' and the risk of SSO is immediately identified, but oil may also become weathered over time or sediments entrained causing oil which initially presents as 'on the surface' increasing in density and becoming SSO.

Oil which is not floating on the surface of the water, is not awash/over washed as a result of wave movement and is not stranded/deposited on the shoreline is defined as SSO. For the purposes of this plan, WCMRC has defined SSO using the Coastal & Ocean Resources uSCAT Technical Reference Manual (which is referred to throughout this plan).

The Coastal & Ocean Resources uSCAT Technical Reference Manual defines SSO as follows:

- **Non-floating oil:** Oil that is below the water's surface (negatively buoyant) and is either suspended within the water column or has sunk to the seabed. It describes (a) oils that submerge due to their densities being greater than that than of the receiving water, (b) oils that are suspended in the water column though turbulence, (c) oils that are neutrally buoyant and move within the water column, and (d) oil that has entrained sediment and becomes submerged or sunken.

- **Submerged oil:** Oil below the surface of the water that is suspended within the water column. This includes oils that are neutrally or slightly positively buoyant and that are temporarily submerged below the surface due to wave or current action.

- **Sunken oil:** Oil that resides at or in the seabed/sediment-water interface.

- **Buried oil:** Oil that is incorporated with seabed sediments.

The response methodology utilized in identifying and mitigating the impact of SSO is often less explicitly covered in oil spill response planning, but the threat is poses must be given equal weight to that of other environmental concerns. This being the case, WCRMC has developed a dedicated SSO plan which outlines the techniques it will use to consider the threat of SSO and respond accordingly in the event of a release.

1.3.1 CONCERN WITH SUBMERGED OR SUNKEN OIL

Floating oil exhibits readily observable behavior through weathering in a combined reaction to gravity and environment factors. Such behaviors occur as the slick thins and reforms into streamers, windrows, patches, tarballs and sheens (NOAA, 2012). Conversely, oil that has entered the water column is not easily observed and any further weathering or changes to the oil takes place out of sight of responders and those tasked with observing the oil spill's fate and behaviour.

While most oils transported at sea float when spilled on water there is a potential for many oils to enter the water column through weathering and other means, such as sediment adhesion/entrainment.

Oil mixing with sediment is of particular concern for WCMRC given the geography of the BC coastline and its rivers. As oil washes towards a shoreline or enters a surf zone, the risk of sediment entraining increases due to wave action and suspended sediment in these areas. Oil Mineral Aggregation may also occur, meaning that finer sediment particles have adhered to oil droplets and effected their buoyancy. Oil in these areas may also be washed on to the shoreline and mix with beach sediment before becoming stranded.

Oils that are denser than the receiving water (such as oil slurries and asphalts) will generally sink immediately when spilled, although some heavy oils and residual oils may initially float but submerge or sink as a result of weathering.

The means by which SSO may form is covered in more detail in Section 2.3.3.

Oil that has entered the water column by any means cannot be effectively monitored, contained or recovered using 'traditional' oil spill response techniques and requires a specified approach and subset of response strategies and techniques as outlined in this plan.

2. ESTABLISHING THE RESPONSE

2.1 SSO RESPONSE PROCESS

The steps shown in Figure 3 and detailed in the following sections outline the process used by WCMRC for SSO response. This process is taken from the Coastal and Ocean Resources uSCAT Guide: Underwater Seabed Cleanup Assessment Technique for Sunken Oil[1] which is reference throughout this plan in conjunction with the associated uSCAT Technical Reference Manual[2].

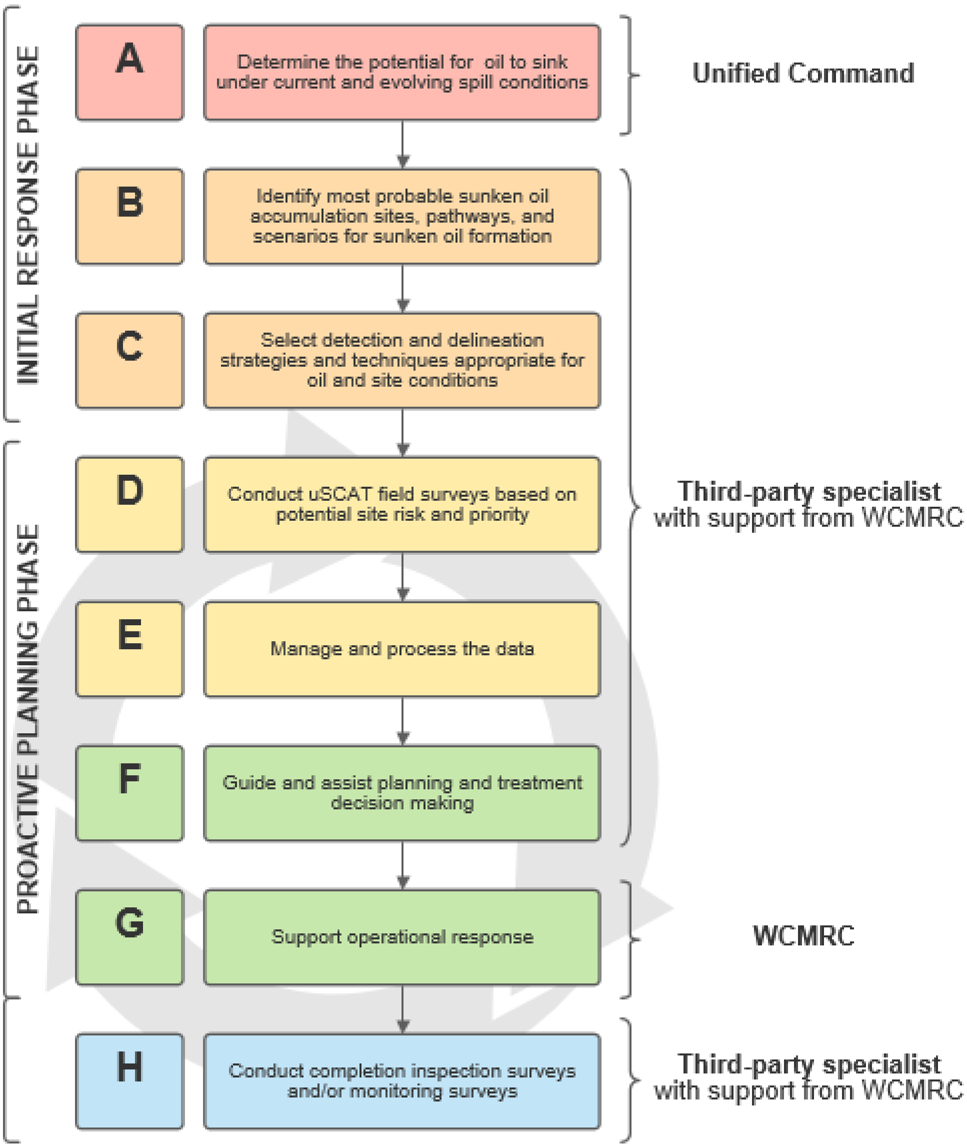

Figure 3 – SSO response process (based on the Coastal and Ocean Resources uSCAT Guide 'uSCAT process overview')

In the context of the Incident Command System, **steps A to C of this process should be taken as part of the initial response phase and include immediate mobilisation of a third-party**

[1] Harper, J.R., G. Sergy and L.A.S. Britton 2019. uSCAT Guide: Underwater Seabed Cleanup Assessment Technique for Sunken Oil prepared by Coastal & Ocean Resources, Victoria, BC, 45p + appendices. www.uscat.ca

[2] Harper, J.R., G. Sergy and L.A.S. Britton 2018. uSCAT Technical Reference Manual: Underwater Seabed Cleanup Assessment Technique for Sunken Oil. Technical Report prepared by Coastal & Ocean Resources, Victoria, BC, 99p + appendices. www.uscat.ca

specialist (Section 2.1.1). All existing data on the pollutant and likely areas of accumulation will be requested from the Polluter by WCMRC so SCAT/uSCAT planning can begin.

2.1.1 THIRD-PARTY SSO SPECIALIST

In order to ensure that the SSO response process are enacted fully and effectively, WCMRC will engage with a specialist third-party contractor who will conduct all tactical operations specific to SSO. WCMRC will, wherever possible, provide the third-party SSO specialist with marine and logistical support to the best of their ability in pursuit of mitigating the effects of a spill and of SSO.

This arrangement has allowed WCRMC to develop an SSO strategic response plan based on best-practice and specialist capabilities. The engagement and the early mobilisation of a specialist forms a key part of WCMRC's overall SSO response strategy and allows WCMRC to respond in accordance with the requirements of this plan.

The third-party SSO specialist recommended and/or activated by WCMRC will be capable of conducting tactical SSO response operations safely, responsibly and effectively following a robust assessment, audit and verification process.

2.2 POLICY AND PRINCIPLES

The primary mission of WCMRC is to respond to floating oil spills on the navigable waters of British Columbia. Within their Geographic Area of Response (GAR), WCMRC has evaluated the risk of a submerged or sunken oil spill from the products shipped, the environmental conditions present in the GAR and the anticipated time it may take for a spilled product to exhibit submerged and sinking behaviour. Research has affirmed that high persistence heavy oils, those at the greatest risk of behaving in a non-floating manner, also offer the best potential encounter rates for on-water skimming (Peigne, 2009). As such, **strategically, it is WCMRC's policy to focus on early and efficient on-water containment and recovery to prevent floating oil from becoming submerged or sunken oil.** The operational actions of this policy follow four widely accepted response principles:

- Control the source of the spill,
- Prevent the released oil from spreading,
- Contain, intercept and promptly recover oil from the water surface,
- Remove oil stranded on the shoreline oil before it can be remobilized,
- Protect sensitive areas including wildlife habitat.

Notwithstanding this, WCMRC recognizes that it is important to match response planning to the risks posed by submerged or sunken oils.

2.3 POTENTIAL FOR SPILLED OIL TO SUBMERGE OR SINK

2.3.1 OIL DENSITY

Whether spilled oil floats on top of water or sinks depends on the initial density of the spilled oil in comparison to the density of the receiving environment. Most hydrocarbon oils, whether crude or refined, have a specific gravity of < 1.0 (API gravity of > 10.0°) and will float in fresh water. For example:

Table 1 – Characteristics of different oil types

Oil Type	Gravity (°API)	Density (kg/m3)
Light crude	> 31.1	< 870
Medium oil	22.3 - 31.1	870 - 920
Heavy crude	10 - 22.3	920 - 1000
Extra heavy crude	< 10	> 1000
Bunker C fuel oil	4.56 - 15	960 -221040
Diluted Bitumen (Dilbit)	20.5 - 21.9	921 - 930

Products	Specific Gravity
Naphtha light	0.66-0.70
Naphtha medium	0.70-0.75
Aviation gasoline	0.70-0.78
Kerosene	0.71-0.79
Naphtha heavy	0.75-0.80
Gas oil	0.78-0.86
Crude oil	0.80-0.97
Diesel oil	0.82-0.90
Lubricating oil	0.82-0.92
Diluted Bitumen	0.92-0.93
Fuel oil	0.92-0.99
Bunker C fuel oil	0.96 – 1.04
Asphaltic bitumen	1.00-1.10

Figure 4 – A naturally occurring heavy crude oil seep collects on the bottom. Source: NOAA

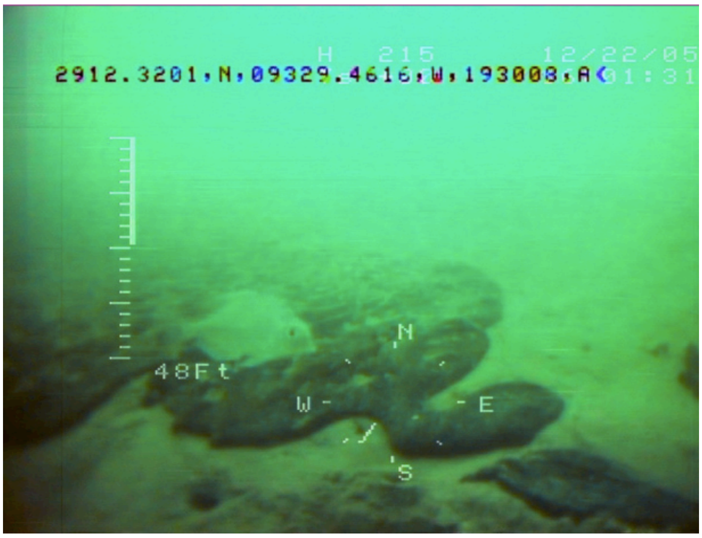

Figure 5 – Geo-referenced ROV image of a sunken slurry oil mat following the DBL-152 spill. Source: NOAA

2.3.2 OIL GROUPING AND PERSISTENCE

The processes of spreading, evaporation, dispersion, emulsification and dissolution are most important during the early stages of a spill whilst oxidation, sedimentation and biodegradation are more important later on and determine the ultimate fate of the oil.
Studies show that the main properties affecting the fate of spilled oil at sea are specific gravity (its density relative to pure water); distillation characteristics (its volatility); viscosity (its resistance to flow); and pour point (the temperature below which it will not flow). In addition, the wax and asphaltene content influence the likelihood that the oil will mix with water to form a water-in-oil emulsion. Oils that form stable oil-in-water emulsions persist longer at the water surface. The resin and asphaltene content determine the likelihood of tar-ball formation.

Oil persistence is often used to classify oils for transportation and allocate resources during an oil spill response. In simple terms, less persistent oils once spilled are expected to remain in the

environment for lesser time that higher persistence oils. This has led to the terms persistent and non-persistent oils within the shipping, oil response and insurance industries.
Some simple grouping has been developed based on oil type according to their density - generally, oils with a lower density will be less persistent. However, some light oils can behave more like heavy ones due to the presence of waxes.

- Group I oils (non-persistent) tend to dissipate completely through evaporation within a few hours and do not normally form emulsions.
- Group II and III oils can lose up to 40 per cent by volume through evaporation but, because of their tendency to form viscous emulsions, there is an initial volume increase as well as a curtailment of natural dispersion, particularly in the case of Group III oils.
- Group IV oils are very persistent due to their lack of volatile material and high viscosity, which preclude both evaporation and dispersion (Table 2).

