ANNEX W Contingency Planning Annex for Group V Oil (non-floating)

Contents:

DEFINITION OF TERMS

Benthic habitats - ecological region at the lowest level of a body of water such as an ocean or a lake, including the sediment surface and some sub-surface layers.

Emulsified fuels - anthropogenic fuels manufactured by mixing water with liquid oils or solid hydrocarbon products.

Group V oils are defined as persistent oils with a specific gravity greater than 1.0

Heavy oil is the term used by the response community to describe dense, viscous oils with the following general characteristics: low volatility (flash point higher than 65 degrees C), very little loss by evaporation, and a viscous to semisolid consistency.

Non-floating oil is used to describe all oils that do not float on water, including oils that are denser than the receiving waters and either sink immediately or mix into the water column and move with the water as suspended oil; as well as the portion of oil that is initially buoyant but sinks after interacting with sand.

BEHAVIORAL MODELS FOR SPILLS OF NON-FLOATING OILS

Based on an understanding of the physical and chemical properties of non-floating oils (mostly from observations of past spills), behavioral models have been developed. These models are descriptive, qualitative predictions of how oils with a density near or higher than the density of the receiving water might behave. The key factors that determine the behavior of spilled nonfloating oils are:

- water density;
- current speed; and
- the potential for interaction with sand.

Water Density

If the ratio of the density of oil to the density of the receiving water is greater than 1.0, the oil will not float. If it less than 1.0, the oil will float. If it is within a few percent of 1.0, then the oil is much more likely to become submerged by wave action. Figure 1 shows the relationship between the density and salinity of the water for a fixed temperature. The density is also shown in terms of the API (American Petroleum Institute) gravity. Oils with densities higher than the receiving water (above the line) will sink; whereas oils with densities lower than the receiving water (below the line) will initially float.

The density of oil relative to the receiving water is important only in determining whether the oil will initially float. Significant currents can keep heavier-than-water oil suspended in the water column.

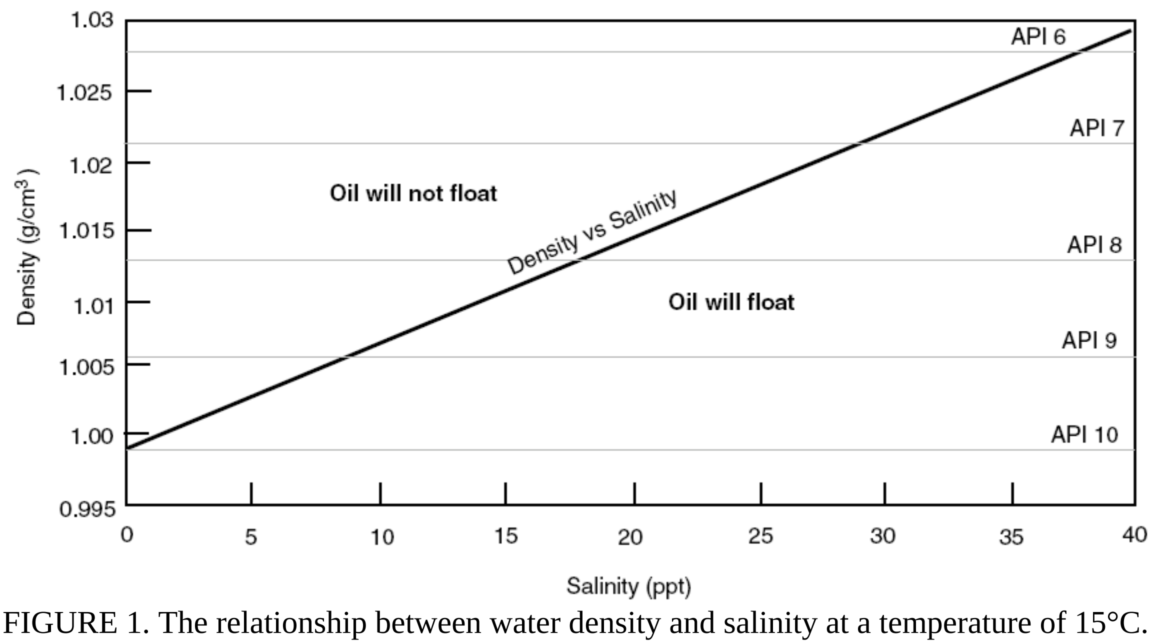


FIGURE 1. The relationship between water density and salinity at a temperature of 15°C. The density is also shown in API gravity units (right vertical axis).

Current Speed

If current speeds are greater than 0.1 m/s, non-floating oils will be suspended in the water column. If the currents are very slow, oils heavier than the receiving water will sink to the bottom (Nielsen, 1992).

Potential for Interaction with Sand
When floating oil is mixed with 2 to 3 percent sand, it becomes heavier than water and sinks (Michel and Galt, 1995). The models in Figures 2 and 3 illustrate combinations of factors that influence the behavior of non-floating oils.

