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Standard Guide for Describing Shoreline Response Techniques[1]

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1. Scope

1.1 This guide describes methods of cleaning and remediating shorelines containing stranded oil. The primary goal of any shoreline countermeasure is to aid recovery while minimizing additional impact.

1.2 This guide describes 21 different countermeasures that are available for consideration. These countermeasures range from natural recovery to active intervention.

1.3 The countermeasures listed may not be the best for use under all possible circumstances, and multiple countermeasures may need to be used on the same shoreline.

1.4 This guide describes technical considerations for selecting one technique or another, or both. Additional guides, presently under development, will address considerations related to habitat and oil characteristics.

1.5 Selection of specific countermeasures for use during a spill response will be guided by the properties of the stranded oil, the degree of contamination, shoreline accessibility, shoreline geomorphology, mobility of available equipment, oceanographic and meteorological conditions, and the presence of sensitive natural and archeological resources. Some of the response options will require government authorization and approval.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

F 1686 Guide for Surveys to Document and Assess Oiling Conditions on Shorelines[2]

F 1687 Guide for Terminology and Indices for Describing the Oiling Conditions on Shorelines[2]

2.2 *API Documents:*

API Publication No. 4558 Options for Minimizing Environmental Impacts of Freshwater Spill Response[3]

API Publication No. 4706 Environmental Considerations for Marine Oil Spill Response[3]

3. Significance and Use

3.1 Once the extent and type of shoreline oiling has been defined and documented using proper procedures (see Guides F 1686 and F 1687), decisions will need to be made on the appropriate course of action for cleaning and restoration. In some cases, natural recovery will be the preferred approach whereas in other cases active intervention may be called for. This guide summarizes the principal response techniques available.

3.2 This guide is intended to minimize possible added impact to the environment that could result from overly-aggressive cleanup. In some cases, local priorities may dictate that intensive clean-up methods may be warranted. In all cases, concurrence to use such techniques should be obtained from all the major stakeholders and must comply with all local regulations.

4. Shoreline Response Options

4.1 This section lists and describes those techniques that may be considered for use in response to shoreline oiling. Some of these methods could require special consideration and authorization prior to commencement of work. Also, some of these options result in larger waste disposal issues than others and these need to be considered in selecting the appropriate option. In most cases, government agency(s) will be involved in the decision-making process. Government approval will be required for many techniques, which will be decided upon on a case-by-case basis. Contingency plans should provide for a range of response options. The methods covered in this guide, consistent with API 4706, are:

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Mechanical Oil Removal	4.5
Sorbents	4.6
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Debris Removal	4.8

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[2] *Annual Book of ASTM Standards*, Vol 11.04.

[3] Available from The American Petroleum Institute (API), 1220 L. St., NW, Washington, DC 20005.

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A description of each shoreline cleanup method is discussed below:

4.2 *Natural Recovery*:

4.2.1 *Objective*—Stranded oil is not removed in order to minimize environmental impacts, or because no effective method for cleanup is available. Oil is left to degrade naturally.

4.2.2 *Description*—Monitoring of conditions. Migration of oil off site may need response.

4.2.3 *Applicable Habitat Types*—Can be used on all habitat types.

4.2.4 *When to Use*—When natural removal rates are very fast, when degree of oiling is light, or when cleanup actions will do more harm than allowing the oil to be removed by natural forces.

4.2.5 *Biological Constraints*—May be inappropriate for areas used by high numbers of mobile animals (birds, marine mammals, crabs, and so forth) or endangered or threatened species.

4.2.6 *Environmental Effects*—No effects beyond that of the oil alone.

4.2.7 *Waste Generation*—None.

4.3 *Barriers/Berms*:

4.3.1 *Objective*—To prevent oil from entering into a sensitive area or to divert oil to a collection area.

4.3.2 *Description*—A physical barrier is placed across an area to prevent oil from moving. Barriers can be earthen berms, trenches, shore-sealing booms, or filter fences. When passage of water must be allowed, underflow or overflow dams are used.