Table 2 – Group I to IV Oils. Source: Government of United States 2013

Group	Density	Examples
Group I	less than 0.8	Gasoline, Kerosene
Group II	0.8 to 0.85	Gas Oil, Abu Dhabi Crude
Group III	0.85 to 0.95	Arabian Light Crude, North Sea Crude Oils (e.g., Forties), diluted bitumen shipped on TMPL and from the Westridge Marine Terminal
Group IV	greater than 0.95	Heavy Fuel, Venezuelan Crude Oils

For most oils once the competing process of emulsification has been considered there would be an increase in volume in the short term. Response organizations take the emulsification phenomenon into account when developing response plans and defining equipment requirements.

There is often mention of a fifth classification, termed Group V that is meant to collectively classify oils whose density is higher than that of fresh water, and even of a density higher than that of sea water and thus liable to sink once spilled to the sea.

2.3.2.1 HEAVY OILS AND DILUTED BITUMEN

The marine transportation of varieties of heavy crude oils, including diluted bitumen such as Cold Blend and Access Western Blend, has become a matter of potential concern for certain Indigenous groups and coastal communities. While WCMRC is not a research organization, it has been following the various published research, both from government scientists and industry on the fate and behaviour of these types of oil. In 2013, WCMRC participated in the field testing of different types of skimmers on the recovery of weathered diluted bitumen (Gainford, 2013). WCMRC did not observe any issues with the recovery of the oil/s at various stages of weathering using the skimmers that were tested at Gainford, which were similar to ones already in WCMRC’s inventory. More skimmers of similar type are to be procured under the enhanced response regime.

In the 2016 CER report on the Trans Mountain Expansion Project, the CER observed that:

- After initial weathering, diluted bitumen behaves similar to other heavy crude oils and common heavy fuel oils;
- The weight of the evidence indicates that any sinking would likely be in limited quantities and only after sufficient weathering over a period of days or interaction with sediment and other organic matter under the right environmental conditions; and,

- Depending on weathering state and environmental conditions, spilled diluted bitumen could be prone to submergence in an aquatic environment and this potential for submergence must be considered in response planning

2.3.3 POTENTIAL PATHWAYS FOR OIL SPILLS TO SUBMERGE OR SINK

After release into water, there are two possible pathways for the oil to enter the water column. While lighter components of hydrocarbons will begin to evaporate, some will dissolve into the water column through a process known as dissolution. The remainder will float as long as the density of the remaining oil is less than the density of the water into which it was released. Wave action can cause water-in-oil emulsions, which will drive the mixture towards neutral buoyancy. Adhesion to bottom sediment (e.g., beaches, riverbeds) or other sinking material can cause the oil to be submerged.

Table 3 – Potential Pathways for Oil Spills

Pathway	Description
Dissolution	Water soluble compounds in oil may dissolve into the surrounding water. This depends on the composition and state of the oil and occurs most quickly when the oil is finely dispersed in the water column. Components that are most soluble in seawater are the light aromatic hydrocarbons compounds such as benzene and toluene. However, these compounds are also those first to be lost through evaporation, a process that is 10 to 100 times faster than dissolution.
Oil-suspended Particulate Matter Aggregates (OMAs)	Crude oils (even those considered as "heavy") are normally less dense than freshwater and seawater, which has a density of approximately 1.025 g/cm3. However, changes in density during weathering and exposure to fine sediment in the presence of high mixing energy are key factors in causing certain oils to submerge and possibly sink. In the process, suspended matter (particles of sediment or organic matter) already in the water could interact and adhere to the weathered oil forming oil-suspended particulate matter aggregates (OMAs), which are generally sufficiently dense that they sink. The sediment in such cases must generally be fine-grained and of moderately high concentration. The energy for the formation of these aggregates is generally derived from breaking waves, but turbulent flow in a river could also facilitate formation of these aggregates. Since shallow waters are often laden with suspended solids, the formation of OMA at sea is more likely near the shoreline.
Sediment Entrainment in the Surf Zone	As oil washes towards the shore it is at risk of entraining sediment in the surf zone. When buoyant oil is mixed into the water column by wave action and interacts with suspended sediments, sediment may become entrained into the oil creating a mixture that is denser than the receiving water. Once sunk, oil will either migrate to a collection point or will become buried in nearshore sediments.
Sinking of Stranded Oil	In addition, oil stranded on sandy shorelines often becomes mixed with sand and other sediments. If this mixture is subsequently washed off the beach back into the sea it may then sink. In addition, if the oil catches fire or is ignited after it has been spilled, the residues that sometimes form can be sufficiently dense to sink.

Further information on factors affecting sinking potential and the sources of SSO is available in the Coastal & Ocean Resources uSCAT Technical Reference Manual.

2.3.4 POTENTIAL CONCERNS

Submerged or sunken oil has the potential to travel unseen under the influence of currents to other locations from the main spill site and pose potential both environmental and economic impacts should they disappear only to reappear later in sensitive areas (Fitzpatrick, 2013). Heavy oil that has sunk to the bottom remains bioavailable to aquatic life for long periods due to its slow degradation (Fingas, 2015). However, Fortunately, inorganic SPM (Suspended Particulate Matter) loads in the open ocean are usually less than a few mg/l, so it can be concluded that oil/SPM interactions during most open-ocean oil spills are generally insignificant. However, localized sedimentation can occur in regions along coastlines where sandy beaches and higher SPM loads might be encountered (Payne et al, 2003).

2.3.4.1 AREAS OF CONCERN

A 2019 study[3] into the fate of oil (namely diluted bitumen and fuel oil) spilled on the BC coastline has indicated that lower Fraser River and its plume in the Strait of Georgia, particularly during freshet in the spring/early summer, and fjords such as Kitimat Arm are areas of particular concern, especially following heavy rainfall.

Table 4 – Potential concerns of Sunken and Submerged Oil

Subject	Concerns
Riverine vs. Marine Environments	Riverine environments typically experience seasonal flow fluctuations with high flow periods characterized by increases in turbulent energy. Riverine current speeds are a function of a drop in course elevation augmented by the volume of influent water entering the system. Regardless of the flow intensity, there will always be impoundments along the course where submerged or sunken oil could settle and collect. The formation of OMA in the Salish Sea and the Lower Fraser River is highly unlikely, even during freshet conditions (Hospital et al, 2016). However, it should be noted that under river flood conditions, during which water levels rise and flood a wetland or flood plain, for instance, spilled oil would have many opportunities to pick up significant organic debris. The resulting aggregate could be a significant factor in the fate of the oil. Additionally, there could be conditions under which oil may stick to a substrate and remain sunk, which could be mistakenly attributed to OMA formation by observers. For example, oil reaching a beach or mud flat, becoming stranded and remaining stuck to the soil/sand even when the tide comes in. The high adhesive qualities of weathered oils such as dilbit make this a likely significant process at shorelines, riverbanks and intertidal flats (Hospital et al, 2016).
Nearshore vs. Confined Channels vs. Open Water	In the nearshore environment, boundary currents can act on floating oil to sequester it close to the shoreline where it can be influenced by breaking waves and suspended sand (Owens et al., 1985). Oil trapped in this area typically strands on the beach and may engage in a cycle of erosion and accretion. Nearshore sunken oil may readily be identified by (Shoreline Cleanup and Assessment Technique) SCAT team observers and recovered through simple manual and mechanical methods. Oil that has submerged or sunk in a confined channel has the benefit of a minimal level of geologic containment potentially increasing detection and recovery subject to water depth. Certain areas of Burrard Inlet present confined channel characteristics. Submerged oil in open water represent the more difficult response situation given the unconfined environment.
Depth Limitations	Limitations on detection and recovery imposed by depth are concerns because at some depth it will be technologically unfeasible or operationally impractical to detect and mitigate submerged or sunken oil depositions. In general, detection technologies have less depth limitation than recovery methods.
Remobilization	Changes in density and viscosity, as a result of environmental factors, can affect the buoyancy of oil in the water column, which may cause remobilization of sunken and sequestered oil, especially if there is possibility of lag time between detection and recovery.
Burial	Oil that has sunk to the bottom, in both the nearshore zone and the offshore zone, is subject to burial by naturally deposited sediments. While burial arrests, at least temporarily, the problem of remobilization, it makes detection more difficult. Further, if recovery is feasible, the incidental deposits covering the sunken oil contribute to the waste stream.
Detection	There are a variety of remote sensing techniques that can be used to detect submerged or sunken oil. However, the process of detecting submerged or sunken oil is typically time consuming because of the spatial dimensions and because of the need to reverify each initial detection. This is often reflected by a disproportionate amount of time that could be consumed by detection before recovery operations can commence.

2.3.5 RISK ASSESSMENT

The methodology used to quantify the likelihood and severity of SSO pollution is outlined in Section 4.1 of this plan as a risk assessment process. This process is used by WCMRC as a decision-making tool when considering the requirement for a large-scale SSO response.

[3] Johannessena, S.C., C.W. Greerb, C.G. Hannaha, T.L. Kingc, K. Leed, R. Pawlowicze and C. A. Wright 2019. Marine Pollution Bulletin: Fate of diluted bitumen spilled in the coastal waters of British Columbia, Canada prepared by Fisheries and Oceans Canada, the National Research Council Canada and the University of British Columbia, 12 p + appendices www.elsevier.com/locate/marpolbul

3. RESPONSE STRUCTURE

3.1 SCALE OF RESPONSE

In the initial stages of a response, WCMRC will use the methodology outlined in the IMP to assess the requirements of the incident and select the appropriate response level based on incident complexity and Polluter requirement.

Generally speaking, for small scale and less complex incidents a core 'Level 1' response organization (Figure 6) is sufficient in meeting the requirements of the incident.

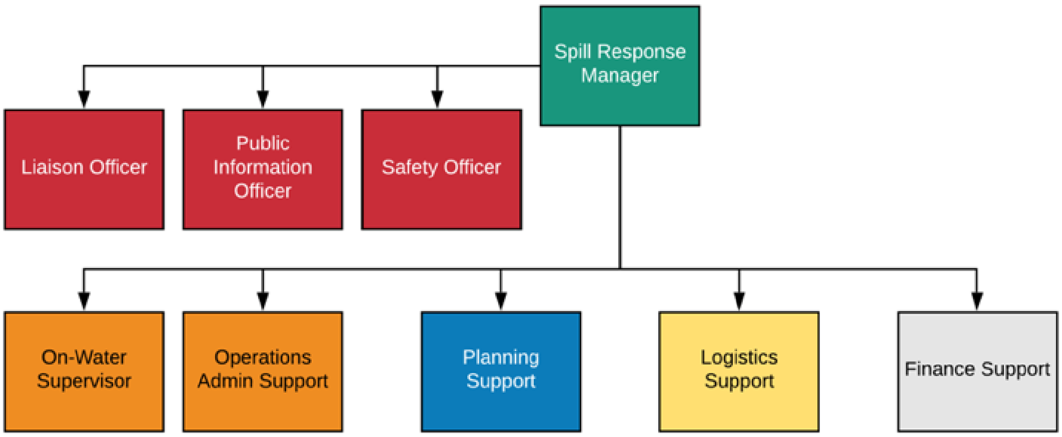

Figure 6 – Recommended Initial IMT Organization: Essential Response ('Level 1')

For larger and more complex incidents, a 'enhanced' or 'expanded' response organization (Figure 7) is likely to be required. Given the additional complexity factors, Polluter requirements and/or limitations and constraints which impact the required scale of response, IMS functions specific to the nature of the incident will be required. It is within these 'enhanced' and 'expanded' response organizations that functions specific to SSO response will be established.

It should be noted that **the presence or potential presence of SSO is an indication that the scale of response should be escalated**, given that SSO is likely to be a characteristic of a larger, more complex incident. This being the case, **it is strongly recommended that, in cases where a risk assessment deems the likelihood of SSO to be moderate or high, an 'enhanced' or 'expanded' response organization is mobilized immediately.**

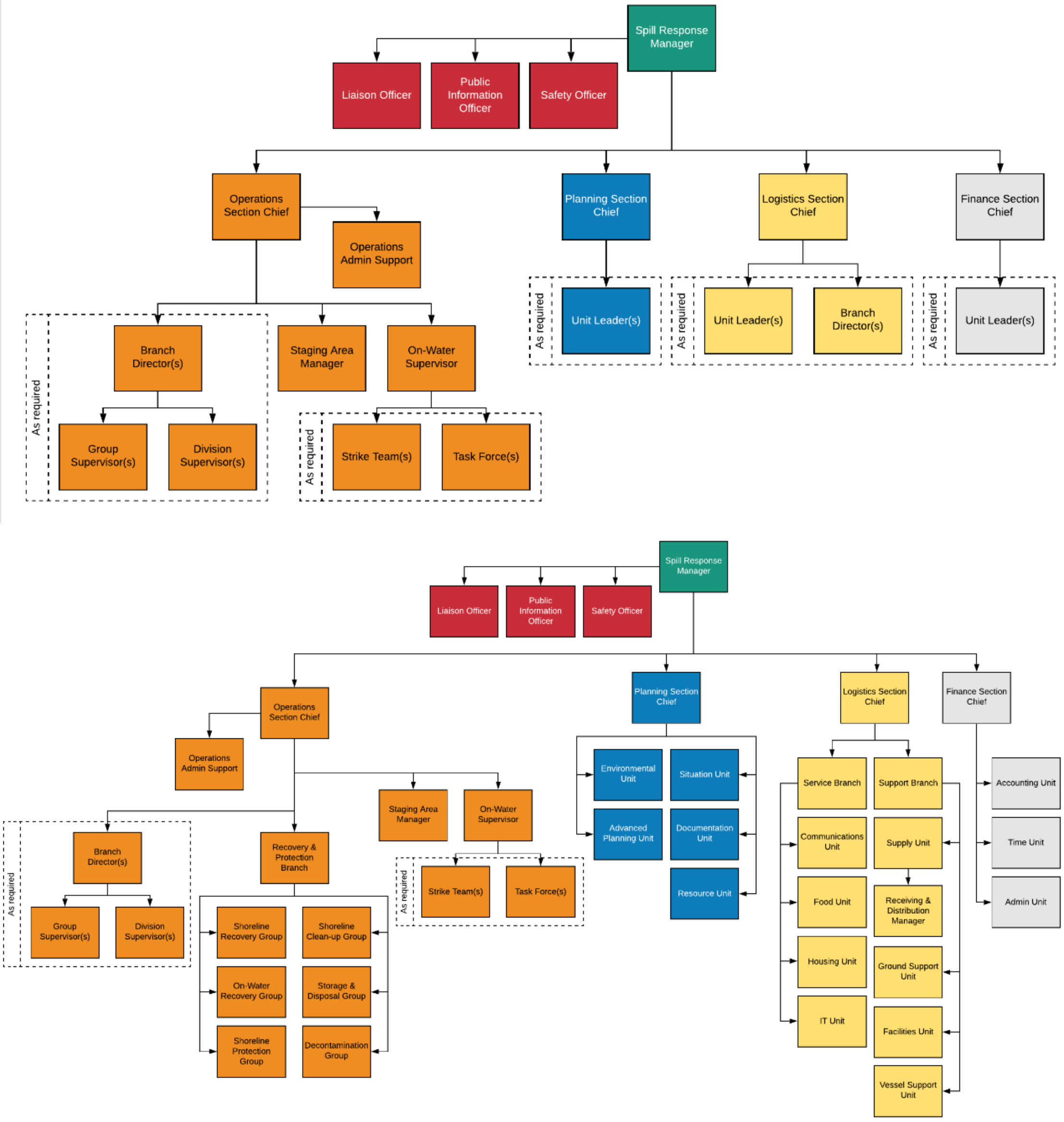

Figure 7 – Recommended Initial IMT Organizations: Enhanced Response ('Level 2') and Expanded Response ('Level 3')

3.2 IMT FUNCTIONS FOR SSO

The ICS Functions outlined in Table 5 are key to conducting successful SSO operations and are therefore likely to be required as part of an enhanced or expanded response organization. As outlined in Section 3.1, the response requirements of SSO are likely to be a characteristic of a larger, more complex incident (i.e. an associated 'on-water' spill) therefore the roles listed in this section encompass the requirements of shoreline response in addition those specific to SSO response.

