Shoreline In Situ Treatment (Sediment Mixing and Relocation) Job Aid

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Shoreline In Situ Treatment (Sediment Mixing and Relocation) Job Aid

Introduction and Purpose

The purpose of this Job Aid is to provide:

- A non-technical tool for planning and conducting shoreline in situ treatment for use by:
    - Shoreline Cleanup Assessment Technique (SCAT) teams as they develop Shoreline Treatment Recommendations (STRs);
    - Environmental Unit personnel and planners during the decision process; and
    - Shoreline Operations to implement the treatment tactics.
- Decision Guides and Checklists to assist in:
    - understanding the advantages and consequences of shoreline in situ treatment options; and
    - the decision, review, and approval process for shoreline in situ treatment.

This Job Aid is part 3 of a series of tools developed for Shoreline In Situ Treatment planning and decisions:

1. Shoreline In Situ Treatment Library [1]: a database of guidance, papers and reports relating to shoreline in situ treatment, natural cleaning, and the formation of Oil-Particle Aggregates (OPA).
2. Shoreline In Situ Treatment (Sediment Mixing and Relocation) Fact Sheet [2]: a document explaining the applications and advantages of using shoreline in situ treatment techniques.
3. Shoreline In Situ Treatment (Sediment Mixing and Relocation) Job Aid (this document).

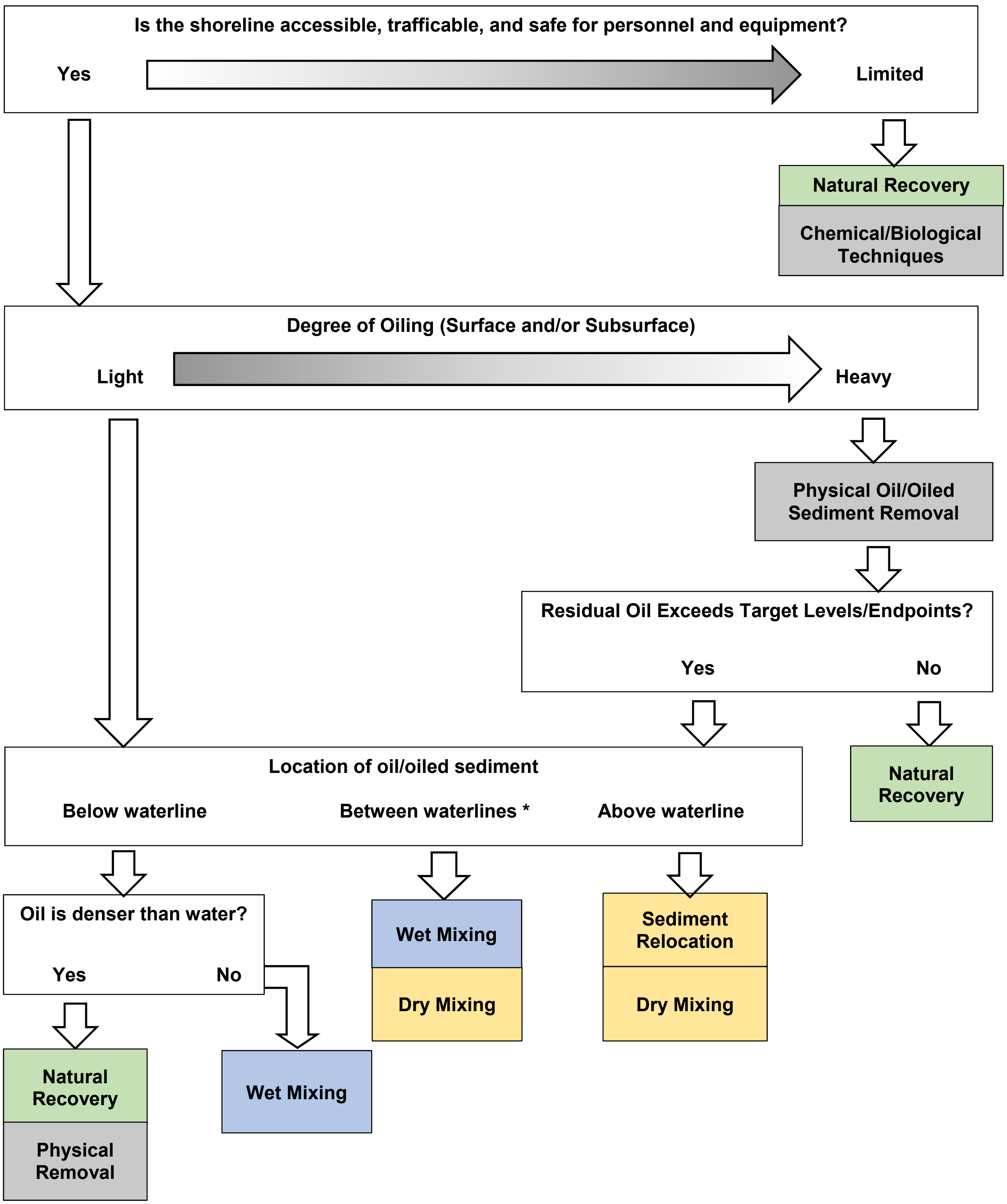
There are four basic groups of techniques available for shoreline oil response, including natural recovery:

Natural Recovery	Removal	In situ	Chemical and Biological
•No intervention •Shoreline recovery may be monitored	•Manual removal •Mechanical removal •Flushing •Washing •Vacuum removal	•Dry mixing •Wet mixing •Sediment relocation •Burning	•Dispersants •Shoreline cleaners •Solidifiers •Bioremediation

This Job Aid provides guidance for the planning and implementation of in situ techniques on shorelines and rivers, including wet and dry **mixing** (also known as tilling or aeration) and **sediment relocation** (also known as surf washing or berm relocation) for oil spill cleanup. Burning on the shoreline is outside the scope of this Job Aid.

[1] API. (2016). Shoreline In Situ Treatment Library: www.shorelineinsitutreatment.com.
[2] API. (2016). *Shoreline In Situ Treatment (Sediment Mixing and Relocation) Fact Sheet*. API Technical Report 1154-2.

Shoreline/River Sediment In Situ Treatment Decision Guide



* The same location can be treated by dry mixing during low water levels and by wet mixing during high water levels.

This Job Aid is organized as follows:

1. Summary of Shoreline In Situ Treatment
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- Operational and Environmental considerations
- Sampling and Monitoring
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1 Summary of Shoreline In Situ Treatment

Objectives

Oiled shoreline or riverbank treatment operations are conducted to accelerate the natural recovery processes by a range of physical removal or treatment tactics, or by chemical or biological treatment. In situ treatment involves techniques that significantly promote natural weathering and removal of oil, require few resources, and do not generate oiled sediment waste. Unlike removal techniques, in situ treatment does not involve the removal, recovery, or transfer of oil or oiled materials from the treatment location, although wet mixing can involve recovery if oil is released to the water surface. Unlike chemical or biological techniques, in situ treatment does not involve the addition of treatment agents. In situ techniques can be used in combination with other tactics as part of a phased response, for example, “polishing” after bulk oil removal.