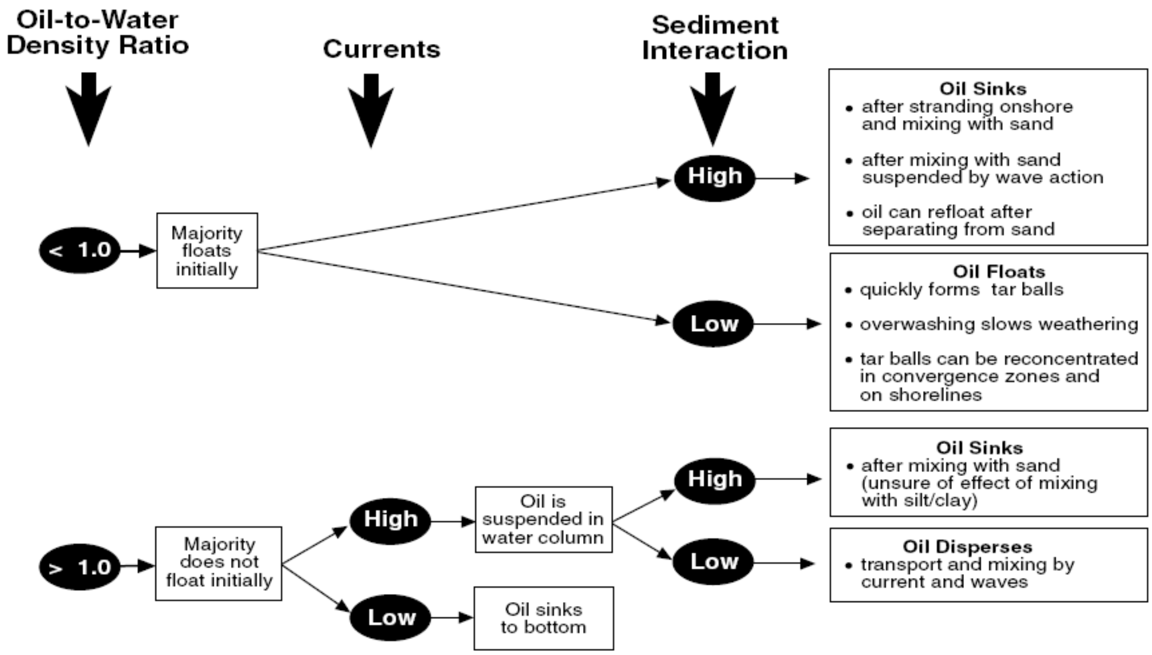


FIGURE 2. Behavior of spilled non-floating oils.

Refloating Mechanisms
Sunken oil can regain buoyancy, creating significant problems for spill-response teams and a chronic source of exposure to sensitive surface receptors.

There are three mechanisms for refloating oil:
(1) still-buoyant oil can separate from the sand;
(2) wave-generated currents can loosen and resuspend pieces of buoyant oil from the bottom; and
(3) increases in water and/or oil temperature can make the oil less viscous and/or more buoyant.

Spill response teams often assume that oil refloats because of a short-term change in temperature. A more likely mechanism for refloating sunken oil is the physical separation of the sediment from oil (Michel and Galt, 1995).

POTENTIAL EFFECTS OF NONFLOATING-OIL SPILLS

Oil on the surface is primarily weathered by evaporation, and to a lesser degree, to the water column by dissolution. Oils suspended in the water column or deposited on the bottom are less likely to evaporate but more likely to dissolve, although the water-soluble fraction of heavy oils is usually very low.

Table 1 compares the predicted impacts of non-floating oil spills and floating oil spills on shoreline and benthic habitats, major assemblages of fish and wildlife, and human-use resources. Spills of non-floating oils are expected to have less impact on shoreline habitats because smaller amounts of oil are likely to be stranded and cleanup activities are likely to be less disruptive (Scholz et al., 1994). Impacts on water-surface resources are also expected to be lower from spills of non-floating oils because of the significant reduction in the amount of oil on the water surface. All water-column and benthic habitats are at increased risks from spills of non-floating oils (Scholz et al., 1994).

TABLE 1. Relative Changes in the Resources at Risk from Spills of Non-floating Oils Compared to Floating Oils

Resource at Risk	**Risks from Spills of Non-floating Oils Compared to Spills of Floating Oils**
Note: (–) indicates a reduction in risk. (+) indicates an increase in risk. Actual risks for a specific spill will be a function of the composition and properties of the spilled oil and environmental conditions at the spill site.	
Rocky Shores (–)	Less oil is likely to be stranded, but oil that is stranded is usually stickier and thicker.
Beaches (–)	Viscous oils are less likely to penetrate porous sediments. Oil often stranded as tar balls are easy to clean up on sand beaches. Chronic recontamination is possible for months.
Wetlands / Tidal Flats (–)	Less oil coats vegetation. Because the oil does not refloat with the rising tide, any oil stranded on the lower intertidal zone will remain, thus increasing risk to biota. Cleanup of oil from these environments is very difficult, and natural recovery takes longer.
Water Surface (–)	Less oil remains on the water surface. Oil tends to form fields of tar balls. Potential for chronic impacts from refloated oil over time is high.
Water Column (+)	Oil can increase exposure as it mixes in the water column. Risks increase if oil refloats after separation from sediments. When submerged, slow weathering of the more toxic components can be a chronic source of risk.
Benthic Habitats (++)	Risks are significantly increased for areas where heavy oils accumulate on the bottom. Slow weathering rates further increase the risk of chronic exposures. Smothering and coating can be heavy. Bioavailability varies with oil and spill conditions.
Birds (–)	Less oil remains on the water surface, so direct and acute impacts are lower. There is a high probability of chronic impacts from exposure to refloated oil and restranded tar balls on shores after storms. Consider life-stages and feeding styles of specific birds.
Fish (++)	Risks are increased to all fish, especially benthic or territorial fish, and to early life stages (i.e., eggs, fry) in areas where oil has accumulated on the bottom.
Shellfish (++)	Risks are increased to all shellfish, especially species that spend most of their time on the sediment surface (e.g., mussels, lobsters, crabs). Risk of chronic exposure from bulk oil, as well as the slow release of water soluble PAHs (polynuclear aromatic hydrocarbons), is high.
Marine Mammals (+/–)	Less oil remains on the water surface, and the potential for contamination of marine mammals on shore is lower. Oil in the water column is not likely to have an impact on highly mobile species. Benthic feeders (such as manatees) could be exposed from accumulations on the bottom, which would weather slowly.
Sea Turtles (–)	Less oil remains on the water surface, and less oil is stranded on nesting beaches.
Water Intakes (++)	Oil mixed into the water column would pose serious risks to water treatment facilities. Closures are likely to be longer.