During a response where the potential for SSO has been identified, the Environment Unit Leader has the critical role of overseeing the establishment of effective SCAT/uSCAT programs, implemented by dedicated SCAT/uSCAT Coordinators and carried out by the respective Groups within the Operations Section.

3.2.1 SCAT AND USCAT RELATIONSHIP

Shoreline Clean-up Assessment Technique (SCAT) surveys provide information to build a spatial or geographic picture of the regional and local shoreline type and oiling conditions. SCAT teams can recommend appropriate clean-up methods and to define constraints or limitations on the application of clean-up techniques, so that the treatment operations do not result in additional damage to the shoreline. This information is provided in a format that can be interpreted easily and applied by planners and decision makers.

Underwater Seabed Cleanup Assessment Technique (uSCAT) is a process which applies the principles and practices of traditional shoreline SCAT, specific to the requires of SSO. Given this close relationship SCAT and uSCAT, it is likely that both activities will be carried out simultaneously and thus managed by a single SCAT Program Manager who is support by dedicated SCAT and uSCAT Coordinators.

See the WCMRC Shoreline Response Plan for more information on SCAT surveys and techniques. Further information on uSCAT Is available in the Coastal and Ocean Resources uSCAT Technical Reference Manual referenced in Section 2.1.

Complete job aids and checklists for all IMT functions listed in Table 5 are contained within tactical plans and supporting documentation (e.g. 'handbooks') as part of the WCMRC document hierarchy outlined in Section 0.

Table 5 – Key IMT functions for SSO Response

Position/Section	Sunken & Submerged Oil Response Role
Initial Response Phase	
On-Scene Supervisor	**Begin initial assessment of spill and provide IMT with any required environmental information from the scene**
Operations Section	
Recovery and Protection Branch	Oversee and implement the protection, containment and cleanup activities established in the IAP.
Shoreline Recovery Group	Establish shoreline response sites as required
Shoreline Clean-up Group	Oversee and manage all shoreline clean-up operations as required
Shoreline Protection Group	Responsible for the deployment of containment, deflection, and adsorbent/absorbent materials in designated locations
Sunken & Submerged Oil Group	Complete surveys and collect the necessary data under the technical direction of a team leader (a combination of experts from third-party specialists and stakeholders). Conduct recovery operations of sunken and submerged oil.
Staging Area Manager	Manages staging areas for equipment to be used for SSO response.
Air Operations Branch	Aerial surveillance – assess extent and severity of oiling (together with SCAT/uSCAT Coordinator)
Planning Section	
Environment Unit	Assessment of environmental implications of response options/strategies
Environment Unit Leader	Determines the need (or potential need) to implement and subsequently monitor a SCAT/uSCAT Program
Sunken Oil Technical Advisory Group	Assist the Environment Unit Leader and SCAT Program Manager with the development and implementation of a uSCAT program and provide specialist technical advice where required
SCAT Program Manager	In charge of all SCAT and uSCAT activities
SCAT/uSCAT Data Manager	Receive and synthesise all data from survey teams and prepare as presentation for Unified Command
SCAT/uSCAT Coordinator(s)	Ensure SCAT/uSCAT surveys are conducted in appropriate locations and a timely manner followed by assessment of the information provided
SCAT/uSCAT Operations Liaison	Ensures that field operations fully understand the recommendations, objectives, and constraints of the SCAT/uSCAT program so that any questions and concerns can be addressed directly
Resources Unit	Maintaining the status of all assigned tactical resources and personnel
Situation Unit	Ensure all spill information is recorded to facilitate spill decision making
Logistics Section	

Service Branch	Management of all service activities (e.g. communications, food, medical provision etc.)
Supply Unit	Ensure distribution of all supplies for the incident and maintaining an inventory
Faculties Unit	Ensure set-up, maintenance and demobilization of incident facilities
Vessel Support Unit	Support third-party specialist with marine-based resources
Ground Support Unit	Repair of primary tactical equipment, vehicles, mobile ground support equipment and fuelling services; transportation of personnel, supplies, food and equipment in support of incident operations
Finance Section	
Accounting Unit	Ensure all costs recorded

3.3 ROLE OF RESPONSE ORGANIZATION (RO)

It is expected that the RO will initially be mobilized to recover floating oil within an organized Incident Command Structure under a Unified Command (UC). Unless it is immediately apparent that the spilled oil is submerging or sinking due to initial higher than water density of the oil, submerged or sunken oil should be recognized as a contingency, where appropriate, but remain subordinate to the floating oil response until directed otherwise by UC. Should it be required, being at the scene, it is reasonable to assume that the RO will act as the initial submerged and sunken oil response lead. Later, as the incident command structure expands, organizational depth might be added to assign dedicated personnel and resources to the task of submerged or sunken oil management. Because WCMRC's expertise is on floating oil response, other advisors and experts on managing submerged and sunken oil are available to WCMRC on contract (see Section 3.3.1). Similarly, while certain equipment may be held in inventory at WCMRC, other extra assets will likely be sourced through third parties who act under the direction of the RO. Spill dynamics could also modify this arrangement by relegating the submerged or sunken oil response out of the incident emergency phase and into a post action remedial phase. Nevertheless, because of WCMRC's overall expertise in countermeasures, logistics and project management, it is probable that their involvement in submerged or sunken oil mitigation could be prolonged.

3.3.1 ROLE OF THE THIRD-PARTY SPECIALIST

As outlined in Section 2.1.1, WCMRC will employ/recommend the services of a third-party SSO specialist in the event of SSO being identified as medium or high risk. This requirement has been identified given the specific technical requirements of uSCAT and the challenges posed by SSO response more generally.

By leveraging the specialist capability of a third-party, WCMRC can effectively support the Polluter in the event of SSO and respond in accordance with the best-practice strategy outlined in this plan.

3.4 ROLE OF UNIFIED COMMAND (UC)

Regardless of the Tier classification and volume of oil discharged, a full Unified Command (UC) within an Incident Command Structure should be stood up as soon as possible in case of anything other than a minor oil spill. UC should be urgently stood in case there is a potential to encounter submerged or sunken oil. This organizational structure is designed to address a spill as a single problem drawing resources from many providers including government, industry, the Polluter, and of course, WCMRC. Integrated into this structure will be the multi-agency Environmental Emergencies Science Table ("Science Table").

3.5 ROLE OF THE SCIENCE TABLE

The Environmental Emergencies Science Table (the "Science Table") can be convened to provide advice to the lead agency and UC as part of the ICS response. The Science Table brings together relevant experts in the field of environmental protection such as response agencies, all levels of government, Aboriginal representatives, local communities, industries, environmental non-government organizations, and academic institutions.

The Science Table of experts would be expected to develop consensus on protection and cleanup priorities, bring the right expertise, adapt the scale of response to the particular environmental emergency, and provide a forum for rapidly moving information to minimize damage to human life or health, or the environment and wildlife while maximizing the use of limited response resources. These discussions can occur on-site, or by telephone or videoconference. The Science Table subject matter experts focused on public health and environmental protection will be influential in first setting up SAP and then weighing the environmental cost/benefit of various countermeasures to be used in combating both floating and submerged or sunken oil

3.6 ROLE OF POLLUTER

In Canada, overall responsibility for an environmental emergency falls on the polluter or Polluter. The law is very clear on this point and Environment and Climate Change Canada has stated: "When an emergency occurs, the Polluter is required to take all reasonable measures to contain and stop the release and notify authorities for which they are regulated. In line with the polluter pays principle, the Polluter is required to assume all costs related to response and recovery of the affected environment." The Polluter's efforts to mitigate the spill will be overseen by federal and provincial agencies. While some Polluters have well-developed spill management teams it is likely that the majority of the cleanup effort, both in the field and in the command center, will be undertaken by WCMRC on behalf of the RP. Thus, from a practical standpoint, the Polluter will fund the response (unless there is an insolvency issue) and defer to WCMRC's expertise on spill management and countermeasure implementation.

3.7 EXAMPLE ORGANIZATION INCLUDING SSO RESPONSE

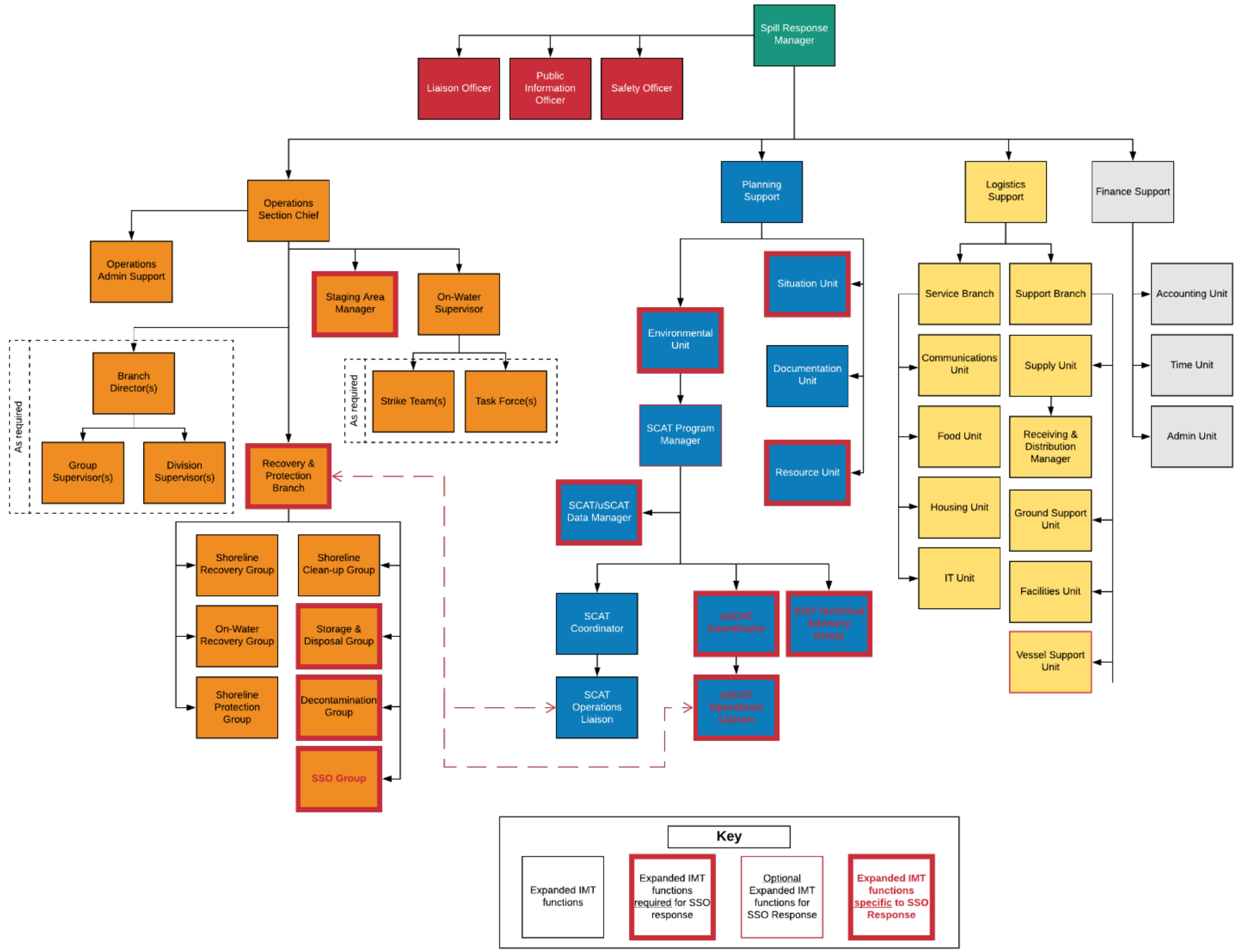

Figure 8 – Expanded IMT response organization showing functions required to carry out SSO response (as part of wider shoreline response structure)

4. RESPONSE STRATEGIES

4.1 RISK ASSESSMENT

The risk of SSO is assessed in two parts, potentially high-risk products are sampled prior to a spill and then again following a spill in comparison to the density of the polluted waters. If the density of the sampled oil exceeds that of the water, it will sink. If the density of the oil is close to that of the water, it may still sink as a result of weathering/sediment entrainment.