4.3.3 *Applicable Habitat Types*—At the mouths of creeks, streams, or rivers. On beaches where a berm can be built above the high-tide line to prevent oil from overwashing the beach and entering a sensitive back-beach habitat such as a lagoon.

4.3.4 *When to Use*—When sensitive habitats are threatened and other barrier options are not feasible.

4.3.5 *Biological Constraints*—Disturbance to bird nesting areas, beaver dams, or other sensitive areas must be minimized. Placement of dams and filter fences may cause significant physical disruptions, especially in wetlands.

4.3.6 *Environmental Effects*—May disrupt or contaminate substrate and vegetation. Trenching may enhance oil penetration and amount of substrate contamination.

4.3.7 *Waste Generation*—Substrate barriers will become contaminated. Filter fence materials will be disposed as oily wastes. Disposal must be in accordance with all applicable regulations.

4.4 *Manual Oil Removal/Cleaning*:

4.4.1 *Objective*—Remove stranded oil with hand tools and manual labor.

4.4.2 *Description*—Surface oil and oily debris are removed by manual means (hands, rakes, shovels, and so forth) and placed in containers for removal from the shoreline for subsequent disposal. No mechanized equipment is used except for transport of waste.

4.4.3 *Applicable Habitat Types*—Can be used for all habitat types.

4.4.4 *When to Use*—Generally used on shorelines where the oil can be easily removed by non-mechanical means. Most appropriate for light to moderate oiling conditions. Manual removal is applicable to viscous oils and weathered patches or tar balls.

4.4.5 *Biological Constraints*—Foot traffic over sensitive areas (wetlands, shellfish beds, algal mats, bird nesting areas, dunes, and so forth) should be restricted. There may be periods when shoreline access is not appropriate (for example, bird nesting, seal pupping).

4.4.6 *Environmental Effects*—Minimal if surface disturbance by responders and waste generation is limited.

4.4.7 *Waste Generation*—May generate significant amounts of oily substrate and debris which require proper disposal or treatment. Decontamination of tools may produce oily wastewater that requires proper treatment. Worker personal protective equipment may be disposed of daily or decontaminated. Oily wastewater resulting from decontamination must be treated properly. Disposal must be in accordance with all applicable regulations.

4.5 *Mechanical Oil Removal*:

4.5.1 *Objective*—To remove oil from shorelines using mechanical equipment.

4.5.2 *Description*—Oil and oiled substrate are removed using mechanical equipment such as backhoes, graders, bulldozers, dredges, and so forth. This method requires systems for temporary storage, transportation, treatment, and disposal.

4.5.3 *Applicable Habitat Types*—Land where surface substrates are amenable to and accessible by heavy equipment.

4.5.4 *When to Use*—When large quantities of oiled materials must be removed. Care should be taken to remove substrates only to the depth of oil penetration, which can be difficult. Method should be used carefully where excessive substrate removal may erode the shoreline. Buried oil recovery includes the removal of clean overburden, removal of oiled substrates, and replacement of the clean overburden. Vehicle traffic should be controlled to minimize further oil penetration.

4.5.5 *Biological Constraints*—Heavy equipment may be restricted in sensitive habitats (for example, wetlands, soft substrates), during breeding or nesting seasons, or in areas containing endangered or threatened species. Special permission will be needed to operate in areas with known cultural resources. Noise generated by mechanical equipment may be a constraint.

4.5.6 *Environmental Effects*—May be detrimental if excessive substrates are removed without replacement. All organisms in the removed substrates will be impacted.

4.5.7 *Waste Generation*—Can generate significant amounts of contaminated substrate and debris that must be cleaned or

landfilled. Disposal must be in accordance with all applicable regulations. The amount of waste generated by this method should be carefully considered when reviewing potential impacts of oily wastes, debris, and substrates.

4.6 *Sorbents*:

4.6.1 *Objective*—Remove oil by sorbing it onto oil-attracting material.