TRACKING AND MAPPING TECHNIQUES

Techniques for tracking and mapping the location of oil throughout a spill and subsequent cleanup are critical to the effective containment and recovery of oil in the water column or deposited on the seabed. As a practical guide to determining which tracking and mapping options are most appropriate, Figure 3 provides a typical decision tree based on oil density and water depth.

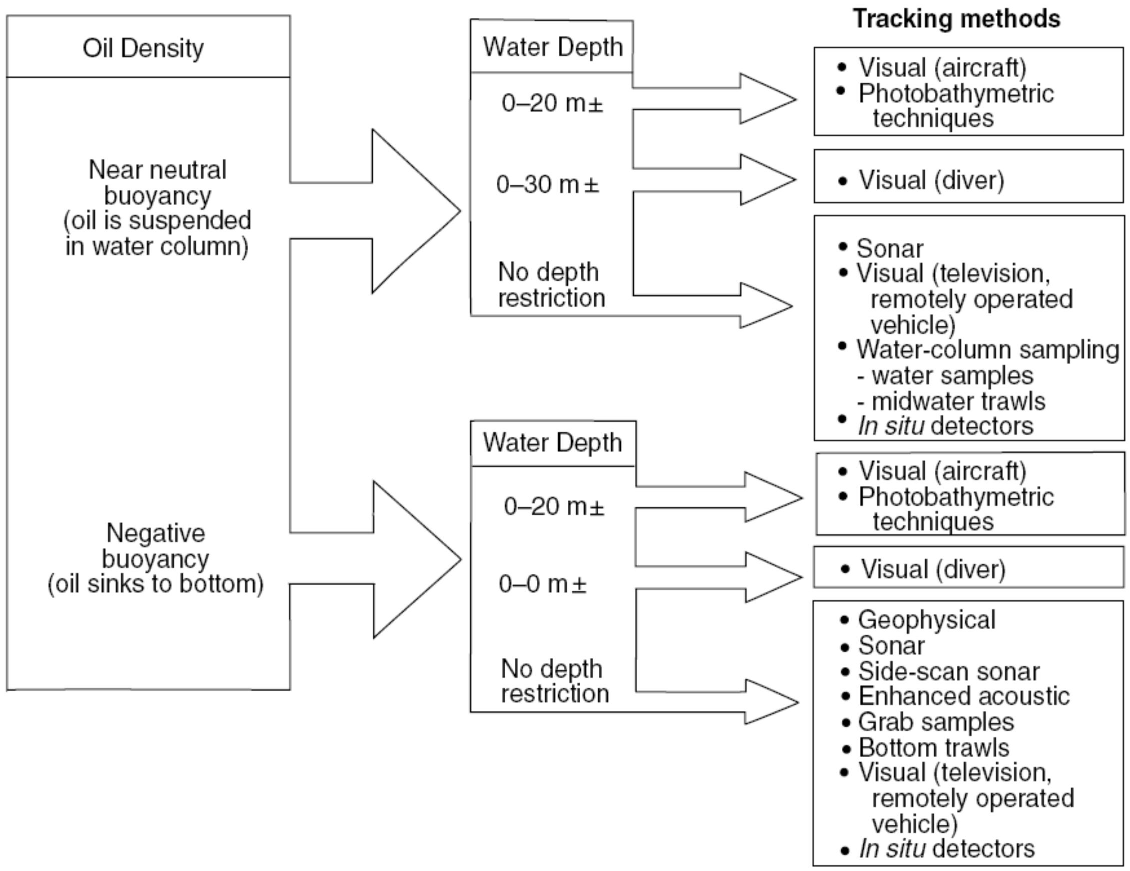


FIGURE 3. Tracking Methods Decision tree based on oil density and water depth. (Source: Castle et al., 1995.)

The appropriate method for tracking and mapping a particular spill depends on whether the oil is suspended in the water column or deposited on the seabed and on the water depth and clarity. In general, visual and photobathymetric techniques are restricted to water depths of 20 meters or less and are suitable for both suspended and deposited oil. Diver-based visual observations can only be used in low-current and small wave areas. Acoustic techniques, television observations, water-column and bottom sampling, *in situ* detectors, and nets and trawls typically have no depth restrictions except that the water must be deep enough for the instrument to be deployed and operated safely. They become more difficult to operate, however, as the current speed and wave height increase. Measurements near the seabed become more challenging as the topographic relief of the bottom increases and the bottom surface becomes rougher. Tables 2-1 and 2-2 provide a summary of the uses and limitations of various tracking and mapping methods.