4.1.1 SINKING OIL RISK ASSESSMENT TOOL

A Sinking Oil Risk Assessment Tool has been developed as part of the Coastal and Ocean Resources uSCAT Guide and provides guidance on assessing the likelihood of an oil to sink based on its density relative to the temperature and salinity of the water. The tool uses two sets of curves, the lower denoting the "sinking density" lines and the upper denoting a density of 10% less than the sinking density to categorize oils as 'Low', 'Medium' or 'High' risk based on where they plot on chart.

The Sinking Oil Risk Assessment Tool is included in this plan (Figure 9) for reference and application in the event of oil spill response.

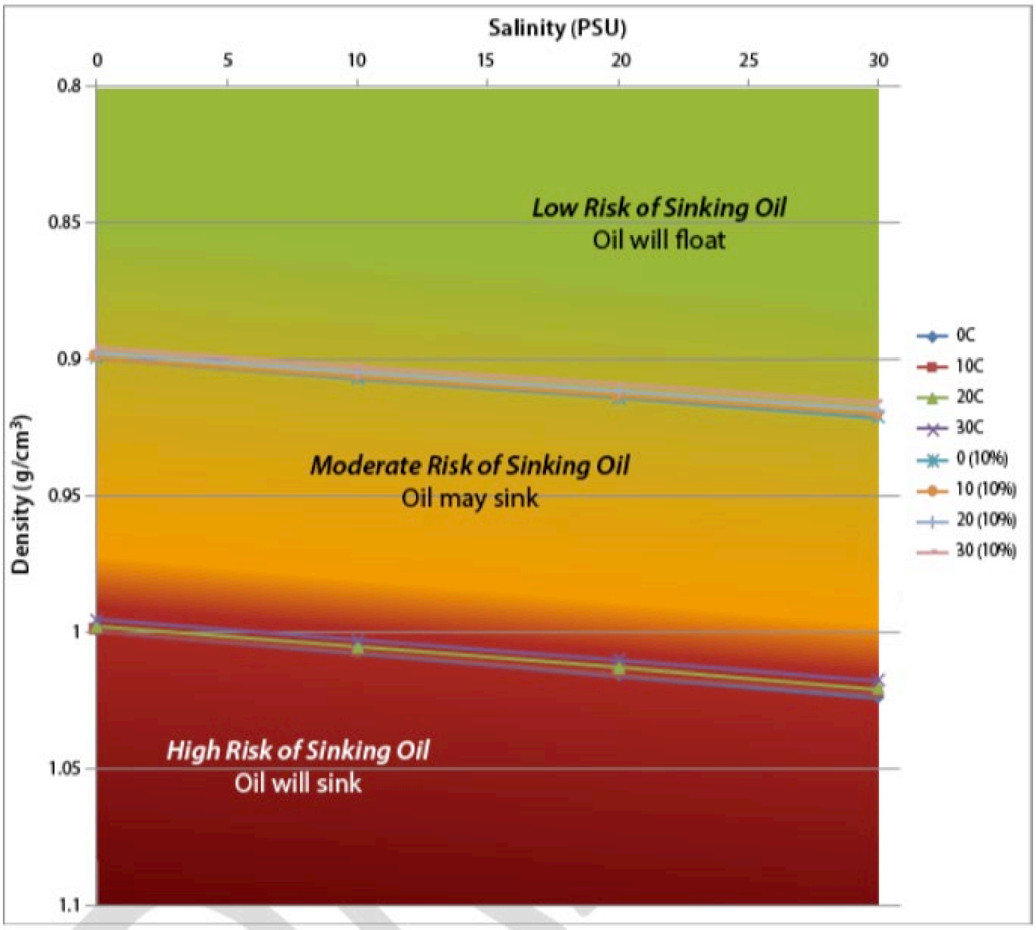

Figure 9 – Sinking Oil Risk Assessment Tool

4.1.2 STEPS FOR ASSESSING THE RISK OF OIL SINKING

The Coastal and Ocean Resources uSCAT Guide outlines the steps to be taken for assessing 'sinking oil risk potential'. These are as follows:

1. Acquire product information from supplier

2. Make preliminary Sinking Oil Risk Assessment

3. Collect field samples as soon as practical and when safe to do so

4. Collect water samples and/or document water properties (salinity, temperature, suspended sediment concentration)

5. Conduct "tail gate" tests of collected oil and water samples (go to Step 8 if oil sinks)

6. Send oil and water samples to lab for confirmation of densities

7. Re-assess Sinking Oil Risk based on laboratory and water property data

8. **If risk is 'High'**, then there is an immediate or imminent threat requiring prompt action:

    a. Alert Unified Command to the High-Risk sinking potential
    b. Collect environmental information relevant to sinking oil (e.g., charts or bathymetry data, seabed substrate maps, oceanographic models and data, hydraulic/numerical models, shoreline mapping)
    c. Delineate uSCAT Seabed Units
    d. Assess sites where sunken oil could potentially form
    e. Assess potential accumulation areas for sunken oil
    f. Develop survey strategies
    g. Select detection and delineation strategies and techniques appropriate for oil and site conditions
    h. Conduct confirmation/reconnaissance surveys to confirm if sunken oil is
    i. actually present, Prepare Sunken Oil Survey uSCAT Plan for UC approval

9. **If risk is 'Moderate'**, then the threat is conditional and less urgent. Identify and monitor suspect conditions and re-assess over time:

    a. Collect environmental information relevant to sinking oil (e.g., charts or bathymetry data, seabed substrate maps, oceanographic models and data, hydraulic/numerical models, shoreline mapping),
    b. Identify shoreline locations where there is a high risk of sinking oil formation (e.g., high sand content; high-energy shorelines); alert SCAT teams to closely monitor these locations,
    c. Conduct periodic confirmation/reconnaissance surveys in high probability locations to confirm if sunken oil is actually present.
    d. Ensure UC is aware of the potential for sunken oil formation and the need for ongoing monitoring and re-assessment – an early warning system

4.2 ENGAGEMENT OF THIRD-PARTY SPECIALIST

As outlined in Section 2.1.1 and Section 3.3.1, a third-party SSO specialist will be mobilized as soon as a medium or high risk of SSO is identified to provide specialist technical advice and support in the development of a uSCAT program.

4.3 DETECTION & ASSESSMENT

4.3.1 CASTLE'S SUMMARY MATRIX

In a paper presented at the 1995 International Oil Spill Conference (IOSC), Robert Castle and three colleagues discussed the issue of submerged or sunken oil. This paper has formed the framework for almost every technical report since on the subject. As part of the publication, Castle presented a series of graphic decision guides to assist in the selection of appropriate technology to assess, contain and recover submerged or sunken oils. Although technology has improved since 1995 to extend the limitations cited in Castle's guides, the core information still remains useful today. Castle's summary matrix for assessment is reproduced below in Figure 10.

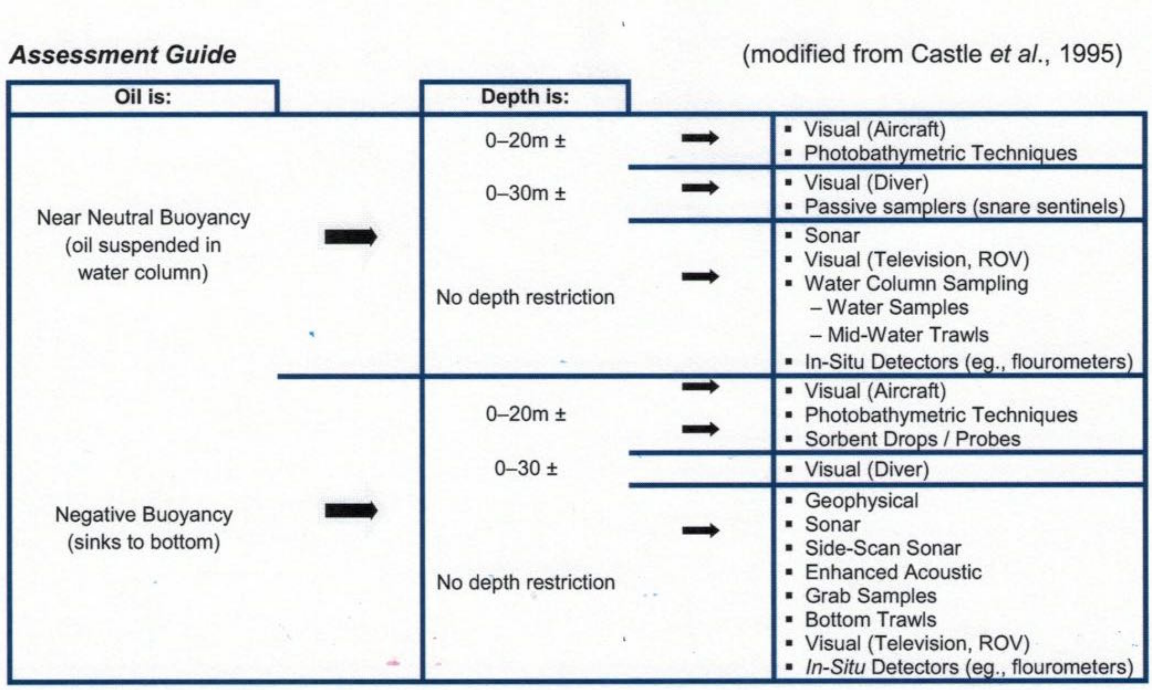

Figure 10 – Submerged or Sunken Oil Assessment Guide

4.3.2 METHODS & TECHNIQUES

The methods and techniques considered for SSO detection and assessment are outlined in this section and summarised by Table 6. As highlighted throughout this report, tactical SSO operations will be carried out by a specialist third-party as recommended by WCMRC and authorised by the Polluter/UC. WCMRC will provide support to the specialist third-party to assist in the assessment, containment and recovery of SSO. Table 6 provides a summary of the support WCRMC expect to provide for each of the methods listed

Table 6 – Summary of SSO detection and assessment methods and anticipated support requirements/capability

Principal	Technique	WCMRC Support Capability
Modelling	Surface Trajectory Analysis	Engagement of 3rd Party Specialist
	Subsurface Analysis	Engagement of 3rd Party Specialist
Acoustic	Multibeam sonar	Logistical Support
	Side-scan sonar	Logistical Support
	Fixed-mount, scanning sonar	Logistical Support
	Hand-held, scanning sonar (acoustic camera)	Logistical Support/Marine Support
	Sub-bottom profiler	Logistical Support
	Single-beam echo sounder	Logistical Support
Visual	Towed video	Logistical Support/Marine Support
	AUV	Logistical Support
	ROV	Logistical Support/Marine Support
	Drop camera (video)	Logistical Support/Marine Support
	Diver/Snorkeler observations	Logistical Support
	Underwater viewing tube/wading	Logistical Support/Marine Support
	Aerial observation	Logistical Support
Chemical	Fluorometers	Logistical Support
	Laser-Induced fluorescence (LIF)	Logistical Support
	Gas Chromatograph-Mass Spectrometer (GC/MS)	Logistical Support
Active Sampling	Sorbent drags	Logistical Support/Marine Support
	Grab samplers	Logistical Support
	Cores	Logistical Support
	Disturbance sampling (poling)	Logistical Support/Marine Support
Passive Sampling	Sorbent Sentinels	Logistical Support/Marine Support
	Sediment traps	Logistical Support/Marine Support
Other	Induced Polarization	Logistical Support/Marine Support

4.3.2.1 NUMERICAL MODELLING

From the preceding critical path discussion, it is evident that there are limited and fleeting opportunities to detect, contain and recover submerged or sunken oils. Numerical models are analytical tools that simulate an environmental system. Models offer hypothesized insight into the spreading pattern of submerged or sunken oil plumes such that they can be useful in providing early detection and tracking efforts as opposed to just prospecting for submerged or sunken oil. These predictions can be improved with feedback from empirical ground truthing, in-situ measurement validation and integration with Geographic Information Systems (GESMAP, 2015). Historically, numerical modelling has been used to predict, with some fidelity, the dispersion of submarine mine tailings plumes (Lescinski et al, 2014). Participants in Norway's outer continental shelf oil industry supported the development of the 3D model, DREAM, for the specific purpose of predicting sinking, dispersion, sedimentation and degradation of cuttings and drilling muds accidentally discharged during exploration and production activities (SINTEF, 2002). While modelling should first be viewed as a tactical aid to countermeasures, it can also be used defensively to contribute credibility to the UC's decisions regarding submerged or sunken oil mitigation.

4.3.2.1.1 AVAILABILITY OF BC COASTAL MODELLING

As part of the permit process for both the Enbridge Northern Gateway Pipeline (NGP) and the Trans Mountain Expansion Project (TMEP), numerical modelling was used as the basis of a mitigation analysis performed on oil spill scenarios (EBA Tetra Tech, 2013). In the case of TMEP, the model inputs encompassed the entire shipping route including the Strait of Georgia, the Juan de Fuca Strait and Puget Sound. The freshwater influence of 50 rivers and creeks, as well as the brackish Fraser River estuary, was also included. This modelling effort embedded a proprietary oil spill trajectory model (SPILLCALC) into a 3D hydrographic model (H3D) to predict the movement of surface oil. Because the model is three dimensional, it can also be used to predict the vertical dispersion of a submerged or sunken oil plume. As part of the TMEP regulatory process, the model was pre-loaded with fate and behaviour characteristics for diluted bitumen.

4.3.2.2 EARLY WARNING

The sum of situational awareness, surface trajectory analyses, bathymetry and other predictive tools can provide responders with an early warning that portions of a floating slick are at risk of transitioning into a submerged or sunken oil plume. In almost all cases involving conditional submerged or sunken oil (i.e., those oils at risk of transformation but not true LAPIOs) there will be a period of time for the oil to change density due to weathering. This period of grace offers a window of opportunity to preposition detection and tracking assets.

4.3.2.2.1 SURFACE TRAJECTORY ANALYSIS

Although the focus of this Plan is submerged or sunken oils, the trajectory of the surface slick cannot be ignored as, intuitively, all submerged or sunken oil originates from the floating mass. As a consequence, tracking the movement of the floating slick and analyzing its trajectory become predictive tools in submerged or sunken oil strategy. Overall, situational awareness and anticipation of onsetting conditions that favour submerged or sunken oil formation will shorten the detection window by narrowing the search field.