The objectives of each of the three tactics and the fate of the treated oil are summarized in the following table:

Tactic	Objective	Fate of Oil
Dry Mixing	Physically break up stranded oil, which reduces sediment adhesion and compaction, and increases the surface area of the oil available for weathering.	The increase in surface area accelerates the natural weathering processes of evaporation, biodegradation, and photo-oxidation.
Wet Mixing	Cause shallow, underwater agitation of oil that is less dense than water to release that oil from intertidal and subtidal or river sediments.	Oil is released from the sediment to the water surface, which accelerates natural weathering and removal processes. Released oil may be collected for disposal/treatment.
Sediment Relocation	Relocate oiled sediments from one section of a beach to an area where the waves or current energy is greater, and/or where fine particles are present for OPA formation.	The physical energy and/or formation of OPA increases the surface area of the oil, and therefore accelerates the natural weathering processes of evaporation, biodegradation, and photo-oxidation.

In most cases, the formation of Oil Particle Aggregates (OPA) is critical for in situ treatment recommendations. The mixing of oil with fine particles, for example, clays, creates an OPA emulsion that significantly increases the surface area of the oil that is exposed to biodegradation and photo-oxidation. OPA and weathering processes are discussed in more detail in the *Shoreline In Situ Treatment Fact Sheet* (API Technical Report 1154-2). It is important to recognize that the various processes associated with OPA generate buoyant or neutrally buoyant emulsions that do not sink. Therefore, the intention of techniques that promote OPA formation is to release oil from sediment and to enhance natural dispersion as opposed to sinking the oil.

Application

In situ treatment techniques can be applied in a variety of situations, including:

- Oiled sediments, ranging from mud to cobbles
- Marine, estuarine and freshwater (e.g. lake and river) environments
- High and low energy environments
- Dry and wet (underwater) environments
- Surface and subsurface oiling.

The following table compares the applicability of the different shoreline in situ treatment tactics for different shoreline or river environments and oil types.

	Dry Mixing	Wet Mixing	Sediment Relocation
Sediment Type *			
Mud	✓	✓	✓
Sand	✓	✓	✓
Mixed Sediment (sand-pebble-cobble)	✓	✓	✓
Pebble	✓	✓	✓
Cobble	✓	✓	✓
Boulder			
Shoreline Location			
Supra-tidal Zone (SUTZ)	✓		✓
Upper Intertidal Zone (UITZ)	✓		✓
Middle Intertidal Zone (MITZ)		✓	✓
Lower Intertidal Zone (LITZ)		✓	
Subtidal (to 3 ft water depth)		✓	
River Location			
Above the water line (dry)	✓		✓
Below the water line (wet)		✓	
Oiling Depth			
Surface	✓	✓	✓
Subsurface: <0.2 ft (0.5 m)	✓	✓	✓
Subsurface: 0.2–3 ft (0.5–1 m)	✓		✓
Subsurface: 3–6 ft (1–2 m)			✓
Subsurface: >6 ft (2 m)			✓
Oil Type			
Volatile		✓	
Light	✓	✓	✓
Medium	✓	✓	✓
Heavy	✓	✓	✓
Solid			
Oil Character			
Pooled		✓	
Emulsion (Mousse)	✓	✓	✓
Surface Residue	✓		✓
Asphalt Pavement	✓		
Tarballs		✓	

* Man-made shorelines may be considered the equivalent of similar sized natural sediments, e.g. rip-rap = man-made boulder.

Advantages of Shoreline In Situ Treatment

The many advantages of using shoreline in situ treatment techniques include:

- ✓ Accelerates natural oil removal and weathering
- ✓ Reduces the persistence of oil on the shoreline
- ✓ Creates Oil Particle Aggregates (OPA), which accelerate the natural degradation of the oil
- ✓ Sediment is not removed, therefore:
  - — The risk of shoreline/river bank erosion is minimized
  - — Waste generation and potential associated impacts due to storage, transportation, treatment, or disposal are minimized
- ✓ Treatment agents/chemicals are not required
- ✓ Treatment is rapid compared to other techniques; therefore, the duration of disturbance due to equipment and personnel is reduced
- ✓ Labor and equipment requirements are low and logistics support is minimal
- ✓ Applicable to remote areas and areas with limited access and/or staging.

Safety

The safety of responders and the public is always the number one priority for an oil spill response. Treatment activities should be assessed for job safety during the planning stage. In addition to personnel and equipment safety, consideration should be given to the site-specific operating environment and conditions, such as:

- Uneven/unstable shoreline or river bank
- Steep slopes or scarps
- Soft and/or wet sediments
- Low load-bearing capacity
- Poor trafficability
- Unsafe access by road, sea, or air
- Strong currents
- High energy shoreline or large tidal range
- Public access.

NOTE Operation in water may be hazardous to equipment and operators. Special equipment preparation and maintenance may be necessary.

2 STRATEGIES—Scope and Application of Shoreline In Situ Treatment

Shoreline in situ techniques may be used for a variety of levels of oiling. Sediment relocation and dry mixing are typically used on light to moderate oiling. For heavier oiling concentrations, in situ treatment techniques can be used in combination with other tactics as part of a phased response, where the bulk oil is removed mechanically or manually before sediment relocation or mixing.

Field tests can be beneficial to provide an understanding of the applicability and effectiveness of the treatment, and of the final fate of the oil. Monitoring during tests and treatment operations should be conducted to assess treatment effectiveness, attainment of endpoint criteria, and to evaluate any potential or actual impacts to the shoreline ecology (i.e. water surface, water column, benthic sediments).

Comparison with Other Treatment Techniques

Operationally, the optimal treatment technique:

- involves minimal labor and logistical requirements;
- provides rapid treatment rates; and
- generates no/minimal oiled waste.

The following table compares these criteria for different cleanup techniques. Note that shoreline in situ techniques are the only options that typically fit all three criteria.

Technique	Labor /Logistics Requirements	Treatment Rate	Oiled Waste Generation	Waste Type
Mixing (dry)	**Minimal**	**Rapid**	**None**	**–**
Mixing (wet)	**Minimal**	**Rapid**	**Low/Moderate**	**Liquids/Solids***
Sediment relocation	**Minimal**	**Rapid**	**None**	**–**
Natural recovery	None	Varies **	None	–
Flooding	High	Medium	High	Liquids
Pressure washing	High	Medium	High	Liquids
Manual removal	High	Slow	Moderate/High	Solids
Mechanical removal	Minimal	Rapid	High	Solids
Vacuums	High	Slow	High	Liquids
Vegetation cutting	High	Slow	Moderate/High	Solids
Passive sorbents	High	Slow	Moderate/High	Solids
Burning	Minimal	Rapid	None	–
Dispersants	Minimal	Rapid	None	–
Shoreline cleaners	Minimal	Rapid	Moderate	Liquids
Bioremediation	Minimal	Very Slow	None	–

* Depending on the recovery method.