TABLE 2-1. Options for Tracking Oil Suspended in the Water Column

	Visual Observations	**Water Sampling**
Description	Trained observers in aircraft or on vessels look for visual evidence of suspended oil; includes use of cameras.	Visual inspection or chemical analysis of grab water samples or a flow-through system with a fluorometer.
Availability of Equipment	Uses readily available equipment.	Uses readily available equipment and supplies.
Logistical Requirements	Low/aircraft and vessels are readily available during spill response.	May require boat, sampling equipment, pumps, GPS for station location, portable oil analyzer.
Coverage Rate	High for aircraft; moderate for vessels.	Very low coverage rate; collecting discrete water samples at multiple depths for testing is very slow.
Data Turnaround	Quick turnaround.	Quick turnaround for visual analysis; chemical results would have to be available in minutes to be effective.
Probability of False Positives	High probability, due to poor water visibility, cloud shadows, seagrass beds, irregular bathymetry, mixing of different waterbodies.	Low probability; field personnel would have to know how to operate all equipment.
Operational Limitations	Requires good water visibility and light conditions; poor weather may restrict flights; limited to daylight hours.	Realistic only for water depths <30 ft; sea conditions may restrict vessel operations.
Pros	Can cover large areas quickly using standard resources available at spills.	Can be used at points of concern, such as water intakes.
Cons	Only effective in areas with very low water turbidity.	Too slow to be effective in dynamic settings or over large areas.

TABLE 2-1 (Continued). Options for Tracking Oil Suspended in the Water Column

	Fish Net Trawl	Sorbent Fences	Airborne Imaging LIDAR
Description	Fish nets or trawling gear are towed for set distances then inspected for presence of oil; or nets can be set at fixed points and regularly inspected.	Sorbents are attached to something like a chain link fence which is submerged into the water then pulled for inspection; or it could be set at a fixed point for regular inspection.	Pulsed laser and video recording system compares back-reflectance from below the water surface for areas of suspended oil versus clean water. Detection depth varies (nominally 45 ft). Operable 24 hours/day.
Availability of Equipment	Readily available in commercial fishing areas.	Uses readily available equipment and supplies.	Uses very specialized equipment of limited availability.
Logistical Requirements	Moderate; requires boat and operators to tow the nets; may require multiple vessels to cover large areas; may require many replacement nets as they become oiled.	Low; can be deployed from small boats or carried to small streams for deployment.	Moderate; equipment must be modified for mounting on local aircraft; requires skilled operators.
Coverage Rate	Low coverage; nets have a small sweep area and must be pulled frequently for inspection.	Low; they have a small sweep area and they have to be pulled frequently for inspection.	High; flown on aircraft with 200 ft swath.
Data Turnaround	Quick turnaround.	Quick.	Moderate; data recorded on video.
Probability of False Positives	Low probability; oil staining should be readily differentiated from other fouling materials.	Low; sorbents are designed to pick up oil, so they would be less likely to be stained by other materials.	High; system images all submerged features, have to learn to identify patterns for different features, thus requires extensive ground truthing.
Operational Limitations	Obstructions in the water can hang up nets; restricted to relatively shallow depths; sea conditions may restrict vessel operations.	Difficult to deploy and retrieve in strong currents; sea conditions may restrict vessel operations.	Weather may restrict flights; minimum detectable size of oil particle is not known, but other individual features detected are usually feet in size or schools of small fish.
Pros	Can sweep various depths or very close to the bottom.	Uses material available anywhere.	Can cover large areas quickly using standard resources available at spills; permanent record or image that is geo-referenced.
Cons	Very slow; nets can fail from excess accumulation of debris.	Very slow; very limited sampling area.	Not proven for detecting suspended oil droplets; very limited availability.

TABLE 2-2. Options for Mapping Oil Deposited on the Seabed.

	Visual Observances	Bottom Sampling from the Surface	Underwater Surveys by Divers
Description	Trained observers in aircraft or on vessels look for visual evidence of oil on the bottom; includes underwater cameras.	A sampling device (corer, grab sampler, sorbents attached to weights) is deployed to collect samples from the bottom for visual inspection.	Divers (trained in diving in contaminated water) survey the sea floor either visually or with video cameras.
Availability of Equipment	Uses readily available equipment.	Uses readily available equipment and supplies.	Underwater video cameras are readily available, but divers and diving gear for contaminated water operations may not be available locally.
Logistical Needs	Aircraft and vessels are readily available during spill response.	Requires boat, sampling equipment, GPS for station location.	Depend on the level of diver protection required.
Coverage Rate	High for aircraft; low for vessels.	Very low coverage; collecting discrete bottom samples is very slow; devices sample only a very small area.	Low coverage, because of slow swimming rates, limited diving time, poor water quality.
Data Turnaround	Quick turnaround.	Quick turnaround because visual analysis is used.	Quick turnaround.
Probability of False Positives	High, due to poor water clarity, cloud shadows, seagrass beds, irregular bathymetry.	Low probability, except in areas with high background oil contamination.	Low probability because divers can verify potential oil deposits.
Operational Limitations	Requires good water clarity and light conditions; weather may restrict flights; can be used only during daylight hours.	Sea conditions may restrict vessel operations.	Water depths of 20 m (for divers); minimum visibility of 0.5-1m; requires low water currents.
Pros	Can cover large areas quickly using standard resources available at spills.	Can be effective in small areas for rapid definition of a known patch of oil on the bottom; low tech option; has been proven effective for certain spills.	Accurate determination of oil on bottom; verbal and visual description of extent and thickness of oil and spatial variations.
Cons	Only effective in areas with high water clarity; sediment cover will prevent detection over time; ground truthing required.	Samples a very small area, which may not be representative; too slow to be effective over large area; does not indicate quantity of oil on bottom.	Slow; difficult to locate deposits without GPS; decontamination of diving gear can be costly/time consuming.