4.3.2.2.2 BATHYMETRY

For the purposes of submerged or sunken oil management, bathymetry is nothing more than mapping the bottom topography of the sea or a riverine streambed. The output of a bathymetric survey can take many forms, from a simple map using contour lines to illustrate changes in relief, to a sophisticated 3D product color-coding bottom variation. To boost the efficiency of submerged or sunken oil detection, a hydrographer conducting post-bathymetric survey processing can identify potential topographical impoundments for further investigation. As always, the strategy is to leverage technology to more productively guide the search for submerged or sunken oil.

4.3.2.2.3 CURRENT CHARTS

Ocean currents are horizontal movements of seawater. They can be tidal in nature, linked to the vertical rise and fall of seawater due to gravitational planetary interactions, or of non-tidal origin typically as part of oceanographic circulatory systems (i.e., the Japan Current, the Gulf Stream, etc.). The Department of Fisheries and Oceans (DFO), and like agencies in other countries, publishes both predictive tables and reference charts that illustrate current patterns for specific geographic locations. Software developers also offer a variety of current-related products. Current data, in any medium, is another tool in the forensic search for submerged or sunken oil.

4.3.2.3 TRACKING

Tracking is a subset of initial submerged or sunken oil detection. It is a function whereby confirmed deposits of submerged or sunken oils is periodically monitored for movement across the area of response (AOR). This monitoring will also include sheen mapping as a witness to submerged contamination. Tracking is a systematic effort that integrates calibration of confirmatory methods and ground truthing to deliver a profile of submerged or sunken oil migration that can be uploaded to a GIS database.

4.3.2.3.1 RE-SUSPENSION AND TRANSPORT

Scouring environmental forces can act on both submerged and sunken oils to remobilize them from rest in a static location. Re-suspension, transport and fractionation of the mass into smaller units represent one of the most challenging aspects of submerged or sunken oil management. Shortening the temporal scale between detection and countermeasure deployment will increase the margin of effectiveness.

4.3.2.3.2 DETECTION AND TRACKING CALIBRATION

Calibration occurs across all scientific disciplines to ensure that measurements taken as part of a task accurately compare to a known standard. As it relates to the detection and tracking of submerged or sunken oils, calibration is the process of ensuring uniformity in the observations of field assessment personnel. Due to the nature of spilled oil, there will always be a blend of qualitative and quantitative assessment methods regardless of whether that data results from first-hand visual encounters or is acquired telemetrically. The goal of calibration is to have all observers reach the same conclusion when measuring the subject.

4.3.2.4 CONFIRMATION AND GROUND-TRUTHING

Earlier in this Plan it was stated that submerged or sunken oils are not easily observed. Their fugitive nature can lead to many false positives in the detection process. The best method for confirming the veracity of a positive detection hit is to employ multiple methods to vet the target. Telemetrically acquired data is subject to the most misinterpretation, which can occur on a real-time basis in the field or latently during post acquisition processing. It will be necessary to check the accuracy of (remotely sensed data) by means of in-situ observations, that is, ground-truthing.

Confirmation and ground truthing efforts must be recorded by GPS track lines and waypoints with the collective output archived in a GIS database. Failure to do so will result in lost submerged or sunken oil formation that could more accurately drive countermeasure deployment.

4.3.2.5 SITE ASSESSMENT AND CHARACTERIZATION

If required to lead a submerged or sunken oil response, WCMRC will use a contracted third-party consultant to design and administer the site assessment and characterization process during a spill involving oil at risk of becoming submerged or sunken oil. Nevertheless, to offer submerged or sunken oil guidance to the Polluter, it is important that the RO understands the site assessment and characterization process in general and, more specifically, the integration of a Sample and Analysis Plan (SAP) into that process. The site assessment process should differ little from the science-based remedial investigations performed on legacy contamination sites. A scientifically defensible site assessment and characterization methodology will avoid dissonance between the Polluter and the agencies regarding the impact of submerged or sunken oil.

4.3.2.5.1 CONCEPTUAL SITE MODELLING

In keeping with generally accepted principles of remedial investigation, a conceptual site model (CSM) will be the foundation of the site assessment and characterization process. In this application, the CSM is both a fact-based and hypothetical representation of the submerged or sunken oil migration path and extent of contamination. It is closely linked to the Sample and Analysis Plan, with the CSM defining the parameters of the site investigation, and the SAP supporting it by gathering sufficient chemical information to define the area and degree of contamination. Because submerged or sunken oil is a fugitive product, both the CSM and the SAP may collectively dictate the methodology for multiple discrete sites or areas of concern (AOC).

4.3.2.5.2 SAMPLE AND ANALYSIS PLAN

The goal of the Sample and Analysis Plan is to acquire statistically significant volumes of chemical data, gathered under strict QA/QC procedures, to support decisions regarding the extent and severity of the contamination (CTDEP, 2007). Quantifying contamination is done to protect the environment and public health. Sample data will figure heavily into a Net Environmental Benefit Analysis regarding the decision to treatment or to naturally attenuate a site affected by submerged or sunken oil. The data will also be admissible as evidence in the post-emergency damage assessment process as well as used to differentiate the Polluter’s oil against possible legacy contamination, some of which may have been deposited by non-point sources.

Sampling may follow a spatial grid system (in the case of an unknown pathway) or biased according to the results of prior investigations. The SAP relies on data quality objectives (DQO) to guide in the acquisition of consistently drawn and statistically relevant samples. Invalid samplings, as a consequence of either quality issues or insufficient quantities, create data gaps that cast an indefensible shadow over environmental risk and actual site conditions. The appearance of some environmental risks can be delayed as a result of constituents that breakdown through latent chemical reactions.

Figure 11 – Sample and analysis plans require strict QA/QC procedures. Source: USEPA

4.3.2.6 MANUAL ASSESSMENT

Manual assessment for submerged or sunken oil consists of human-in-control, direct visual observations. In some situations, it is the simplest method for investigating submerged or sunken oil areas. The accuracy of manual assessment is limited by water conditions and the skill of the observer who may be prone to recording false positives and false negatives. The principle drawbacks associated with manual assessments are the amount of time required to inspect what typically is a narrow field of investigation.

4.3.2.6.1 VIEW TUBES

Manual view tube assessment occurs from a boat with the observer employing a glass lens scope to penetrate the water surface to peer at the bottom topography. Understandably, water clarity and the vertical distance to the bottom influence the image quality seen through a view tube. Those limitations notwithstanding, view tube assessments recorded by GPS track lines, with positive hit memorialized by waypoints, can offer good first effort detection. Intended for use by sportsmen and fisheries management personnel, view tubes are readily available from suppliers who cater to that market.

Figure 12 – Responders using view tubes to assess submerged or sunken oil. Source: NOAA

4.3.2.6.2 VISUAL SURFACE ASSESSMENT

Visual surface assessments are shallow water tasks conducted from boats. Three responders per small boat offer an efficient division of labor such that one person operates the boat, another uses a long probe to agitate the bottom, and the third person records any blooms of oil that float to the surface as evidence of submerged or sunken oil. Water depth and sea state limit the effectiveness of this manual assessment technique.

Figure 13 – Manual agitation to probe the bottom for submerged or sunken oil. Source: USEPA

4.3.2.6.3 SNORKEL SCAT

During the Deepwater Horizon incident, special wading SCAT teams were organized to assess nearshore areas for the presence of submerged or sunken oil (Challenger, 2015). Following a grid system, participants used shoves to probe the bottom for evidence of oil mats, many of which were covered by accreted sand. Snorkel SCAT efforts were limited to wading-water depth and benign surf conditions.

Figure 14 – Snorkel SCAT team enters the water at the practical. Source: Polaris Applied Sciences

Figure 15 – Submerged or sunken oil and shell hash recovered by snorkel SCAT. Source: Polaris Applied Sciences

4.3.2.6.4 DIVER ASSESSMENT

Diver assessment is the ultimate method to vet suspected deposits of submerged or sunken oil. Divers using feel to differentiate between bottom sediment and sunken oil have even overcome low visibility conditions in assessing areas of concern. Safety issues associated with water depth and sea state form practical limits for divers who should always work in helmets with surface supplied air, scuba divers are never acceptable.

Figure 16 – Nothing compares to positive submerged or sunken oil identification by a diver, but it does increases decontamination requirements. Source: USCG

4.3.2.6.5 SORBENT SENTINELS

Sorbent sentinels are passive ad hoc methods for the detection of submerged or sunken oil both in the water column and on the bottom. The materials available and the creativity of the designer are the only fabrication limits on both towed and moored devices. Typical sorbent sentinels employ weighted sorbent arrays to record witness marks of encountered submerged or sunken oil. By the random narrow-field nature of these encounters, any positive hits will also require further confirmatory ground-truthing.

Figure 17 – Crab pot stuffed with viscous oil snare to make a passive oil sentinel. Source: NOAA

Figure 18 – Weighted sorbent sentinel array. Source: NOAA

4.3.2.7 MECHANICAL ASSESSMENT

Mechanical assessment techniques take a physical sample of the medium of concern, whether that is the bottom sediment matrix or the water column. While there will understandably be a certain level of qualitative assessment involved, the implication is that the samples taken will undergo quantitative chemical analysis either through field screening kits or sent to off-site laboratories. For samples to be considered viable the extraction protocol must follow the guidance published in the incident Sample and Analysis Plan.

4.3.2.7.1 BOTTOM SAMPLING

Gathering a sediment sample from an area of concern is typically done from a small workboat with an installed davit. Geotechnical and oceanographic consultants have a number of devices of varying complexity to withdraw the sample. Unpowered samplers for use on soft sediments include: 1) clamshell devices like Van Veen and Ponar grab samplers; 2) weighted push corers that operate by gravity; and 3) various messenger actuated devices. For greater subsurface penetration or harder sediments, sampling is generally performed by a powered vibracore. Vibracores are portable percussive devices lowered to the bottom by a davit or small crane; the units fill a sleeved core barrel with a compacted vertical sediment sample.

Figure 19 – Using a clamshell device to gather sediment samples. Source: USEPA

Figure 20 – Using a push core to gather soft sediment samples. Source: USEPA

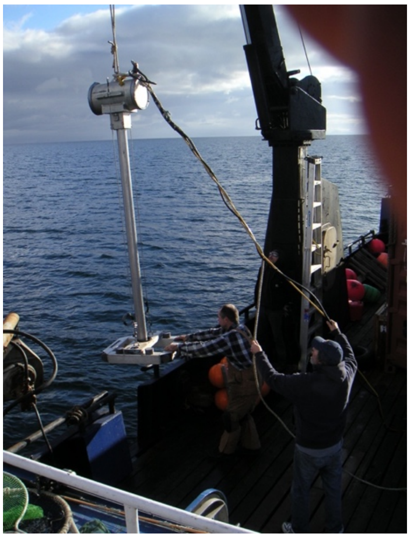

Figure 21 – Launching a vibracore over the side. Source: M.W. (Mac) McCarthy

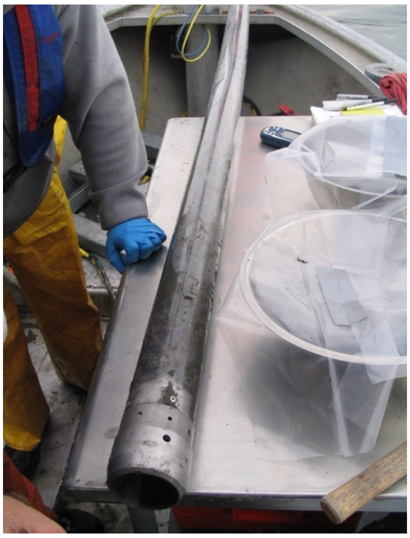

Figure 22 – Vibracore barrel containing sediment samples. Source: M.W. (Mac) McCarthy

4.3.2.8 ASSESSMENT BY TELEMETRY

Telemetric assessment methods employ a wide variety of devices to measure and communicate digitally acquired data from the area of concern. Most of these units are tethered to a floating platform and transmit their data through hardwire. An advantage of telemetry is that it enables the submerged or sunken oil assessment team to inspect a greater area per unit of time than any of the manual or mechanical assessment methods. Although telemetry offers real-time opportunities to assess conditions, data post-processing is generally required to complete the visualizations, and it is imperative that all data be geo-referenced, ideally using differential GPS (DGPS). In the end, response decisions will be made after telemetrically acquired positives are vetted by some form of visual or sample confirmation. The only telemetric systems presented in this Plan are those that are readily available for industrial use.

4.3.2.8.1 FLUOROMETRIC WATER COLUMN SAMPLING

Fluorometers have a long history of use in water science. Hydrologists and wastewater treatment engineers use them to measure the dispersion of tracing dyes in a receiving body of water. As part of the SMART protocol in oil spill science, fluorometers are used to measure the dispersion of oil droplets in the water column following dispersant applications (Comney et al., 2014). These same principles can be applied to the assessment of submerged or sunken oils. Fluorometers are typically connected by hardwire to a data logger; they can be dropped vertically from a stationary platform or towed behind a mobile unit. Experiments with submersible mass spectrometers have also shown promise but evidence has been insufficient to validate their effectiveness under all conditions (API, 2016).

4.3.2.8.2 SONAR

The marine industry has had a long relationship with sonar in geophysical mapping applications. For the purposes of this Plan, Sonar is defined as an acoustic signal actively pulsed through the water column to detect objects of differing reflectivity – submerged or sunken oil in this application. Not all submerged or sunken oils will lend themselves to sonar detection with the rate of success contingent on operator skill. Bulk oil mats resting on the bottom and shallowly buried mats represent the most promising targets. Dispersed submerged oil plumes are not considered good candidates for sonar detection.

Sonar is deployed from a mobile platform either towed in a hydrophone array or installed as a through-hull transponder. New sonar devices plot the data as color-coded 3D images. Commonly available sonar devices include side scan sonars, echo sounders and sub-bottom profilers. Each sonar type offers an individual benefit that can be optimized when used in concert with the others; as with all telemetrically acquired positives, ground truthing will be required.