** Depending on oiling, shoreline, and environmental conditions.

Summary of In Situ Treatment Applications, Advantages, and Limitations

	Applications	Advantages	Limitations
Dry Mixing	Conducted above the water line (i.e. dry): • to physically break up the surface oil layer to expose a larger surface area for weathering; • to physically break up the surface oil layer to prevent formation of a weathered oil layer, such as asphalt pavement; or • to physically move oiled materials from below the surface to the surface, exposing the oil to weathering processes	Accelerates natural weathering and removal of oil Reduces oiled sediment adhesion and compaction, increasing the surface area of the oil for weathering Increases oil exposure to oxygen, sunlight, and water, therefore increasing the rates of biodegradation and photo-oxidation Promotes OPA formation in intertidal sediments when water levels rise Sediment is not removed Oiled waste generation is zero/minimal	Oil remains on the shoreline/riverbank during the period of subsequent weathering If implemented poorly, dry mixing may result in burial of oiled sediments Shoreline/riverbank requires sufficient bearing capacity for equipment If applied on steep river banks, dry mixing may induce slope instability
Wet Mixing	Conducted below the water line to release oil retained in shallow underwater, subtidal and/or intertidal sediments on rivers or shorelines • in tidal waters, conducted on a rising tide so released oil may be contained and recovered on the water • Oil released to the water surface may be collected for disposal/treatment if recoverable	Releases oil from intertidal and subtidal/underwater sediments Reduces benthic concentrations of oil Promotes OPA formation Sediment is not removed Provides additional energy in low-energy environments, therefore accelerates weathering	Oil that is denser than the ambient water will not be refloated by wet mixing Wet mixing can result in coarse sediments adhering to the oil, which can cause the oil to sink or be driven into the bottom sediments
Sediment Relocation	Relocation of: • oiled sediments stranded in the supratidal, upper intertidal, or upper river bank zones to a higher energy environment in order to accelerate physical breakup of the oil, and thereby accelerating weathering processes • subsurface oil that is below the zone of normal sediment reworking Useful: • in remote areas, or where access or staging are limited, so that logistics and waste management are problematic or operationally constraining • in locations where erosion is a concern, (e.g. slow natural sediment replenishment) and sediment removal must be minimized • for the rapid polishing of stained or residually oiled sediments following bulk oil removal	Accelerates the natural weathering and removal of oil by rapid dispersion Promotes OPA formation, even in low-energy environments, therefore increasing the surface area of the oil for biodegradation and photo-oxidation Sediment is not removed Oiled waste generation is zero/minimal Enables rapid treatment of oiled sediments	Poor implementation can impact resources, such as healthy biological communities in the lower intertidal zone In some cases, released oil could be redeposited elsewhere (this can be controlled by containment/recovery where necessary) If implemented poorly, relocation could cause oil to become buried Sediment relocation is rarely effective for highly viscous or weathered oil Shoreline/riverbank requires sufficient bearing capacity for equipment

3 TACTICS—Dry Mixing

Dry mixing is typically conducted to break up the surface oil layer to provide a larger surface area for natural removal and weathering, and to prevent the formation of a hardened, weathered layer, such as an asphalt pavement. In the event that oil has penetrated into, or become buried by sediment, dry mixing can also be used on beaches or riverbanks to move oiled materials from below the surface to the surface, which breaks up the oil and exposes it to natural weathering and removal processes.

Dry mixing can be used as part of a phased response, to break up residual oil and oiled sediment following bulk oil removal.

Applicable Oiling and Shoreline Conditions

DRY MIXING			
SHORLINE/RIVER INFORMATION		**OIL INFORMATION**	
Sediment Type *		Oiling Depth	
Mud	✓	Surface	✓
Sand	✓	Subsurface: <0.2 ft (0.5 m)	✓
Mixed Sediment	✓	Subsurface: 0.2–3 ft (0.5–1 m)	✓
Pebble	✓	Subsurface: 3–6 ft (1–2 m)	
Cobble	✓	Subsurface: >6 ft (2 m)	
Boulder		Oil Type	
Shoreline Location		Volatile	
Supra-tidal Zone (SUTZ)	✓	Light	✓
Upper Intertidal Zone (UITZ)	✓	Medium	✓
Middle Intertidal Zone (MITZ)		Heavy	✓
Lower Intertidal Zone (LITZ)		Solid	
Subtidal (to 3 ft water depth)		Oil Character	
River Location		Pooled	
Above the water line (dry)	✓	Emulsion (Mousse)	✓
Below the water line (wet)		Surface Residue	✓
* Man-made shorelines may be considered the equivalent of similar sized natural sediments, e.g. rip-rap = man-made boulder		Asphalt Pavement	✓
		Tarballs	

Equipment and Personnel Requirements

See also API (in prep.). *Manual of Practice for the Mechanical Cleanup of Sand Beaches*, API Technical Report 1151-3, Section 6.5.

Oiling	Equipment	Personnel
Surface and shallow (<6 in.) deposits	• Mechanical raking or mixing using: o raking type beach cleaners, o agricultural rotary tillers, or o disking equipment • Towed by farm-type tractors or Utility Task Vehicles (UTVs) • Small patches can be mixed manually using rakes	• Trained equipment operators; or • Manual laborers
Larger areas or moderate depth (<28 in.) deposits	• Mechanical mixing with agricultural or construction equipment, such as: o tractor-towed agricultural equipment, e.g. disks, harrows, plows, tillers o bulldozers or motor graders equipped with tines, rippers, excavators, or backhoes	• Trained equipment operators • Safety spotters for large machinery
Deep (>28 in.) deposits	• Deeper oiling may require: o larger agricultural subsoilers using straight or v-shaped shanks, or o construction equipment (bulldozers or motor graders) using large rippers	• Trained equipment operators • Safety spotters for large machinery

Operational Considerations

- Site access for equipment and personnel should be assessed during the planning stage. Logistics might include road access, access by vessel, such as a barge or landing craft, or even by air-lifting personnel and equipment.
- The weight-bearing capacity and trafficability of the oiled surface should be assessed during the planning stage. Mechanical equipment typically requires a relatively flat and stable surface. The effectiveness of dry mixing should be evaluated if the mixing activity encounters water-saturated sediments at the surface or at the water table in the sub-surface.
- Dry mixing can be conducted as part of a phased approach, for further cleaning ("polishing") after the removal of bulk oil. Multiple treatments may be necessary to achieve endpoints.
- For subsurface oiling, consideration should be given to the temporary removal or relocation of clean overburden, its temporary storage, and then replacement after treatment.
- For subsurface oiling, once the oil becomes exposed on the surface by dry mixing, mechanical or manual tactics can remove larger deposits of oil.
- Consideration should be given to the potential volatility of newly exposed oil, and the safety of responders.
- Typical treatment rates are in the range of 0.2–0.3 hours per acre (for a tractor with 12 ft wide disker) to 0.6 hours per acre (for a tractor with ripper operating at 1.5 mph).