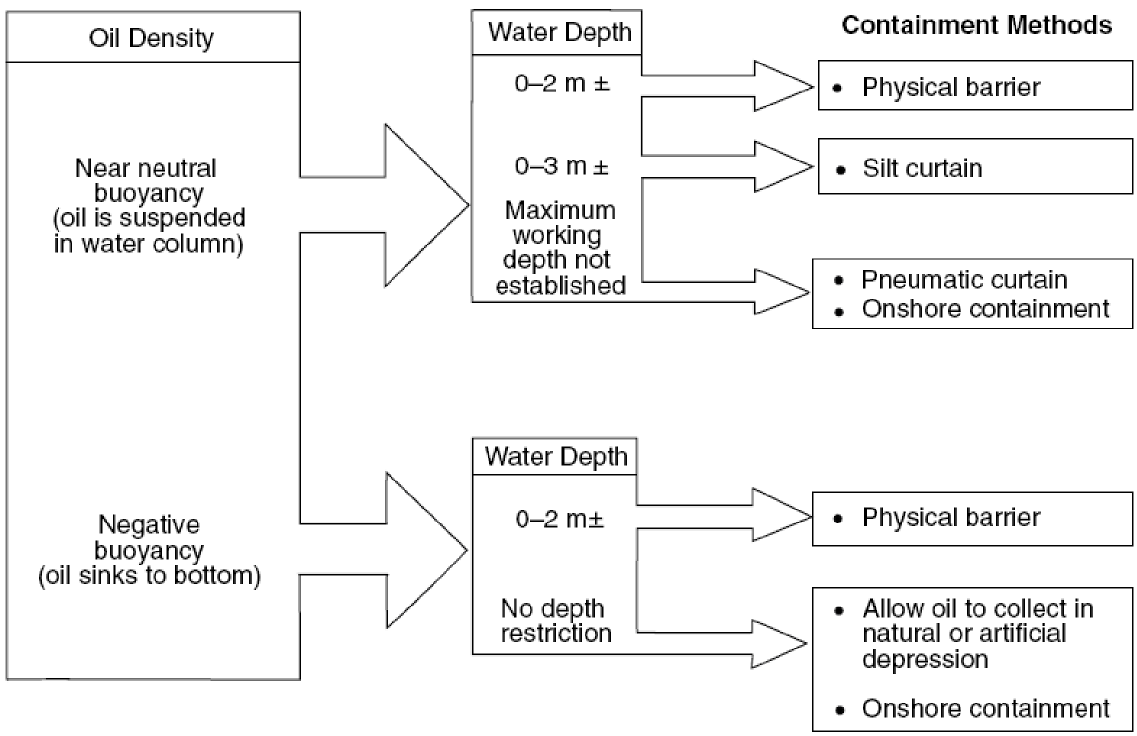
TABLE 2-2 (Continued). Options for Mapping Oil Deposited on the Seabed.

	Bottom Trawls	**Photobathymetry**	**Geophysical/Acoustic Techniques**
Description	Fish nets or trawling gear are towed on the bottom for set distance then inspected for presence of oil.	Aerial stereo photography mapping technique used to identify and map underwater features (a realistic scale is 1:10000).	Sonar system that uses the differential density and sound speeds in oil and sediment to detect oil layers on the bottom; a fathometer records a single line under the sounder; side-scan sonar records a swath; output can be enhanced to increase detection.
Availability of Equipment	Readily available in commercial fishing areas.	Available from most private aerial mapping companies, with specifications.	Requirements vary; often not available locally; need trained personnel.
Logistical Needs	Requires boat and operators to tow the nets; may require multiple vessels to cover large areas; may require many replacement nets as they become oiled.	Aircraft specially equipped to obtain vertical aerial photography with GPS interface.	Requires boat on which equipment can be mounted; requires updated charts so that search area can be defined.
Coverage Rate	Low coverage; nets have a small sweep area and they have to be pulled up frequently for inspection.	High coverage.	Moderate coverage; data collected at speeds up to m/s.
Data Turnaround	Quick turnaround.	Slow turnaround; aerial photographs can be produced in a few days in most places; data interpretation takes one or tow additional days.	Medium turnaround; data processing takes hours; preliminary data usually available next day; requires ground truthing.
Probability of False Positives	Low probability; oil staining should be readily differentiated from other fouling materials.	High probability; photography can be used to identify potential sites, which require ground truthing.	High probability identifies potential sites, but all need ground truthing.
Operational Limitations	Obstructions on the bottom can hang up nets; restricted to relatively shallow depths; sea conditions may restrict vessel operations.	Specifications call for low sun angles and calm sea state; water penetration is limited by water clarity; maximum penetration is 10m for very clear water, 1m for turbid water; best if baseline “before” photography is available for comparison.	Sea conditions must be relatively calm to minimize noise in the record.
Pros	Can provide data on relative concentrations on the bottom per unit trawl area/time; can survey in grids for more representative area coverage.	Rapid assessment of large areas; high spatial resolution; good documentation and mapping.	Can be used to identify potential accumulation areas; complete systems can generate high-quality data with track lines, good locational accuracy.

Cons	Very slow; nets can fail from excess accumulation of debris.	Limited by water clarity, sun angle, and availability of historic photography for comparison.	Data processing can be slow; requires extensive ground truthing; requires skilled operators.

CONTAINMENT AND RECOVERY METHODS
Figures 4 and 5 captures the current state of practice for containing and recovering heavy oils.

FIGURE 4. Decision tree for containment options for sunken oil. Source: Castle et al., 1995.