4.3.2.8.3 ROV / AUV ASSESSMENT

A hybrid of manual assessment and telemetry is assessment facilitated by remotely operated vehicles (ROV). The ROV is a tethered unmanned device guided from a moored platform by a surface operator; only the length of its umbilical and pressure threshold limits its range. ROVs feed live video, enhanced by high intensity lights, to the surface controller. Many ROV units are equipped with manipulator arms to allow them to grasp items as well as take push core samples. Many telemetrically acquired positives can be ground-truthed with ROVs. The main disadvantages with ROVs are: 1) limited field of vision, 2) relocating the support platform each time the ROV reaches the end of its tether; and 3) sensitivity to turbid conditions. Autonomous underwater vehicles (AUV) are the untethered version of the ROV. While their utility is still impaired by a limited field of vision and turbidity, their investigative track is freed from time-consuming support platform re-mooring cycles. Unfortunately, AUVs are not as readily available as ROVs.

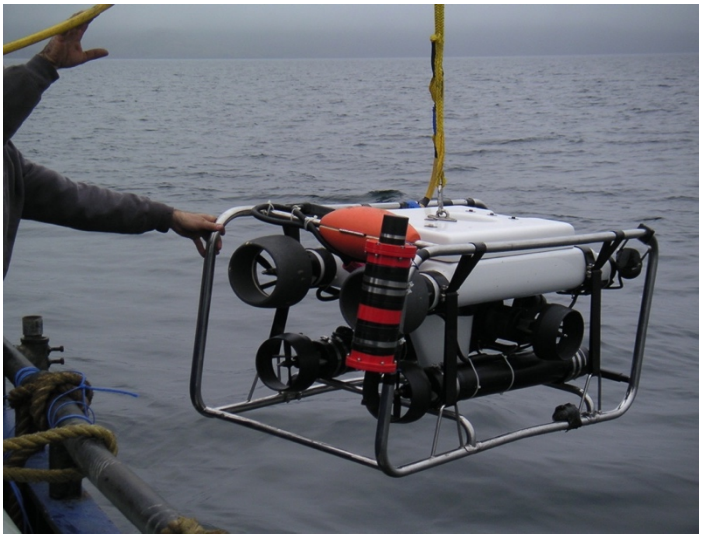

Figure 23 – ROV launch. Source: M.W. (Mac) McCarthy

4.3.2.8.4 UNDERWATER VISUALIZATION

The American Petroleum Institute, in its 2016 submerged or sunken oil technical report, collectivized four camera devices as underwater visualization systems (API, 2016). Digital still and video camera units are almost always standard equipment for divers and ROVs. Specialty contractors operate the remaining two types: sediment profiling cameras and acoustic cameras. The latter two types are mentioned here to illustrate the breadth of options that may be required to assess the extent of submerged or sunken oil contamination.

4.3.2.9 DATABASE MANAGEMENT

Heretofore, this section has focused on the methods for detecting submerged or sunken oils. In practice, detection is a two-part exercise consisting of finding the product and then recording the data associated with that search. To be useful, the data must be both geo-referenced and time stamped. Because the areas of concern will be three dimensional, and possibly extensively distributed along the horizontal axes, the volume of data acquired will be huge. This volume includes data generated throughout the detection process and from the subset tasks of tracking and site assessment and characterization. This data should be uploaded to a master database where it can be easily accessed for GIS analysis to track plumes, identify impoundments and account for submerged or sunken oil remobilization. Plotting the datapoints as an overlay on a digital orthoimage chart creates a powerful graphic to support recovery efforts.

4.3.2.10 SCAT

As outlined in Section 3.2, SCAT specialists are part of the Environmental Unit. SCAT personnel typically include field teams, coastal science advisors and GIS technicians. There is a precedent from the Deepwater Horizon response of SCAT teams conducting nearshore submerged or sunken oil assessments through Snorkel SCAT while traditional SCAT shoreline teams assessed irregularly shaped tarballs for indications of sunken mats offshore (Challenger, 2015). This case history supports the logic that the task of detecting submerged or sunken oil, whether nearshore or offshore, can be assigned to SCAT whose members are trained to assimilate qualitative calibration exercises and, as part of their normal duties, record large quantities of data.

Figure 24 – Irregularly shaped tarballs often indicate offshore submerged or sunken oil mats. Source: M.W. (Mac) McCarthy

4.4 UNDERWATER SHORELINE CLEAN UP ASSESSMENT TECHNIQUE (USCAT)

WCMRC participated as a peer reviewer throughout uSCAT development and plans to train some employees on this specialized aspect of submerged and sunken oil response and also enter into formal arrangements with experts in the field. However, for the most part, WCMRC expects that UC shall require uSCAT be carried out as part of a structured response. The uSCAT protocol generally follows that of the Shoreline Cleanup Assessment Technique (SCAT) but recognizes that oil detection techniques will be quite different and reporting formats will also differ. An established uSCAT Guide and Technical Reference Manual are referenced in Section 2.1 of this plan and form the basis of all uSCAT planning and operations.

4.5 ESTABLISHING THE FINGERPRINT

The Enbridge Line 6B spill highlighted the importance of establishing an early consensus-based Sample and Analysis Plan (SAP) for the positive identification of the spiller or Polluter's submerged or sunken oil. It may seem counterintuitive that any oil found on the bottom could be something other than that belonging to the Polluter, but case studies have shown that, in an industrialized world, that is a distinct possibility. Loss of the submerged or sunken oil fingerprint against a scattered background leads to errors in mass balance calculations, tracking and submerged or sunken oil distribution estimates. Maintaining the submerged or sunken oil fingerprint through sample and analysis is a highly technical geochemical function that must be assigned to qualified experts. During the Kalamazoo spill, the USEPA accused Enbridge of underestimating the volume of submerged or sunken oil by a factor of 100 (Dollhopf, 2013). This discord was largely due to dissonance over sample and analysis methods and inconsistency in the Polluter's chemical fingerprinting method. Early confusion over the submerged or sunken oil fingerprint will complicate and extend detection and recovery operations associated with the incident. The RO should be prepared to provide the Polluter and UC with education and guidance on this issue and try to set up an SAP, as soon as possible.

4.6 NEBA

WCMRC recommends UC conducts a Net Environmental Benefit Analysis (NEBA) as a formal process to evaluate the risks and benefits of certain proposed cleanup strategies and techniques. NEBA is a stakeholder's performance metric that weighs many factors – both operational and environmental – against the cleanup endpoints established by the Unified Command. This analysis will consider specific treatment options appropriate to the response; the potential for successfully implementing those discrete options; the environmental trade-offs attached to each technique; and, lastly, the types of treatments that can be authorized within the existing regulatory framework.

Although each oil spill is unique, NEBA will conceptually develop a decision tree to answer the questions of:

- What will be the probable outcome if no countermeasures are deployed?
- What will be the probable outcome if only conventional surface mechanical countermeasures are deployed?
- On a priority basis, what are the resources (environmental, social and economic) at risk if applied countermeasures prove to be inadequate?
- Can alternative countermeasures be executed successfully to augment conventional techniques?
- How long should any treatment technique continue?
- Are certain areas within the response candidates for or amenable to natural attenuation?
- Should some oil be left for remedial treatment?
- What is the regulatory process for permitting a remedial treatment?

The proposed recovery of submerged or sunken oils is a good example of a situation where a rational assessment of the environmental trade-offs associated with cleanup techniques is required. The UC will initiate a Net Environmental Benefit Analysis request to vet countermeasure techniques. NEBA must proceed in a rapid systematic manner to be effective, given the time sensitivity to track and recover submerged or sunken oils before they remobilize.

Answers to the questions posed from the conceptual decision tree will offer a reasonable first indicator as to whether or not submerged or sunken oil recovery operations may present an effective countermeasure and, if so, should be screened to another level of detail with respect to environmental benefit. As an example, the initial operational investigation within the NEBA process associated with submerged or sunken oils will likely consider among other factors (NWACP, 2017):

- Incident Characteristics – this will include the type and volume of oil spilled with respect to the receiving body of water.
- Aquatic Environment – a characterization of water density, temperature, turbidity and bathymetry.
- Environmental Influences – such as weather and sea state.
- Countermeasure Options – this can be viewed as the systemic options to detect, track and recover submerged or sunken oil.
- Logistics – briefly, an assessment of logistics seeks to answer the question of whether countermeasures can fully be supported to reach cleanup endpoints.

When conducting a formal NEBA, the Spill Impact Mitigation Assessment methodology will be used. This methodology allows for, amongst other benefits, the consistent consideration of socioeconomic, cultural and ecological concerns and relies on expects to provide qualitative feedback (or a 'score') on the impact of pollution on various sensitivities.

4.7 DECISION TREE

With respect to a submerged or sunken oil response, the critical path represents the most direct method to sequence and schedule response tactics. A clearly defined decision tree addresses the situation and prevents bottlenecks to decision-making. This path is graphically summarized by the flowchart in Figure 25.

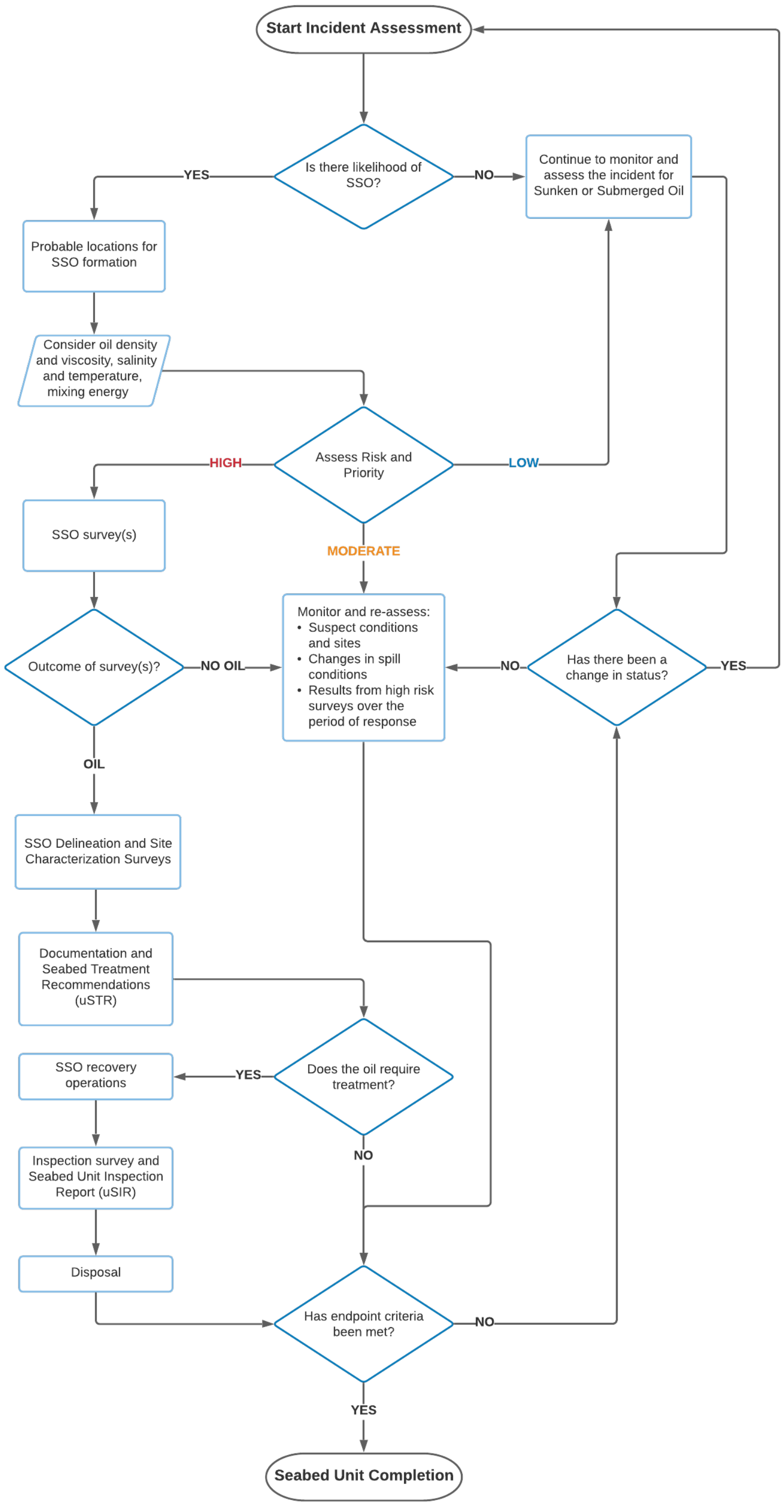

Figure 25 – Submerged or Sunken Oil Actions Decision Tree

4.7.1 INCIDENT ASSESSMENT

4.7.1.1 THE PRODUCT SPILLED

Incident assessment begins by identifying the product spilled and understanding its potential behaviour. It is standard operating procedure that all incidents commence with a health and safety evaluation typically supported by a Material Safety Data Sheet (MSDS) that identifies the physical properties and hazards of the product spilled. MSDSs vary in the depth of information offered; ideally these formal documents will detail the following information offered in no standard order:

- Product Common Name and Alternate Numeric Identifiers
- Hazard Identification
- Chemical Composition
- First Aid Measures
- Firefighting Measures
- Spill and Cleanup Measures
- Handling and Storage Instructions
- Personal Protection and Exposure Limits
- Physical and Chemical Properties
- Stability and Reactivity
- Toxicological Information
- Ecological Information
- Disposal Consideration
- Transport Information
- Regulatory Information

The product name (i.e., crude oil, heavy fuel oil, diluted bitumen, etc.) will offer the first indication of the oil's potential to become submerged or sunken oil. Specific gravity (SG) values will likely appear in the Physical and Chemical Properties section. It is most probable that the SG value will be in reference to water (water = 1.0); API gravity is unlikely to be used in an MSDS. Recall that that product density need not always equal or exceed water density for an oil to become conditionally submerged or sunken oil; therefore, all medium and heavier weight products should be suspect.

4.7.1.2 THE RECEIVING WATER BODY

An assessment of the receiving waterbody involves an evaluation of the aquatic environment. The evaluator may consider many factors, but the degree of salinity (fresh, brackish or salt), water temperature, sediment load and the presence of mixing energy will be indicators of the conditions favourable to the transformation of spilled product into a submerged or sunken oil. Recall that it is the simultaneous combination of these environmental factors, rather than any single factor, that encourages medium or heavier oils to become submerged or sunken oil.

4.7.2 DETECTION

Detecting a spilled product that has transformed into a submerged or sunken oil is by far the most difficult – and the most important – task along the critical path. This Plan has stated that productive recovery efforts are tied to the verified detection of submerged or sunken oil such that recovery cannot be initiated until the oil is found. The performance of detection methods is improved in shallow water but inhibited in deep water.