Environmental Considerations

- Dry mixing disturbs infauna and epifauna in the treatment area. Consideration should be given to the importance and sensitivity of the resources at risk, as well as the resilience and expected rate of recolonization and recovery.

- Unlike removal methods, dry mixing does not remove sediment; however, the physical activity can temporarily loosen sediments. Consideration should be given to the erosion potential and sensitivity of the treatment area, as well as the expected rate for return to pre-treatment sediment cohesion.

- The mixing of intertidal oiled sediments promotes the formation of OPA when water levels rise, and therefore accelerates natural weathering and removal of oil. If heavily oiled sediments are treated and water levels subsequently rise, there is the potential for remobilization of oil. Consideration should be given to the applicability and effectiveness of bulk oil removal prior to mixing in order to reduce the volume of oil being treated.

- Dry mixing may potentially make oil more available to wildlife, for example, by exposing sub-surface oil to the surface environment. Consideration should be given to the sensitivity and vulnerability of local wildlife, the seasonality of the species compared with the timing of the proposed treatment, and the applicability and effectiveness of removal of the newly exposed surface oiling to reduce the risk of wildlife impacts, for example, by using beach cleaners. Consideration might be given to the use of a wildlife deterrent during and immediately following treatment.

- By mixing oil with sediment, this technique changes the properties of the oil, often reducing the potential exposure and/or effect to wildlife, for example, by making the oiled sediment surface less "sticky" to feathers and fur.

Sampling and Monitoring

- Initial (pre-treatment) SCAT data should record surface and subsurface oiling.

- Ongoing monitoring should evaluate the effectiveness of the treatment, in terms of changes in oil properties and the physical breakup and exposure of oiled sediments.

- Monitoring should continue until agreed cleanup endpoints are reached. Multiple treatments may be necessary to achieve endpoints.

- Additional monitoring and sampling may be appropriate if rising water levels generate concerns regarding remobilization of oil into the surface water, water column, or benthic sediments, in which case pre- and post-treatment sampling for hydrocarbons, ideally during a small scale trial, would evaluate whether remobilization is a concern.

- Post-treatment SCAT data should be compared with endpoint criteria for the treated segment.

Information Requirements for Decision Making: DRY MIXING	
SCAT Data	• Shoreline/riverbank character and width • Sediment type • Oil location (including tidal/river zone), extent and character • Oil thickness • Depth of oil burial or penetration • Site access and staging • Sensitive resources (ecology/wildlife, cultural/historic, economic, human use) • Safety concerns
EU Data	• Weather forecast (including wind, rain, snow, predicted storms) • Water conditions (tide, currents, water/river level, ice) • Oil properties (including density, viscosity, volatility) • Resources at Risk (including seasonality) • Approval and permitting requirements for access and treatment
Planning/Logistics	• Available equipment and personnel • Operational limitations (e.g. tine/rake depth, surface type, etc.) • Transportation and access requirements • Available logistics for waste management (to allow comparison with physical removal tactics)
Additional surveys may be required for:	• Site safety • Beach/river dynamics and erosion potential • Beach/riverbank profiles • Specific in-/epi-fauna data (e.g. species diversity, population numbers, etc.)

Decision Checklist: DRY MIXING

1 FATE AND PERSISTENCE: Is the oil likely to be removed by NATURAL PROCESSES within an acceptable time frame?

Consider shoreline/riverbank conditions (exposure, energy), weather, oiling conditions (degree, character, location on the shore/riverbank, burial or penetration), and the potential for natural weathering and removal

YES: Monitor NATURAL RECOVERY of the shoreline

NO: Continue to 2 below

2 Is the OBJECTIVE to accelerate/enhance the natural recovery of oiled surface or subsurface sediments?

Consider oiling conditions compared with endpoints/cleanup targets

YES: Continue to 3 below

NO: Consider alternative options, including NATURAL RECOVERY

3 Can Dry Mixing be conducted SAFELY?

Consider shoreline/riverbank conditions, weather and sea/river conditions, shoreline substrate, slope, weight-bearing capacity, trafficability, oil type/properties, transportation requirements, equipment needs, training requirements

YES: Continue to 4 below

NO: Consider alternative options, including NATURAL RECOVERY

4 Is the shoreline/riverbank ACCESSIBLE?

Consider the access requirements for personnel/equipment/vehicles, by land, sea, or air

YES: Continue to 5 below

NO: Consider alternative options, including NATURAL RECOVERY

5 Is the necessary equipment and personnel AVAILABLE to the responders?

Consider the ability to work to the maximum depth of the oil in the sediment. Consider sourcing from outside the area, if not locally available

YES: Continue to 6 below

NO: Consider alternative options, including NATURAL RECOVERY

6 Is Dry Mixing likely to provide a NET ENVIRONMENTAL BENEFIT?

Consider potential impacts to wildlife, vegetation, in-/epi-fauna and flora, human use, historical/cultural resources. Consider seasonality, treatment/recovery time, mitigation options. Consider waste management and shoreline/riverbank erosion concerns. Compare with other available techniques (potential impacts, invasiveness, duration) including natural recovery

YES: Continue to 7 below

NO: Consider alternative options, including NATURAL RECOVERY

7 Is Dry Mixing likely to be EFFECTIVE?

Consider the shoreline/sediment type, oil type and character (SCAT data). Consider the water content of the sediments: dry mixing may not be effective for saturated sediments except for very light oils

YES: Continue to 8 below

NO: Consider alternative options, including NATURAL RECOVERY

8 Could WEATHER/WATER CONDITIONS remove the need for Dry Mixing?

For example, are storm-generated waves or river flood conditions anticipated that would mix the sediment as well as, or better than, dry mixing?

YES: Consider re-evaluating the need for treatment after the weather event

NO: Continue to 9 below

9 Is there any HEAVY or BULK OILING that could be effectively removed manually or mechanically prior to conducting Dry Mixing?

Consider the degree of oiling and mobilization potential, equipment availability and accessibility, logistics, waste management issues, erosion potential

YES: Plan for bulk/heavy oiling prior to Dry Mixing, and continue to 10 below

NO: Continue to 10 below

10 Is the oil SUBSURFACE?

For example buried under, or penetrated into, sediments

YES: Continue to 11 below

NO: Continue to 13 below

11 Is the depth of burial/penetration within the DEPTH RANGE of the available equipment (with overburden management if applicable)?