4.6.2 *Description*—Sorbent material is placed on the shoreline to absorb oil as it is carried in by tidal or wave action. Sorbents can be used to wipe stranded oil off substrates. Sorbent forms include sausage boom, pads, rolls, sweeps, snares, and granules. Removal efficiency is dependent on the capacity of the sorbent, the wave or tidal energy available for freeing oil from the shoreline, and the oil type and the degree of weathering. Recovery of all sorbent material is required. Loose granular sorbents must be contained in mesh or other material.

4.6.3 *Applicable Habitat Types*—Can be used on any habitat type.

4.6.4 *When to Use*—When the oil is floating nearshore or has stranded onshore. The oil must not be too adherent in order to be released by the substrate and absorbed by the sorbent. Sorbents are often used as a secondary treatment method after gross oil has been removed or in sensitive habitats having restricted access. Sorbents should not be used on or near high energy or steep shorelines. Sorbents may break apart in high energy conditions. Steep shorelines make recovery of sorbents difficult.

4.6.5 *Biological Constraints*—Deploying and retrieving sorbents should not adversely affect wildlife. Sorbents should not be placed in a manner that would endanger or trap wildlife. Sorbents left in place too long may break apart and present an ingestion hazard to wildlife. Sorbents can be slow, thus allowing oil to remain in critical habitats for extended periods during potentially sensitive periods.

4.6.6 *Environmental Effects*—Deployment and retrieval can cause physical disturbance to habitats. Improperly deployed or tended sorbents can crush or smother sensitive organisms.

4.6.7 *Waste Generation*—Careful consideration must be given to the selection and proper use of sorbents. Sorbents should be monitored for removal when not being effective at collecting oil any further. Generation of large amounts of lightly oiled sorbents should be prevented. Recycling should be emphasized. Disposal must be in accordance with all applicable regulations.

4.7 *Vacuuming*:

4.7.1 *Objective*—To remove free oil pooled on shoreline substrate.

4.7.2 *Description*—A vacuum unit with a suction head is used to recover free oil. The equipment can range from small portable units to fill 55-gal drums to large devices that are truck-mounted and can even lift large rocks. Oil removal rates can be extremely slow with this method. Water spray systems may be used to flush the oil toward the suction head.

4.7.3 *Applicable Habitat Types*—Vacuums can be used on any accessible shoreline habitat. Vacuums may be mounted offshore on barges, onshore on trucks, or deployed as individual units on boats or ashore at low tide.

4.7.4 *When to Use*—When liquid oil is pooled against a shoreline, stranded on the shoreline (usually along the high-tide line), concentrated in trenches, or trapped in accessible vegetation.

4.7.5 *Biological Constraints*—Special restrictions should be established for areas where foot traffic and equipment operation may be damaging, such as soft substrates. Wetland operations need to be closely monitored. A site-specific list of procedures and restrictions is recommended to prevent damage to vegetation.

4.7.6 *Environmental Effects*—Effects are minimal if foot and vehicular traffic are controlled and minimal substrate is impacted.

4.7.7 *Waste Generation*—Collected oil and oil-water mixtures need to be stored temporarily prior to recycling or disposal. Large amounts of water are often collected, which requires separation and treatment. If oil is not recyclable, disposal must be in accordance with all applicable regulations.

4.8 *Debris Removal*:

4.8.1 *Objective*—Remove debris in the path of oil prior to stranding and remove oiled debris.

4.8.2 *Description*—Manual or mechanical removal of debris (wood, seaweed, trash, wreckage) from the shoreline. This includes the cutting and removal of oiled logs.

4.8.3 *Applicable Habitat Types*—Can be used on any habitat type with safe access.

4.8.4 *When to Use*—When debris is oiled and, is a potential source of chronic re-oiling, an aesthetic problem, a potential source of contamination of biological resources, or likely to be a safety hazard for responders. Used in shoreline areas where debris has accumulated in order to reduce the amount of oiled debris to be handled.