4.7.3 ESTABLISHING THE LOCATION (DELINEATION)

Closely related to detection is the process of delineation of the area of submerged or sunken oil establishing spatial boundaries. If the oil has sunk, an impoundment will likely establish these boundaries. An impoundment may be defined as a localized benthic area where current and geomorphology are favorable to having the product settle out. If the oil remains submerged being vertically stratified in the water column, then no boundaries will truly exist, and delineation becomes an exercise in tracking a moving target.

4.7.4 VERIFICATION OF SAMPLES

Verification of submerged or sunken oil samples is the geochemical function that:

- Positively identifies the oil as belonging to the Polluter.
- Provides clues on the product's weathering and fate.
- Defines the sediment matrix with which the oil may have interacted.

The ultimate goal of submerged or sunken oil characterization in a response is: "to unambiguously characterize, identify, categorize and quantify all sources of hydrocarbons entering the environment as very important for environmental damage assessment, evaluation of the relative risks to the ecosystem posed by each spill, and selecting appropriate spill response and taking effective cleanup measures (Wang et al., 2006)."

4.7.5 CONTAINMENT

Commensurate with a floating-oil-spill objective, achieving containment of as much of the submerged or sunken oil mass as possible is a valid, if optimistic, tactic. Sadly, there may be few opportunities to successfully contain a submerged or sunken oil spill. Ideal conditions for feasible containment include shallow impoundments, with little or no current to interfere with countermeasure deployment. Such conditions are likely to be more prevalent in a riverine environment than in open water.

See section 5.1 for further details on preparing for containment and recovery.

4.7.6 RECOVERY

Successful recovery of submerged or sunken oil is closely linked to depth and bulk accumulation. Non-migratory oil that has collected in a shallow impoundment offers the best-case recovery scenario. Poorly accumulated fugitive oil is seldom feasible to recover.

See section 5.3 for more information on recovery techniques.

4.7.7 DISPOSAL

Submerged or sunken oil recovery operations generate substantial waste streams that will include both contaminated water and sediments. In many cases, the sediments will need to be dewatered before they can be transferred to off-site disposal. The disposal function is so critical that, if improperly managed, it will shut down recovery operations. Delaying recovery operations can re-enter found submerged or sunken oil back into the cycle of mobilization and detection, each iteration of which offers diminishing returns to the response operation.

See section 5.4 for more information on waste management.

4.8 REMEDIATION

Remediation is an engineered process to remove harmful contaminants from the environment. It is a non-emergency activity guided by NEBA that considers the long-term impacts contaminants pose to environmental and human health. Legal proceedings factor heavily into remedial actions as all stakeholder strive to document their compliance and limit their liability. It is not uncommon for remediation to extend over a period of years. Natural attenuation can also be part of a remedial strategy.

4.8.1 RELEASE OF THE RO

It is unclear what role the RO might play in a remedial phase, although it is highly unlikely, they will self-perform any remedial work. As an emergency response organization, the first mission of WCMRC will be to return to normal duties as soon as possible. However, it is conceivable the RO would be asked to project manage, on behalf of the Polluter, remedial actions undertaken by third-party service providers. At some point between the end of the emergency phase and the end of the remedial phase, WCMRC will be released.

4.8.2 LONG-TERM MONITORING AND COLLECTION

Regardless of how aggressively submerged or sunken oil is pursued in the response, or later through remedial actions, oil contaminated sites will undergo long-term monitoring and sample collection. This compendium of data can be used to verify compliance with cleanup endpoints as well as form the basis for natural resource damage assessments. It is within expectations that the RO could be asked to project manage long-term monitoring and sample collection, which sometimes spans a period of years.

5. RESPONSE SUPPORT

5.1 CONTAINMENT AND RECOVERY PHASE PREPARATION

There are parallel containment and recovery phase preparations between a floating and a submerged or sunken oil response. However, it is short-sighted to assume that just because submerged or sunken oil has evolved from a floating spill, preparations reciprocally apply through the transition. As such, the following subparagraphs present a curated checklist to ensure the RO systematically moves into the active countermeasure phase.

5.1.1 NEBA

The results of a Net Environmental Benefit Analysis (NEBA) will dictate whether or not there will be an effort to recover confirmed deposits of submerged or sunken oils. Prior to mounting an affirmative recovery effort, the tasks must be sequentially planned to ensure the work engenders no secondary environmental and economic impacts.

5.1.2 HEALTH AND SAFETY

Recovery of submerged or sunken oil will introduce more equipment into the area of concern. Responders may not be familiar with working around some of this equipment. Further, submerged or sunken oil recovery almost always generates large volumes of contaminated water and sediment to manage. These conditions may raise new health and safety concerns that must be communicated to the participants.

5.1.3 CROSS CONTAMINATION AND DECONTAMINATION

Closely allied with health and safety are cross contamination and decontamination issues. Contaminated sediments and straight liquid wastes from sediment dewatering and pumping submerged or sunken oils will be the principle vectors for cross contamination. Equipment engaged in submerged or sunken oil recovery should be enclosed by anchored containment boom where conditions allow. The boom watch circle should be generous to accommodate submerged or sunken oil that might be remobilized to rise to the surface as floating oil. Depending on the extent of re-flotation, mechanical surface skimming may be more efficient than recovery with sorbents. To minimize cross contamination, work areas and related equipment, should be sectioned off into hot, warm and cold zones. At the end of the operating period, response assets should be field-decontaminated so that the next period starts with a clean baseline. Experience has shown that uncontrolled cross contamination issues become additive over time, reducing productivity and increasing the risk of workplace injuries.

5.1.4 CULTURAL AND ARCHAEOLOGICAL CONSIDERATIONS

Removal of bottom sediments has the potential to adversely affect submerged objects of cultural and archaeological significance. Provincial and First Nations trustees may have already identified areas of potential value, but such awareness may be outside the immediate knowledge of operations personnel. Consultations with Cultural and Historical Resource Specialists are typically requested through the Planning Section of a standard ICS organization. It is the responsibility of these specialists to identify culturally and archaeologically significant sites and to develop a strategy for their protection.

5.2 PERMITS

In-water work involving the removal of contaminated sediments may involve a series of federal, provincial and First Nations permits. Concerns over increased turbidity and the migration of contaminants into biologically active aquatic habitats generally appear as permit requirements. While it is unlikely WCMRC will be expected to take the lead on permit applications, it is important for the RO to know where to seek permit expertise within the ICS organization. As permitting is a very process-oriented endeavour, the urgency associated with submerged or sunken oil detection, remobilization risk and recovery must be communicated to the trustee agencies.

5.2.1 PROTECTION AND CONTAINMENT TACTICS

Submerged or sunken oils have the best chance of being contained in shallow impoundments where current flow conditions are low. Containment is almost impossible in deep wide expanses of water and in current speeds above 0.75-knots (0.39 meters/second). Literature searched found a number of clever ideas for potentially containing submerged or sunken oil, but few have been validated. These countermeasures tend to be ad hoc low-tech physical barriers adapted to individual situations. Among the options presented by others include bottom booms, sheet piles, nets, bubble curtains and fence devices (Castle et al., 1995, IMO, 2014, and API, 2016). The containment section of Castle's summary matrix is reproduced in Figure 26 with two of the more reasonable deployments (given the proper conditions) discussed in the sub-paragraphs thereafter.

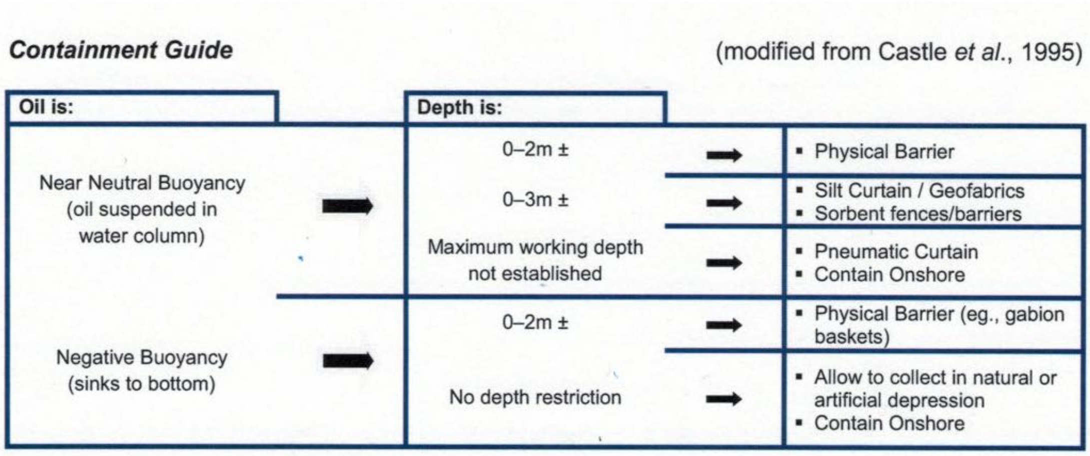

Figure 26 – Submerged or Sunken Oil Containment Guide

5.2.2 SILT CURTAINS

The dredging industry has long used silt curtains to combat turbidity in water bodies that are intolerant of increased sedimentation or fugitive contaminants. Silt curtains and oil containment booms have much in common insomuch as they are both constructed with a top flotation chamber, a middle fabric skirt barrier and a bottom ballast member. The purpose of oil containment boom is to corral floating oil in a discrete location; silt curtains promote the natural settling of suspended solids within an area of impoundment. The skirt depth of oil containment booms rarely exceeds 120 cm (48”), however, silt curtains’ drafts can extend to 30 metres (~ 100’). Practical considerations to handle silt curtains involve choosing a suitable site and mobilizing the appropriate deployment platform (ideally a deck barge with a crane and air tuggers).

5.2.3 FENCE-LIKE BARRIERS

Fence devices are a term used here to collectivize a number of rigid or semi-rigid physical barriers that extend from just below the water surface to the bottom. These devices can be permeable or impermeable as necessary to accommodate the force of the water acting upon their vertical face. On a scale of complexity, fence-like barriers can range from driven sheet piles to vertically staked filter fabrics. Among the more achievable designs are: 1) chain link fence lined with sorbent products, and 2) stacked wire gabion baskets stuffed with sorbent products.

Figure 27 – Gabion baskets stuffed with viscous oil snares. Source: USEPA

5.3 RECOVERY TECHNIQUES

The relative success of approved submerged or sunken oil recovery techniques will be closely tied to the ability to visualize the product where it rests and how the appointed technique will interact with the oil. This insight is especially important at depth. Visualization can be technologically enhanced through schematics or infographics, through photographs and through real-time video feed. In addition to making tactics more effective, visualization tools can prevent secondary environmental impacts that result from overly aggressive execution. Field-testing recovery tactics to verify no uncontained submerged or sunken oil remobilization occurs or that the techniques do not drive oil deeper into the bottom sediment, can avoid environmental harm as a by-product of countermeasures. Submerged or sunken oil recovery areas should be treated as no wake zones since subsurface turbulence tends to be orbital and contributes to oil remobilization. Figure 28, adapted from Castle, presents an excellent graphic of submerged or sunken oil recovery options and their limitations. A discussion of some of the more actionable recovery techniques ensues in the paragraphs below.

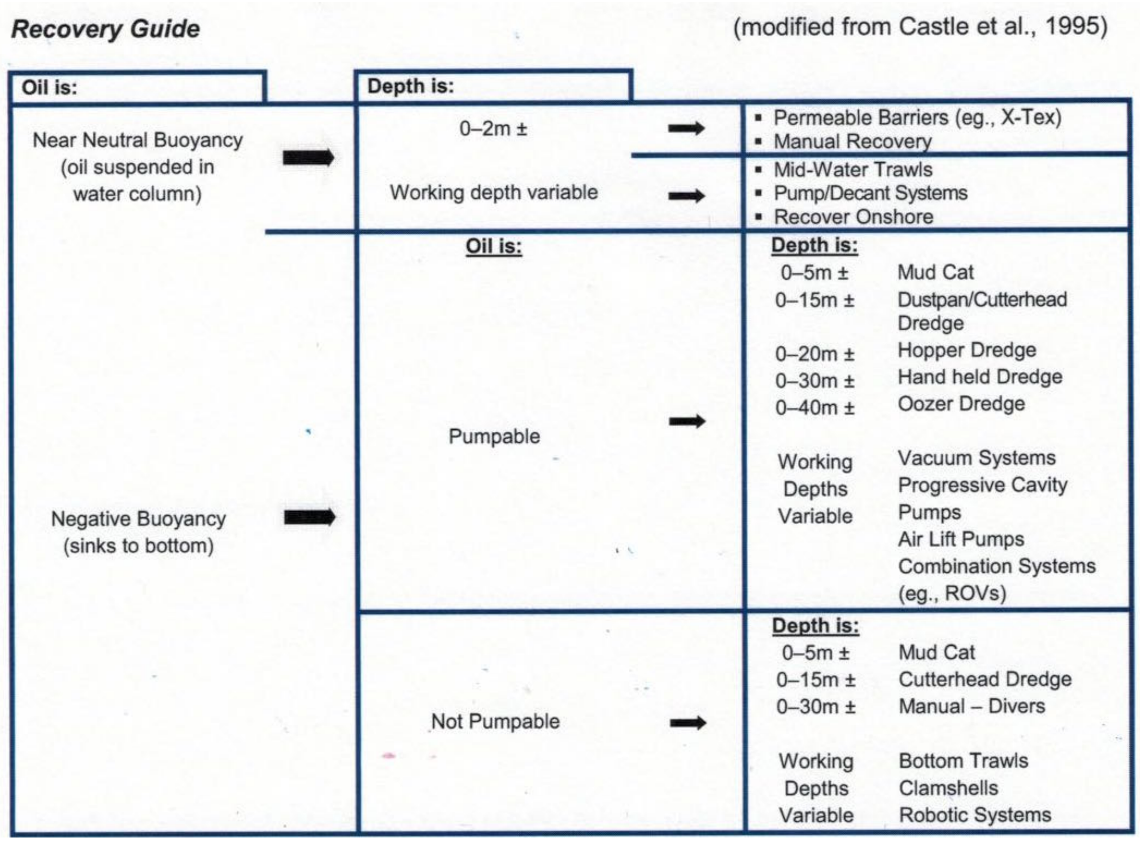

Figure 28 – Submerged or Sunken Oil Recovery Guide

5.3.1 DREDGING

Resources to recover overburdened sediment through dredging exist in almost every maritime economy throughout the world. Because of the nature of industrial waterways, most dredging contractors have experience in managing contaminated sediments, both in terms of dewatering and spoils disposal. In its simplest form, dredging can be executed with a clamshell bucket and floating crane. More sophisticated hydraulic dredges and robotically operated environmental dredges also exist and may prove to be more appropriate to the task. Depth is a limiting factor to all dredging methods, which rarely effectively occurs below 30 metres.