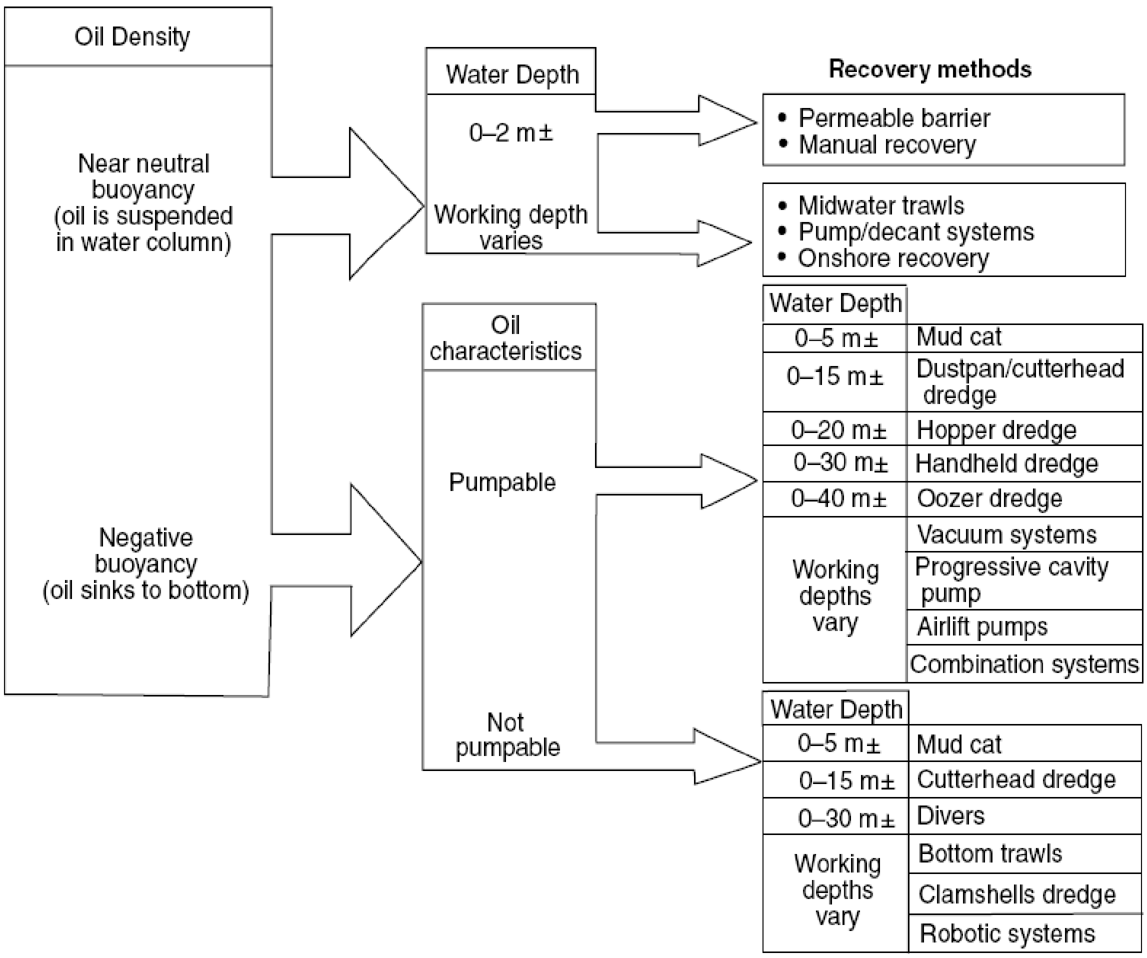


FIGURE 5. Decision tree for recovery options for sunken oil. Source: Castle et al., 1995.

Containment

Different strategies for containing these oils can be used depending on the location of the oil. Typical response strategies are described below. Few of these techniques have been used and their performance has not been documented during spill events.

Oil in the Water Column

*Silt Curtains***.** Silt curtains, which are normally used to control the transport of suspended sediment during dredging operations, are typically restricted to water depths of 3 to 6 meters and are deployed so that the bottom of the curtain does not extend to the seabed.

*Nets and Trawls***.** Delvigne (1987) has suggested that nets can successfully contain oil if the currents are low (less than 10 cm/sec) and the viscosity of the oil is high. Nets can be towed, moored, or mounted on moving floats. This method is sometimes used to protect fixed structures (water intake systems) or resources at risk.

*Pneumatic Barriers and Booms***.** Pneumatic barriers involve injecting air at the seabed and forming a bubble plume that rises to the surface. Standard oil booms (deep draft) have been considered for containing subsurface oil. Booms can be used only when the oil remains in the upper water column, the currents are low (less than 0.20 m/sec), and the waves are small (less than 0.25 m).

Oil on the Seabed

*Seabed Depressions***.** Sedimented oil tends to collect in natural or man-made depressions on the bottom. Dredging to create depressions for oil collection is not practical as part of a spill response except for very large spills or spills that have very substantial benthic impacts. Identification of natural depressions and collection points, however, may be very useful for locating sedimented oil and planning for its recovery.

*Bottom Booms***.** Bottom-mounted boom systems could be used to contain oil on the seabed. The booms could be moored to the seabed and flotation used to maintain the vertical structure of the boom. These systems are only suitable for locations with low currents and little wave activity.

Recovery

The recovery of sunken oil has proven to be very difficult and expensive because the oil is usually widely dispersed. Several of the most widely used recovery methods are reviewed below.

Manual Removal The manual removal of oil, one of the most widely used recovery methods, involves divers or boat-based personnel using dip nets or seines to collect oil, which is temporarily stored in bags or containers. The purpose of manual recovery is to remove the oil and minimize the collection, handling, treatment, storage, and disposal of other material (oiled sediment, sediment, and water). This approach can be useful for widely dispersed oil, and its effectiveness can be assessed by cleanup standards or criteria. The biggest disadvantages of manual removal are the large manpower and logistical requirements, slow rates of recovery, strong dependency on weather conditions, and the potential for the oil to be transported while it is being recovered.