Consider the depth of burial/penetration, the equipment required/available to move clean overburden, available storage, and available time

YES: Continue to 12 below

NO: Consider alternative options, including NATURAL RECOVERY

12 Is there CLEAN SEDIMENT (overburden) above the oiled layer that can be temporarily removed, stored, and replaced?

Consider the depth of burial/penetration and the limitations of the equipment available

YES: Plan for overburden management, and continue to 13 below

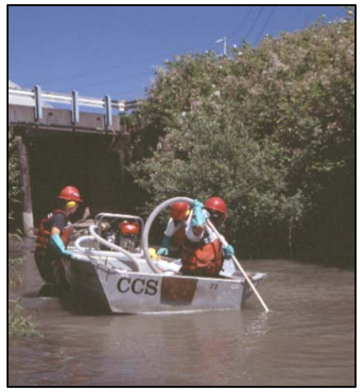
NO: Continue to 13 below

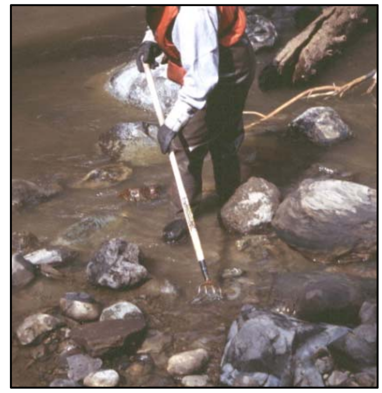
13 APPROVAL

Create a segment/reach-specific Shoreline Treatment Recommendation (STR) form for Dry Mixing for approval by Command. Include:

- Location of oiled area for treatment
- Description of oiling
- Endpoint criteria
- Equipment and personnel requirements
- Operational and Safety constraints
- Environmental/Ecological constraints
- Historical/Cultural Constraints
- Monitoring requirements
- Signature blocks for approval of the STR

4 TACTICS—Wet Mixing





Wet mixing is typically conducted to cause shallow (<3 ft), underwater agitation on shorelines and in rivers to release oil that is mixed with, or buried under, underwater sediments. Wet mixing is effective on oils that are less dense than the ambient water, and therefore float on release from underwater sediments. Wet mixing reduces benthic concentrations of oil, causing it to float on the water's surface, and accelerates natural weathering processes by evaporation, biodegradation, photo-oxidation, and dispersion, as well as enhancing OPA formation. For heavy oiling, oil released on the surface may be contained and recovered using booms, skimmers, vacuums, and/or sorbents.

Applicable Oiling and Shoreline Conditions

WET MIXING			
SHORLINE/RIVER INFORMATION		**OIL INFORMATION**	
Sediment Type *		Oiling Depth	
Mud	✓	Surface	✓
Sand	✓	Subsurface: <0.2 ft (0.5 m)	✓
Mixed Sediment	✓	Subsurface: 0.2–3 ft (0.5–1 m)	
Pebble	✓	Subsurface: 3–6 ft (1–2 m)	
Cobble	✓	Subsurface: >6 ft (2 m)	
Boulder		Oil Type	
Shoreline Location		Volatile	✓
Supra-tidal Zone (SUTZ)		Light	✓
Upper Intertidal Zone (UITZ)	✓	Medium	✓
Middle Intertidal Zone (MITZ)	✓	Heavy	✓
Lower Intertidal Zone (LITZ)	✓	Solid	
Subtidal (to 3 ft water depth)	✓	Oil Character	
River Location		Pooled	✓
Above the water line(dry)		Emulsion (Mousse)	✓
Below the water line (wet)	✓	Surface Residue	✓
* Man-made shorelines may be considered the equivalent of similar sized natural sediments, e.g. rip-rap = man-made boulder		Asphalt Pavement	
		Tarballs	

Equipment and Personnel Requirements

See also API (in prep.). *Manual of Practice for the Mechanical Cleanup of Sand Beaches*, API Technical Report 1151-3, Section 6.5.

Option	Equipment	Personnel
Manual (for small patches of oil)	• Rakes/shovels	• Manual labor
Mechanical	• Tractor-towed agricultural tillers • Bulldozers or motor graders equipped with rippers, excavators, or backhoes • Extraction equipment for stuck vehicles	• Trained equipment operators • Safety spotters for large machinery
Hydraulic	• High volume, low pressure water jets; or low volume, high pressure water jets operated from land or vessel (e.g. landing craft, barge, workboat) • Shallow water dredging equipment (e.g. Mud Cat or excavator slurry pump attachment)	• Trained equipment operators • Safety spotters for large machinery • Boat crew for vessel operations
Combination	• Mechanical AND hydraulic equipment used in combination, e.g. bulldozer with rippers and water jets [a]	• Trained equipment operators • Safety spotters for large machinery • Boat crew for vessel operations
Optional containment and recovery (where necessary)	• Hard and/or sorbent boom • Skimmers, vacuums, sorbent material • Silt screens (for collecting disturbed sediment in rivers)	• Trained equipment operators, or • Manual labor • Boat crew for vessel operations (if necessary)

[a] Miller, J.A. (1987) Beach Agitation for Crude Oil Removal from Intertidal Beach Sediments. *Proceedings International Oil Spill Conference.* American Petroleum Institute, Washington DC.

Operational Considerations

- Access for equipment and personnel should be assessed during the planning stage. Logistics might include road access, access by vessel, such as a barge or landing craft, or even by air-lifting personnel and equipment.

- The weight-bearing capacity and trafficability of the treatment area should be assessed during the planning stage. Mechanical equipment typically requires a relatively flat and stable surface.

- The ability of available equipment capable to operate safely in water and to the required sediment depth should be assessed at the planning stage. Most types of mechanical equipment will not operate in water deeper than 3 ft (1 m).

- In sheltered environments or rivers, hydraulic mixing can be conducted from shallow draft vessels/platforms.

- Consideration should be given to the applicability and effectiveness of containment and recovery of the released oil on the water surface using hard containment boom, sorbent boom, snare boom, skimmers, vacuums, sorbent pads, etc., depending on the volume of oil to be collected. Containment of volatile oils may be unnecessary or unsafe.

- The timing of the treatment should be planned according to anticipated changes in tidal or river water levels. Falling water levels may result in the grounding and subsequent ineffectiveness of containment and recovery equipment.

- Consideration should be given to tidal movements, currents, and winds, and the potential transportation of released oil on the water. Any containment and recovery equipment should be positioned in the path of predicted oil movement.

- Consideration should be given to the potential volatility of newly exposed oil, and the safety of responders.

- Typical treatment rates are in the range of 0.2–0.3 hours per acre (for a tractor with 12 ft wide disker) to 0.6 hours per acre (for a tractor with ripper operating at 1.5 mph).

Environmental Considerations

- Wet mixing disturbs infauna and epifauna in the treatment area. Consideration should be given to the importance and sensitivity of the resources at risk, as well as the resilience and expected rate of recolonization and recovery.

- Unlike removal methods, wet mixing does not remove sediment; however, the physical activity might temporarily loosen underwater sediments. Consideration should be given to the erosion potential and sensitivity of the treatment area, the potential for movement of suspended sediments (e.g. via downriver currents or longshore drift), as well as the expected rate of return to pre-treatment sediment cohesion. For river operations, consideration might be given to the use of a silt screen or similar to prevent downstream movement of disturbed sediment.

- If the water is high energy/turbulent, some oil may remain in suspension in the water column. This has the benefit of enhancing OPA formation and biodegradation.

- The objective of wet mixing is to mobilize oil to the water surface. Consideration should be given to any associated down-current risks without containment and recovery of the released oil.