Figure 29 – Amphibex environmental dredger. Source: USEPA

5.3.1.1 CHARACTERIZATION, DELINEATION, DREDGE PRISM DESIGN AND CONTROL

Delineation of the dredge area is important because effective dredging depends on the chemical characterization of the spoils and an accurate estimate of the volume to be removed. An accurate volume estimate can only be calculated from a 3D delineation of the area identified for removal. Almost all dredging is guided by an engineered design of a dredge prism or cut area. Submersible GPS transceivers, relaying positioning data to programmable logic controllers in the dredge, have improved the accuracy of operations to reduce over-excavation and unnecessary disposal requirements. Underwater video cameras have also been fitted to dredging equipment to improve its accuracy. Optimizing cut accuracy is important since waste management associated with dredging is a significant logistical consideration.

5.3.2 LONG REACH MECHANICAL RECOVERY

Mechanical recovery is really a subset of dredging; in this application it utilizes a long reach boom mounted on a conventional excavator to remove bottom material. Because of their universal availability, utilitarian excavators tend to be ad hoc solutions, often lacking the installed positioning systems of purpose-built dredges. Nevertheless, this type of mechanical recovery is simple and versatile limited only by water depth and sea conditions. In benign conditions, mechanical excavators have successfully removed material from a platform of pontoons pinned together to provide enough stabile waterplane area for the machine to swing and dip without capsizing.

Figure 30 – Long-reach excavator for submerged or sunken oil nearshore. Source: M.W. (Mac) McCarthy

5.3.3 DIVER-DIRECTED RECOVERY SYSTEMS

Hardhat divers in constant communications with the surface provide the most accurate means of recovering submerged or sunken oil. The API reviewed 38 sunken oil case studies and found that divers had successfully recovered oil in 13 of those incidents (API, 2016). These diver-directed recovery systems included airlifts, vacuum units and modified submersible pumps. Divers themselves are limited by depth and the recovery systems they operate are also depth limited, which then becomes additive to the topside head pressure the system discharge must overcome. Advancing diver-directed recovery to another level, one spill response contractor, Marine Pollution Control, has developed a manned submersible for the detection and recovery of sunken oil.

Figure 31 – Marine Pollution Control's manned submersible for the detection and recovery of submerged or sunken oil. Source: NOAA

5.3.4 NETS AND TRAWLS

Spill responders have undertaken experiments to contain and recover submerged or sunken oil with mesh fabric and trawl nets for more than 30 years. Work on these techniques has occurred in laboratory test tanks and in the field as part of actual response countermeasures. Equipment adaptations using mesh and fishing nets are directed at poorly floating oils or those submerged throughout the water column. In one experiment, a series of variable sized mesh-draft extensions was added to conventional containment boom in an effort to retain poorly floating heavy crude oil. After a number of test runs using increasing current speeds on each mesh, the experimenters concluded that, "None of the mesh skirted booms appreciably contained oil (Cooper et al., 2007)." During the 1999 Erika spill off the coast of France, vessel-of-opportunity fishermen used their trawl nets with some success to recover poorly floating segments of very heavy oil (Peigne, 2009). Ultimately, according to a temporal scale of product concentration and exposure, the trawl nets became unworkable and were sacrificed. Spanish fishermen favoured smaller landing nets over trawls to more successfully dip oil during the 2002 Prestige spill (Peigne, 2009). Although deployment of nets and trawls as a countermeasure shows some promise, it should be considered only as an experiment and not as a first line of response.

5.3.5 POLISHING AREAS WITH SUBMERGED OR SUNKEN OIL IMPACT

Shallow low-flow area impoundments may respond well to labor-intensive manual stimulation of bottom sediments to release submerged or sunken oils to the surface. A battery of techniques was so applied during the Enbridge Kalamazoo spill. For the purposes of this Plan, the laborious nature and low yield of these techniques suggests they are better classified as polishing efforts as opposed to recovery efforts.

5.3.5.1 RECOVERY BY MANUAL AGITATION AND CELLULAR APPORTIONMENT

The manual agitation of bottom sediments originated as a shallow water detection method. Responders operating from small boats would use pike poles, sometimes with footplates attached to one end, to stimulate bottom sediments. If submerged or sunken oil was present the agitation encouraged remobilization of the oil to the surface as a witness to benthic contamination (USEPA, 2010). Responders realized manual agitation could also be used to remobilize enough submerged or sunken oil to make recovery efforts worthwhile. While poling is the simplest method of agitation, raking, air sparging and flushing have also been used (Dollhopf, 2015).

Recovery efforts initiated by manual agitations are only effective if the area of interest has been pre-boomed into cells. Though floating, these cellular apportionments reflect the same practice the RO might conduct with shore seal boom during beach flushing operations. Since submerged or sunken oil remobilized to float could surface some distance from the point of agitation, recovery segments need to be of sufficient scope to accommodate this drift. Oil volumes released by this method will vary such that recovery may be more efficient with either sorbents or with small portable skimmers. The use of sorbents, especially sorbent sweeps, is always good practice for sheen management.

Figure 32 – Submerged oil recovery executed in pre-boomed cells. Source: USEPA

5.4 WASTE MANAGEMENT

The WCMRC Waste Management Plan outlines WCMRC's strategic approach to waste management. The issues outlined below cover topics from the Waste Management Plan in more detail and specific to SSO response.

5.4.1 WASTE STREAMS

There are two principle waste streams associated with submerged or sunken oil recovery: solid wastes in the form of contaminated sediments and liquid wastes, which may include recovered bulk oil, oil/water emulsions and oily water. Each waste stream should be screened for chemicals of concern and guided by regulations to ultimate disposal. While it is certain that off-site disposal will be mandated for portions of each waste stream, careful segregation and QA/QC sampling may allow for in-situ treatment and return to the natal waterbody. Consequently, it is a matter of response best practices to have waste management discussions with regulators early and often.

5.4.2 VOLUME ANTICIPATION

Responders should anticipate high waste volumes during submerged or sunken oil recovery. To avoid bottlenecks and process shutdowns, waste management resources must be matched to submerged or sunken oil recovery rates. This is an engineering calculation that seeks to optimize recovery production, process residence time, transport logistics and surge capacity. It is reasonable to ask: How much waste should be anticipated? This is best answered qualitatively by citing the Enbridge Line 6B spill in the example below.

During the Enbridge Line 6B submerged oil recovery, remedial dredging occurred along 10 kilometres of fluvial environment (Enbridge, 2014). The Enbridge estimated 314,849 m3 of material would be removed, dewatered and sent to upland disposal sites – an equivalent volume of 14,707 truckload deliveries. Approximately 67, 575 m3 of recovered liquids were shipped for off-site treatment and disposal. Additionally, dredge-material dewatering operations generated an order of magnitude more wastewater that was treated in situ and subsequently discharged back into the river.

5.4.3 SEDIMENT

During site assessment and characterization, sediments are screened both to establish the extent of contamination and to determine their ultimate disposal site. While assessment and characterization are pre-recovery tasks, confirmatory samples should also be pulled during recovery operations for QA/QC purposes. This sampling will provide a compliance audit trail for the protection of all stakeholders. It may be part of the main SAP or be a standalone plan, particularly so if recovery is assigned as a post-emergency remedial action.

5.4.3.1 DEWATERING

Sediments recovered from depth will have high water contents. Because wet sediments generate leachate, they cannot be sent off-site for disposal without dewatering. The dredging industry typically dewaters uncontaminated sediments by gravity. This is achieved by trimming a deck barge so that the solids remain forward while the water drains aft. The drainage is contained in a curtained impoundment to allow residual turbidity to settle out. Contaminated sediments require more complex treatments often involving large permeable geotextile bags ubiquitously called geotubes. Dewatering with geotubes must be done in a full containment to capture all the water that osmotically passes across the fabric membrane; this water must not enter a receiving body untreated. Prior to entering the geotubes, the dredge slurry is treated with polymers to enhance the separation of solids from the conveyance water. The sediment is retained in the geotubes while the water drains out. At the end of the process the sediment will be sufficiently dry to be transported for off-site disposal. This method of dewatering consumes a large footprint although it can, nevertheless, also be executed on barges.

Figure 33 – Dredge spoils being dewatered through geotubes. Source: NOAA

5.4.4 LIQUID WASTE

This section on liquid waste focuses on by-product recovered water defined as lightly contaminated oily water. Recovered bulk oil and oil/water emulsions generally have no disposal options other than to be transported off-site for treatment. However, situations could arise, especially in remote areas, where the only practical means of managing large volumes of lightly contaminated oily water is on-site treatment. This option is more of a situational regulatory issue than a technical one; it must be presented in the context of NEBA, with possibly the carbon footprint impact of hauling large lightly contaminated waste volumes off-site when the same compliance could be achieved in-situ.

5.4.4.1 IN-SITU WATER TREATMENT – PLANNING

In-situ water treatment for hydrocarbons is a process of phase separation that progressively moves water with a higher level of contamination (influent) to one that is within the regulatory discharge criteria. Water treatment requires significant volumes of tankage to support both the process and to provide surge storage during outage periods. The goal is not to treat all water available to the system, but only the portion that has failed the screening process. As such, keeping the influent to a minimum volume avoids the wasteful consumption of treatment resources. Though not approved in Canada, properly screened decanting facilitates in-situ water treatment by preventing unnecessary volumes from entering the system. Pre-authorized, product-conditional decanting exists in Washington State after the Polluter submits an application to the UC (Region Ten Area Committee, 2017). The International Association of Oil and Gas Producers also recommend that worldwide, decanting should follow a similar process (IPIECA, 2013). It is debatable whether Canadian regulators would embrace decanting; nevertheless, it remains a response best practice to present decanting to regulators early as a viable practice.

5.4.4.2 IN-SITU WATER TREATMENT – PROCESS

Briefly, the process of water treatment begins by pumping a volume of contaminated water into batch storage. While some treatment systems can be continuously fed, batch treatment facilitates good QA/QC accountability. Ideally, most of the free oil is recovered before the process stream enters the filtration stage. The simplest method to recover free oil before filtration is to provide a detention period to allow for phase separation by specific gravity. Mechanical oil-water separators can enhance this phase separation, if those resources are available. Influent water that has undergone phase separation, either by gravity or mechanically, can then be pumped through media-filled pressure vessels to remove any residual contamination. The pressurized influent stream may be treated in stages using multiple filtration media typically consisting of granulated activated carbon or organo-clay. Once again, batch water treatment affords the opportunity for a QA/QC verified audit trail. At the completion of the process, the treated stream (effluent) is ready for discharge into the receiving body of water.

Figure 34 – In-situ treatment of dredge spoil water. Source: USEPA

5.4.5 LIQUID PHASE MANAGEMENT FOR OFF-SITE DISPOSAL

Liquid phase waste streams will typically consist of recovered bulk oil, oil/water emulsions and oily water. All of these waste streams are likely to be designated for off-site disposal with transportation provided by tank barges and ships. Because water content has already been entrained in these recovered products, the RO should be prepared for significant physical changes to occur during the transportation. Transportation by sea almost always results in some liquid agitation despite tank baffles that reduce free surface effects. The sloshing of the oil and water mixture augments product emulsification that increases viscosity and volume. At the final destination, those physical changes will make pumping the liquid from the tank vessel more difficult. These physical changes can be overcome by heat applied to the recovered product, either through integral heating coils or portable heat exchangers fitted on the suction side of over-the-top pumps. Emulsified oils can also be phase separated by the addition of a family of chemicals called de-emulsifiers or emulsion breakers (EB). Prior to the addition of EBs, it is important to verify that the chemicals will be compatible with the final process employed by the treatment, storage and disposal (TSD) facility. This is a consultation between TSD personnel and the EB manufacturer.

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APPENDIX A: EXPERIENCE WITH SUBMERGED OR SUNKEN OILS

REVIEW OF CASE STUDIES

To support the development of this Submerged and Sunken Oil Management Plan, 70 case studies of spills occurring between 1967 and 2015 were examined at a high level to identify submerged or sunken oil commonalties among them (Castle, 1995), (Michel, 2006) (Lehman, 2006) (Fitzpatrick, 2013) (IMO, 2014) (API, 2016). The conditions under which these products submerged and/or sank covered all the possibilities: fresh water, saltwater, rivers, oceans, swift currents, surf, sediment, fire, etc. The API gravities associated with these submerged or sunken oil cases ranged from -12.5°to 36.5°. There was no common denominator evident other than that of multiple simultaneous influences acting upon the spilled oils. The product allocation of the cases reviewed appears in Table 1.

Table 1 – Submerged or Sunken Oil Case Study Allocation by Product

Oil Class	Number of Incidents
Group V Oils	19
Bunker Fuels	35
Crude Oils	16

In 2016, the American Petroleum Institute released a technical report on Sunken Oil Detection and Recovery. This document builds on work done by Castle (1995), Michel (2006), Lehman, (2006), Fitzpatrick (2013), and the IMO (2014), among many others. The causes of submerged or sunken oil can be sorted into the following categories (API, 2016):

- Oil that was heavier than the water and sank to the bottom or was suspended in the water column by high turbulence
- Oil that initially floated then sank after stranding onshore
- Spilled oil that initially floated then sank or submerged without stranding onshore
- Spilled oil that initially floated then became submerged and moved on the bottom with the currents, with little to no accumulation
- Spilled oil that sank after burning or intense heating

Three variable influences caused the oil spills in these incidents to submerge or sink. These were, increased density due to weathering or temperature changes, exposure to sediment and exposure to high mixing energy. Alteration of any of those three influences can cause submerged or sunken oil to rise to the surface where it can be recovered by conventional mechanical countermeasures.

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