Pump and Vacuum Systems They typically consist of a submersible pump/vacuum system, an oil-water separator, and a storage container. The systems can be mounted on trucks, on land, or on barges or ships. The suction head of the system is normally directed and controlled by divers and may have an air or water injection system to assist in fluidizing and transporting the slurry. Highly viscous or solid oils are usually not pumpable and, hence, are not recoverable with this method. The pumped mixture is typically routed to an oil-water separator from which the oil and oiled sediment are removed and stored. Pumps and vacuum systems are effective if the oil is localized but are not practical for large areas. They also require extensive equipment and the capacity to handle and treat large volumes of water and sediments.

Nets and Trawls Nets and trawls can also be used as collection devices. This approach is most successful when the relative velocity of the water and the oil collected in the net or trawl is low and the viscosity of the oil is high. The effectiveness decreases as the permeability of the net is reduced and flows are diverted around the net (Delvigne, 1987).

Dredging Dredging is an efficient, well developed method for removing large volumes of sediment (and oil) from the seabed at high recovery rates. Large volumes of water, oil, and sediment are typically generated in the dredging process and must be handled, stored, and disposed of as the recovery operation proceeds. Accurate vertical control of the dredge depths is critical to minimizing the amount of dredged material and the amount of clean sediment contaminated with oil as the result of the dredging operation. Operational costs and logistics requirements are lower for land-based than for barge based methods of handling and storing dredged materials.

Pooled Oil Recovery Methods Several methods were evaluated for recovery of the pooled oil in the trench. Options included: - Diver-directed pumping systems with positive displacement pumps that can move viscous oils - Dredging systems of different sizes - Subsurface recovery using sorbents, either by divers or remote techniques

Onshore Recovery In some cases, oil that has been submerged and mixed with sediment enters the surf zone and is eventually moved onshore and deposited on the shoreline. In these cases, conventional shoreline cleanup methods can be used to remove the oil.

Containment and Recovery Summation

The containment and recovery of oil dispersed in the water column or deposited on the seabed are very difficult. The problem begins with locating the oil and determining its status. The success of current methods varies greatly but is usually limited because the oil, which is mixed with sediments and water, is usually widely dispensed. The selection of containment and recovery methods is highly dependent on the specific location and environmental conditions during the spill, the characteristics of the oil and its state of weathering and interaction with sediments, the availability of equipment, and logistical support for the cleanup operation. In addition, the potential environmental impacts of implementing these methods, particularly in sensitive benthic habitats, must be considered. Tables 3-1 and 3-2 summarize the uses and limitations of various containment and recovery methods.

Oil that is spilled and transported subsurface either remains suspended in the water column or is deposited on the seabed, usually after interaction with suspended sediments or sand. Different strategies for containing these oils can be used depending on the location of the oil. Typical response strategies are described below. Few of these techniques have been used and their performance has not been documented during spill events.

TABLE 3-1: Options for Containing Oil Suspended in the Water Column

	Pneumatic Barriers	**Net Booms**	**Silt Curtains**
Description	Piping with holes is placed on the bottom, and compressed air is pumped through it, creating an air	Floating booms with weighted skirts (1-2 m long) composed of mesh designed to allow water to	During dredging operations, silt curtains are deployed as a physical barrier to the

	bubble barrier.	pass while containing suspended oil.	spread of suspended oil; weighted ballast chains keep the curtain in place.
Availability of Equipment	Uses readily available equipment, although in unique configuration.	There are commercially available net booms that have been developed and tested for containing spills of Orimulsion; little availability in the United States.	Not readily available; limited expertise in deployment and maintenance.
Logistical Requirements	Moderate; requires a system to deploy and maintain bubbler; piping has tendency to clog; high installation costs.	Moderate; similar to deployment of standard booms, but with added difficulty because of longer skirt; can become heavy and unmanageable.	Moderate; deployment and maintenance.
Operational Limitations	Only effective in low currents (<0.2 m/sec), small waves, and shallow water >2 m.	In field tests, the booms failed in currents <0.75 knots; very limited few conditions.	Only effective in very low currents (<10cm/sec); practical limits on curtain depth are 3-6m, which normally doesn't extend to the bottom.
Optimal Conditions	To contain oil spilled in dead-end canals and piers; to protect water intakes.	Will contain oil in very low-flow areas, such as dead-end canals and piers.	Stilt water bodies such as lakes; dead-end canals.
Pros	Does not interfere with vessel traffic.	Can be deployed similar to traditional booms.	Can be deployed throughout the entire water column.
Cons	Only effective under very limited conditions; takes time to fabricated and deploy, thus only effective where pre-deployed; little data available to assess performance.	Only contains oil suspended in the upper water column, to the depth of the mesh skirt; unknown whether the mesh will clog and fail at lower currents.	Effective under very limited conditions, not likely to coincide with location where oil needs containment; oil droplets are larger that silk and could clog curtain.

TABLE 3-2: Options for Recovering Oil Deposited on the Seabed.