- Wet mixing may potentially make oil more available to certain wildlife, by releasing oil to the water surface. Consideration should be given to the sensitivity and vulnerability of local wildlife, the seasonality of the species compared with the timing of the proposed treatment, and the applicability and effectiveness of containment and recovery of released oil on the surface. Consideration might be given to the use of a wildlife deterrent during and immediately following treatment.

Sampling and Monitoring

- Initial (pre-treatment) SCAT data record intertidal and/or subtidal oiling. For intertidal oiling, this may be conducted when the oil is exposed during low tide. For subtidal/underwater sediments, this may be conducted using viewing tubes or by snorkeling.

- Ongoing monitoring should evaluate the effectiveness of the treatment, in terms of the release of underwater oil from sediments.

- Monitoring should continue until agreed clean up endpoints are reached. Multiple treatments may be necessary to achieve endpoints.

- Beach profiling may be conducted to determine any changes in the beach or riverbank profile following treatment, and its subsequent recovery to a pre-treatment profile.

- Additional monitoring and sampling may be appropriate if there are concerns that oil may be mobilized into the water column and/or clean benthic sediments, in which case pre- and post-treatment sampling for hydrocarbons, ideally during a small scale trial, would evaluate whether remobilization is a concern.

- Post-treatment SCAT data should be compared with endpoint criteria for the treated segment.
- If containment/recovery is deemed necessary: estimation of the volume of oil recovered, and/or assessment of visual fouling of any sorbent materials used.

Information Requirements for Decision Making: WET MIXING	
SCAT Data	• Shoreline/riverbank character and width • Sediment type • Oil location, extent and character • Depth /thickness of oil • Depth of water • Site access and staging • Sensitive resources (ecology/wildlife, cultural/historic, economic, human use) • Safety concerns
EU Data	• Weather forecast (including wind, rain, snow, predicated storms) • Water conditions (tide, currents, water/river level, ice) • Oil properties (including density, viscosity, volatility) • Resources at Risk (including seasonality) • Approval and permitting requirements for access and treatment
Planning/Logistics	• Available equipment and personnel • Operational limitations (e.g. tine/rake depth, surface type, underwater operations, etc.) • Transportation and access requirements • Available logistics for waste management (to allow comparison with physical removal tactics)
Additional surveys may be required for:	• Site safety • Beach/riverbank dynamics and erosion potential • Beach/riverbank profiles • Specific in-/epi-fauna data (species diversity, population numbers, etc.)

Decision Checklist: WET MIXING

1 FATE AND PERSISTENCE: Is the oil likely to be removed by NATURAL PROCESSES within an acceptable time frame?

Consider shoreline/riverbank conditions (exposure, energy), weather, oiling conditions (degree, character, location on the shore/riverbank, burial or penetration), and the potential for natural weathering and removal

YES: Monitor NATURAL RECOVERY of the shoreline

NO: Continue to 2 below

2 Is the OBJECTIVE to accelerate/enhance the natural recovery of oiled underwater sediments?

Consider oiling conditions compared with endpoints/cleanup targets

YES: Continue to 3 below

NO: Consider alternative options, including NATURAL RECOVERY

3 Can Wet Mixing be conducted SAFELY?

Consider shoreline/riverbank conditions, weather and sea/river conditions, shoreline substrate, slope, weight-bearing capacity, trafficability, oil type/properties, transportation requirements, equipment needs, training requirements

YES: Continue to 4 below

NO: Consider alternative options, including NATURAL RECOVERY

4 Is the shoreline/riverbank ACCESSIBLE?

Consider the access requirements for personnel/equipment/vehicles, by land, sea, or air

YES: Continue to 5 below

NO: Consider alternative options, including NATURAL RECOVERY

5 Is the necessary equipment and personnel AVAILABLE to the responders?

Consider the ability to work in/around water, and to the maximum operating water depth and to the maximum depth of the oil in the sediment. Consider sourcing from outside the area, if not locally available

YES: Continue to 6 below

NO: Consider alternative options, including NATURAL RECOVERY

6 Is Wet Mixing likely to provide a NET ENVIRONMENTAL BENEFIT?

Consider potential impacts to wildlife, vegetation, in-/epi-fauna and flora, human use, historical/cultural resources. Consider seasonality, treatment/recovery time, mitigation. Consider waste management and shoreline/riverbank erosion concerns. Compare with other available techniques (potential impacts, invasiveness, duration) including natural recovery

YES: Continue to 7 below

NO: Consider alternative options, including NATURAL RECOVERY

7 Is Wet Mixing likely to be EFFECTIVE?

Consider the shoreline/sediment type, oil type and character (SCAT data). Consider if the released oil will float and can be recovered: wet mixing will not be effective if the action creates a sunken oil/sediment mixture

YES: Continue to 8 below

NO: Consider alternative options, including NATURAL RECOVERY

8 Could WEATHER/WATER CONDITIONS remove the need for Wet Mixing?

For example, are storm-generated waves or river flooding anticipated that would release the oil as well as, or better than, wet mixing?

YES: Consider re-evaluating the need for treatment after the weather event

NO: Continue to 9 below

9 Is the RELEASED OIL likely to be a concern and to warrant containment and recovery?

Consider the potential for significant mobilization of released oil, pre-treatment oiling data, tides and currents, accessibility, equipment availability, logistics, waste management issues

YES: Plan for Containment and Recovery of released oil, and continue to 10 below

NO: Continue to 10 below

10 If oil is buried under, or penetrated into, sediment, is there CLEAN SEDIMENT (overburden) above the oiled layer that can be temporarily removed, stored, and replaced?

Consider the depth of burial/penetration, the equipment required/available to move overburden, available storage, and available time. Overburden removal in underwater environments is likely to be challenging, given the reduced visibility and control of underwater operations

YES: Plan for Overburden Management and continue to 11 below

NO (or N/A): Continue to 11 below

11 If the treatment area is intertidal, is there a sufficient time window of opportunity before the water gets either too deep or shallow to operate?

Consider the tidal range of the treatment area, and the times at which the water level is within a suitable range for wet mixing and floating oil containment and recovery (where necessary)

YES (or N/A): Continue to 12 below

NO: Consider alternative options, including NATURAL RECOVERY

12 APPROVAL

Create a segment/reach-specific Shoreline Treatment Recommendation (STR) form for Wet Mixing for approval by Command. Include:

- Location of oiled area for treatment
- Description of oiling
- Endpoint criteria
- Equipment and personnel requirements
- Operational and Safety constraints
- Environmental/Ecological constraints
- Historical/Cultural constraints
- Monitoring requirements
- Signature blocks for approval of the STR

5 TACTICS—Sediment Relocation

Sediment relocation is conducted to move oiled sediment from one section of a beach or riverbank into a higher energy environment, to accelerate the physical breakup of the oil and weathering processes. Even in low energy environments, sediment relocation promotes OPA formation, which increases the surface area of the oil for biodegradation.