	Manual Removal by Divers	**Nets/Trawls**
Description	Divers pick up solid and semi-solid oil by hand or with nets on the bottom, placing it in bags or other containers.	Fish nets and trawls are dragged on the bottom to collect solidified oil.
Availability of Equipment	Contaminated-water dive gear may not be locally available.	Nets and vessels readily available in areas with commercial fishing industry.
Logistical Needs	Moderate; diving in contaminated water requires special gear and decon procedures; handling of oily wastes on water can be difficult.	Low; uses standard equipment, though nets will have to be replaced often because of fouling.
Operational Limitations	Water depths up to 60-80 ft for routine dive operations; water visibility of 1-2 ft so divers can see the oil; bad weather can shut down operations.	Water depths normally reached by bottom trawlers; obstructions on the bottom which will hang up nets; rough sea conditions; too shallow for boat operations.
Optimal Conditions	Shallow, protected areas where dive operations can be conducted safely; small amount of oil; scattered oil deposits.	Areas where bottom trawlers normally work; solidified oil.
Pros	Divers can be very selective, removing only oil, minimizing the volume of recovered materials; most effective method for widely scattered oil deposits.	Uses available resources; low tech.
Cons	Large manpower and logistics requirements; problems with contaminated water diving and equipment decon; slow recovery rates; weather dependent operations.	Not effective for liquid or semi-solid oil; nets can quickly become clogged and fail; can become heavy and unmanageable if loaded with oil; could required many nets which are expensive.

TABLE 3-2 (Continued): Options for Recovering Oil Deposited on the Seabed.

	Pump and Vacuum Systems (Diver-directed)	Dredging
Description	Divers direct a suction hose connected to a pump and vacuum system, connected to oil-water separator, and solids containers. Viscous oils require special pumps and suction heads. Even in low water visibility, divers can identify oil by feel or get feedback from top-side monitors of changes in oil recovery rates in effluents.	Special purpose dredges, usually small and mobile, with ability for accurate vertical control. Uses land or barge-based systems for storage and separation of the large volumes of oil-water-solids.
Availability of Equipment	Readily available equipment, but needs modification to spill conditions, particularly pumping systems, and capacity for handling large volumes of materials during oil-water-solids separation.	Varies; readily available in active port areas; takes days/week to mobilize complete systems.
Logistical Needs	High, especially if recovery operations are not very close to shore. On-water systems will be very complicated and subject to weather, vessel traffic, and other safety issues.	High, especially if recovery operations are not very close to shore, because of large volumes of materials handled. On-water systems will be very complicated and subject to weather, vessel, traffic and other safety issues.
Operational Limitations	Water depths up to 60-80 ft for routine dive operations; water visibility of 1-2 ft so divers can see the oil; bad weather can shut down operations; solid oil which is not pumpable.	Min/max water depths are a function of dredge type, usually 2-100 ft; not in rocky substrates; bad weather can shut down operations.
Optimal Conditions	Sites adjacent to shore, requiring minimal on-water systems; liquid or semi-solid oil; thick oil deposits, good visibility; low currents.	Large volume of thick oil on the bottom; need for rapid removal before conditions change and oil is remobilized, buried by clean sediment, or will have larger environmental effects.
Pros	Most experience is with this type of recovery; diver can be selective in recovering only oil and effective with scattered deposits.	Rapid removal rates; can recover non-pumpable oil.
Cons	Very large manpower and logistics requirements, including large volumes of water-oil-solids handling, separation, storage, and disposal; problems with contaminated water diving and equipment decon; slow recovery rates; weather dependent operations.	Generates large volumes of water/solids for handling, treatment, disposal; large logistics requirements; could re-suspend oil/turbidity and affect other resources.

Table 3-3. Options for containing oil suspended in the water column.

	Pneumatic Barriers	Net Booms	Silt Curtains
Description	Piping with holes is placed on the bottom, and compressed air is pumped through it, creating an air bubble barrier.	Floating booms with weighted skirts (1-2 m long) composed of mesh designed to allow water to pass while containing suspended oil.	During dredging operations, silt curtains are deployed as a physical barrier to the spread of suspended oil; weighted ballast chains keep the curtain in place.
Availability of Equipment	Uses readily available equipment, although in unique configuration.	There are commercially available net booms that have been developed and tested for containing spills of Orimulsion; little availability in the United States.	Not readily available; limited expertise in deployment and maintenance.
Logistical Requirements	Moderate; requires a system to deploy and maintain bubbler; piping has tendency to clog; high installation costs.	Moderate; similar to deployment of standard booms, but with added difficulty because of longer skirt; can become heavy and unmanageable.	Moderate; deployment and maintenance.
Operational Limitations	Only effective in low currents (<0.2 m/sec), small waves, and shallow water >2 m.	In field tests, the booms failed in currents <0.75 knots; very limited few conditions.	Only effective in very low currents (<10cm/sec); practical limits on curtain depth are 3-6m, which normally doesn't extend to the bottom.
Optimal Conditions	To contain oil spilled in dead-end canals and piers; to protect water intakes.	Will contain oil in very low-flow areas, such as dead-end canals and piers.	Stilt water bodies such as lakes; dead-end canals.
Pros	Does not interfere with vessel traffic.	Can be deployed similar to traditional booms.	Can be deployed throughout the entire water column.
Cons	Only effective under very limited conditions; takes time to fabricated and deploy, thus only effective where pre-deployed; little data available to assess performance.	Only contains oil suspended in the upper water column, to the depth of the mesh skirt; unknown whether the mesh will clog and fail at lower currents.	Effective under very limited conditions, not likely to coincide with location where oil needs containment; oil droplets are larger that silk and could clog curtain.

References

Material referenced in this Annex is taken from:
Spills of Non-floating Oils: Risk and Response
Committee on Marine Transportation of Heavy Oils, National Research Council
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The full PDF can be downloaded from: http://www.nap.edu/catalog/9640.html