Applicable Oiling and Shoreline Conditions

SEDIMENT RELOCATION				
SHORLINE/RIVER INFORMATION			**OIL INFORMATION**	
Sediment Type *			Oiling Depth	
Mud	✓		Surface	✓
Sand	✓		Subsurface: <0.2 ft (0.5 m)	✓
Mixed Sediment	✓		Subsurface: 0.2–3 ft (0.5–1 m)	✓
Pebble	✓		Subsurface: 3–6 ft (1–2 m)	✓
Cobble	✓		Subsurface: >6 ft (2 m)	✓
Boulder			Oil Type **	
Shoreline Location			Volatile	
Supra-tidal Zone (SUTZ)	✓		Light	✓
Upper Intertidal Zone (UITZ)	✓		Medium	✓
Middle Intertidal Zone (MITZ)	✓		Heavy	✓
Lower Intertidal Zone (LITZ)			Solid	
Subtidal (to 3 ft water depth)			Oil Character	
River Location			Pooled	
Above the water line(dry)	✓		Emulsion (Mousse)	✓
Below the water line (wet)			Surface Residue	✓
* Man-made shorelines may be considered the equivalent of similar sized natural sediments, e.g. rip-rap = man-made boulder			Asphalt Pavement	
			Tarballs	

Equipment and Personnel Requirements

See also API (in prep.). *Manual of Practice for the Mechanical Cleanup of Sand Beaches*, API Technical Report 1151-3, Section 6.5.

Option	Equipment	Personnel
Manual (for small volumes of oiled sediment)	• Shovels • Wheelbarrows	• Manual labor
Mechanical	• Front-end loaders • Graders • Excavators • Bulldozers • Backhoes	• Trained equipment operators • Safety spotters for large machinery
Optional containment and recovery (where necessary)	• Passive sorbents (e.g. snare or sorbent boom)	• Manual labor • Boat crew for vessel operations (if necessary)

Operational Considerations

- Sediment relocation requires either one or both of:
  - Wave or current energy
  - The presence of fine particles for OPA formation.
- Access for equipment and personnel should be assessed during the planning stage. Logistics might include road access, access by vessel, such as a barge or landing craft, or even by air-lifting personnel and equipment.
- The weight-bearing capacity and trafficability of the treatment area should be assessed during the planning stage. Mechanical equipment typically requires a relatively flat and stable surface.
- For subsurface oil, consideration should be given to the temporary removal or relocation of clean overburden, its temporary storage, and then replacement after treatment.
- Sediment relocation can be conducted as part of a phased approach, for further cleaning ("polishing") after the removal of bulk oil.
- Sediment relocation can be conducted in combination with wet mixing to accelerate the natural removal of oil.
- Consideration should be given to the applicability and effectiveness of containment and recovery of the released oil on the water surface using sorbent materials, such as snare or sorbent boom, depending on the volume of oil to be collected. Containment of volatile oils may be unnecessary or unsafe.
- Passive sorbents may be placed in the adjacent intertidal zone to collect any oil that might strand near the treatment site.
- Consider scheduling sediment relocation immediately prior to predicted storm or high energy events.

- Consideration should be given to the potential volatility of newly exposed oil, and the safety of responders.

- In lakes, rivers, or areas with a small tidal range, it may be necessary to relocate oiled sediment directly into the water, in which case the ability of available equipment to operate in shallow water should be assessed at the planning stage.

- Typical treatment rates are approximately 5 hr/acre for one bulldozer.

Environmental Considerations

- Sediment relocation disturbs or buries infauna and epifauna in the treatment area. Consideration should be given to the importance and sensitivity of the resources at risk, as well as the expected resilience and rate of recolonization and recovery. Oiled materials should not be moved into areas where the oil and/or the sediments could impact other resources, such as healthy, unoiled biological communities, for example, in the lower tidal zone. This could be achieved by lateral relocation.

- With heavy oiling, consideration should be given to the applicability of the use of passive sorbents on the water or adjacent shoreline/riverbank to prevent oil/sheen transportation and stranding.

- With high energy/turbulent water and disturbance, there is a potential that oil some oil may remain in suspension in the water column. This has the benefit of enhancing OPA formation and biodegradation.

- Unlike removal methods, sediment relocation does not remove sediment; however, the action will temporarily loosen surface sediments. Consideration should be given to the erosion potential and sensitivity of the treatment area, as well as the expected rate for the natural return of the clean sediment back up the beach or riverbank. On shorelines, this is typically a matter of a few tidal cycles in most circumstances.

- If downdrift sediment loss or movement is a concern, then consideration should be given to relocating the oiled sediment updrift, so that clean sediment can be carried naturally back to the original location.

- Sediment relocation may potentially make oil more available to wildlife, for example, by exposing previously mixed or subsurface oil. Consideration should be given to the sensitivity and vulnerability of wildlife, the seasonality of the wildlife compared with the timing of the proposed treatment, and the applicability and effectiveness of containment and recovery of released oil on the surface. Consideration might be given to the use of a wildlife deterrent during and immediately following treatment.

Sampling and Monitoring

- Initial (pre-treatment) SCAT data should documented surface and subsurface oiling.

- A field test may be conducted to assess the effectiveness of sediment relocation, including OPA formation (see Annex A), and of the potential fate and behavior of the oil.

- Typically, where high concentrations of fines are present, a short-lived (minutes) brown foam is observed during the oil-fine sediment interaction process (see photograph at the end of this section).

This foam is a result of dispersion processes and is an emulsion of oil and fine particles; an indication that the OPA process is active.

- Ongoing monitoring should evaluate the effectiveness of the treatment, in terms of changes in oil properties and the physical breakup and exposure of oiled sediments.
- Monitoring should continue until agreed cleanup endpoints are reached. Multiple treatments may be necessary to achieve endpoints.
- Post-treatment SCAT data should be compared with endpoint criteria for the treated segment.
- Additional monitoring and sampling may be appropriate if there are concerns that oil may be mobilized into the water column and/or clean sediments, in which case pre- and post- treatment sampling for hydrocarbons, ideally during a small scale trial, would evaluate whether remobilization is a concern.
- Beach profiles may be surveyed pre- and post-treatment (short- and longer-term) to address any concerns regarding erosion of beach sediment or changes in the profile of the beach.
- If containment/recovery is deemed necessary: estimation of the volume of oil recovered, and/or assessment of visual fouling of any sorbent materials used.

Typical brown foam observed during sediment relocation, indicating interaction between oil and fine sediments. No oil or sheen on the water is visible.

Information Requirements for Decision Making: SEDIMENT RELOCATION	
SCAT Data	• Shoreline/riverbank character and width • Sediment type • Oil location (including tidal/river zone), extent and character • Depth of oil burial or penetration • Site access • Sensitive resources (ecology/wildlife, cultural/historic, economic, human use) • Safety concerns
EU Data	• Weather forecast (including wind, rain, snow, predicted storms) • Water conditions (tide, currents, water/river level, ice) • Oil properties (including density, viscosity, volatility) • Resources at Risk (including seasonality) • Approval and permitting requirements for access and treatment
Planning/Logistics	• Available equipment and personnel • Operational limitation (e.g. surface type, shallow-water operations, etc.) • Transportation and access requirements • Available logistics for waste management (to allow comparison with physical removal tactics)
Additional surveys may be required for:	• Site safety • Operating surface • Beach/riverbank dynamics and erosion potential, including longshore or downdrift • Specific in-/epi-fauna data (e.g. species diversity, population numbers, etc.) • Beach/riverbank profiles • OPA formation potential test (Annex A)

Decision Checklist: SEDIMENT RELOCATION

1 FATE AND PERSISTENCE: Is the oil likely to be removed by NATURAL PROCESSES within an acceptable time frame?

Consider shoreline/riverbank conditions (exposure, energy), weather, oiling conditions (degree, character, location on the shore/riverbank, burial or penetration), and the potential for natural weathering and removal
YES: Monitor NATURAL RECOVERY of the shoreline
NO: Continue to 2 below

2 Is the OBJECTIVE to accelerate/enhance the natural recovery of lightly/moderately oiled sediment?

Consider oiling conditions compared with endpoints/cleanup targets
YES: Continue to 3 below
NO: Consider alternative options, including NATURAL RECOVERY

3 Can Sediment Relocation be conducted SAFELY?

Consider shoreline/riverbank conditions, weather and sea/river conditions, shoreline substrate, slope, weight-bearing capacity, trafficability, oil type/properties, transportation requirements, equipment needs, training requirements
YES: Continue to 4 below
NO: Consider alternative options, including NATURAL RECOVERY

4 Is the shoreline/riverbank ACCESSIBLE?

Consider the access requirements for personnel/equipment/vehicles, by land, sea, or air
YES: Continue to 5 below
NO: Consider alternative options, including NATURAL RECOVERY

5 Is the necessary equipment and personnel AVAILABLE to the responders?

Consider the ability to work in/around water, and to the maximum depth of the oil in the sediment. Consider sourcing from outside the area, if not locally available
YES: Continue to 6 below
NO: Consider alternative options, including NATURAL RECOVERY

6 Is Sediment Relocation likely to provide a NET ENVIRONMENTAL BENEFIT?

Consider potential impacts to wildlife, vegetation, in-/epi-fauna and flora, human use, historical/cultural resources. Consider seasonality, treatment/recovery time, mitigation. Consider waste management and shoreline/riverbank erosion concerns. Compare with other available techniques (potential impacts, invasiveness, duration) including natural recovery. Consider where the treatment will occur (does not necessarily have to be immediately adjacent to the oiled area)

YES: Continue to 7 below

NO: Consider alternative options, including NATURAL RECOVERY

7 Is Sediment Relocation likely to be EFFECTIVE?

Consider the shoreline/sediment type, oil type and character (SCAT data), weather and sea/river energy/conditions, OPA formation potential (Annex A). Consider where the treatment will occur (does not necessarily have to be immediately adjacent to the oiled area)

YES: Continue to 8 below

NO: Consider alternative options, including NATURAL RECOVERY

8 Could WEATHER/WATER CONDITIONS remove the need for Sediment Relocation?

For example, are spring tides, storm-generated waves, or river flood conditions anticipated that would reach the proposed treatment area and promote natural cleaning through water energy, turbulence, and/or OPA formation?

YES: Consider re-evaluating the need for treatment after the weather event

NO: Continue to 9 below

9 Is there any HEAVY or BULK OILING that could be effectively removed manually or mechanically prior to conducting Sediment Relocation?

Consider the degree of oiling and mobilization potential, equipment availability and accessibility, logistics, waste management issues, erosion potential

YES: Plan for bulk/heavy oiling prior to Sediment Relocation, and continue to 10 below

NO: Continue to 10 below

10 Is the RELEASED OIL likely to be a concern and to warrant containment and recovery?

Consider the potential for mobilization of released oil, pre-treatment oiling data, tides and currents, accessibility, equipment availability, logistics, waste management issues

YES: Plan for Containment and Recovery of released oil, and continue to 11 below

NO: Continue to 11 below

11 If oil is buried by, or penetrated into, sediment, is there CLEAN SEDIMENT (overburden) above the oiled layer that can be temporarily removed, stored and replaced?

Consider the depth of burial/penetration, the equipment required/available to move overburden, available storage, and available time

YES: Plan for Overburden Management, and continue to 12 below

NO (or N/A): Continue to 12 below

12 Will a FIELD TEST provide a better understanding of the effectiveness, effects, and fate of the oil due to Sediment Relocation?

Consider the expected outcomes, fate of the oil and sediment, monitoring requirements, and stakeholder concerns

YES: Conduct a field trial prior to approval. If trial confirms expectations, continue to 13 below

NO: Continue to 13 below

13 APPROVAL

Create a segment/reach-specific Shoreline Treatment Recommendation (STR) form for approval for Sediment Relocation by Command and Regional Response Team (RRT), where required. Include:

- Location of oiled area for treatment
- Description of oiling
- Endpoint criteria
- Equipment and personnel requirements
- Operational and Safety constraints
- Environmental/Ecological constraints
- Historical/Cultural constraints
- Monitoring requirements
- Signature blocks for approval of the STR

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Annex A—Field Testing for OPA Formation Potential

This section describes a rapid and simple field screening method to qualitatively test the potential for OPA formation at a particular location. Other test methods, including laboratory confirmation of OPA formation using a microscope, can be found in Environmental Canada's *Methods for the Assessment of Oil-Mineral Aggregates* [4].

Equipment Required

2× clear plastic containers with screw caps (approx. 1 cup)

Sample of the spilled oil

Pipette to transfer oil into samples

Nitrile gloves for handling the oil

Procedure

1. At the site to which the sediment will be relocated, collect approximately $^{3}/_{4}$ of the volume of the container of clean (unoiled, untreated) water with suspended sediment and fines from the surf zone. Label the container "sediment."
2. Fill another container (approx. $^{3}/_{4}$) with clean drinking water. Label the container "control."
3. Add 1 ml oil to each container, screw caps tightly.
4. Shake the containers vigorously for 1 to 2 minutes.
5. Observe the quantity of oil coating the container walls:
   - If there is **no OPA formation**, the oil will stick to the container walls or float on the surface of the water.
   - In many cases **OPA formation** will result in less oil on the container walls than in the control test.
   - The extent of the difference between the "control" and "sediment" tests provides a qualitative measure of the oil dispersion that can be attributed to OPA formation; see examples using a similar sampling methodology below. For each example, the control sample is on the left, sediment sample is on the right (source: Stoffyn-Egli et al., 2000) [3].

   - If there is no difference in the degree of oiling between the "control" and the "sediment" slides, OPA formation is not occurring or is negligible in the "sediment" container. OPA formation might not occur if the oil is too viscous or if the sediment contains too few fine particles.
6. Replicate tests should be conducted to account for any variability in the sediment, and in the oil type and degree of weathering.
7. Containers and their contents should be disposed of appropriately.

[3] Stoffyn-Egli, P., Blenkinsopp, S., Lee, K., and Sergy, G. (2000). *Methods for the Assessment of Oil-Mineral Aggregates*. Environment Canada, Edmonton.

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