4.8.5 *Biological Constraints*—Foot traffic over sensitive areas (wetlands, algal mats, bird nesting area, dunes, and so forth) must be restricted. There may be periods when shoreline access is restricted (for example, bird nesting, influx of large numbers of migratory birds, seal pupping). Debris may be a habitat. Adjacent upland areas could contain endangered plant species, so removal activities or foot traffic may need to be restricted.

4.8.6 *Waste Generation*—Unless there is an approved hazardous waste incinerator that will accept oily debris, burning will rarely be allowed, especially on-site. The option of burning, especially for remote locations, should still be explored with appropriate state or federal agencies that must approve burning. An advantage of collecting debris prior to oiling, is that waste disposal requirements will likely be less restrictive than if the debris is oiled. Oiled debris is likely to be handled as hazardous waste. Disposal of oiled debris must be in accordance with all applicable regulations.

4.9 *Substrate Reworking and Tilling*:

4.9.1 *Objective*—Physically work on oiled substrate to break up oil deposits, increase surface area, and mix deeper subsurface oil layers, to expose the oil to natural removal processes and enhance the rate of oil degradation.

4.9.2 *Description*—Oiled substrate is roto-tilled, disked, or otherwise mechanically or manually mixed. This method may be aided with high volume flushing of gravel. Oiled substrate

may also be relocated lower on the beach to enhance natural cleanup by wave activity (berm relocation).

4.9.3 *Applicable Habitat Types*—Any substrate that can support mechanical equipment or foot traffic and hand tilling.

4.9.4 *When to Use*—On sand to gravel beaches containing subsurface oil, where substrate removal is not feasible due to erosion or waste disposal issues. Appropriate for areas where oil is stranded above the high waterline.

4.9.5 *Biological Constraints*—Cannot be used on shorelines near sensitive habitats (shellfish beds, fish-spawning areas, bird nesting or concentration areas) because of the potential for continued release of oil and oiled substrates into adjacent water.

4.9.6 *Environmental Effects*—Mixing of oil into substrate could further expose biota that occur below the original layer of oil. Continual reworking could delay re-establishment of organisms. Refloated oil from reworked areas may contaminate adjacent areas.

4.9.7 *Waste Generation*—None.

4.10 *Vegetation Cutting/Removal*:

4.10.1 *Objective*—The removal of oiled vegetation to prevent oiling of wildlife and secondary oil releases.

4.10.2 *Description*—Oiled vegetation is cut using weed trimmers or other appropriate tools, and picked or raked up. Cut vegetation is bagged for disposal.

4.10.3 *Applicable Habitat Types*—Habitats, such as wetlands, composed of emergent, herbaceous vegetation.

4.10.4 *When to Use*—Use when the risk of oiled vegetation contaminating wildlife outweighs the value of the vegetation that is to be cut, and there is no less destructive method to remove or reduce the risk to acceptable levels.

4.10.5 *Biological Constraints*—Strict monitoring of the operations must be conducted to minimize the degree of root destruction and mixing of oil deeper into the sediments. Access to bird nesting areas should be restricted during nesting seasons. Cutting only the oiled parts of the plants and leaving roots and as much of the stem as possible will minimize impact.

4.10.6 *Environmental Effects*—Vegetation removal will impact habitats. Reduced plant growth and plant mortality may occur in cut areas. If the base of the plant stem is cut, oil may penetrate the substrate and cause subsurface contamination. Vegetation may not recover along exposed areas of shoreline, resulting in loss of habitat and erosion. Recovery may be slow in trampled areas.

4.10.7 *Waste Generation*—Oiled plant cuttings must be collected and disposed. Disposal must be in accordance with all applicable regulations.

4.11 *Flooding (Deluge)*:

4.11.1 *Objective*—Wash stranded oil to the water's edge for collection.

4.11.2 *Description*—A large diameter (2 to 6 in.; 5 to 15 cm) perforated header pipe is placed above the oiled area. A flexible perforated header hose may be used during deluge of inter-tidal areas to better conform to shoreline profiles. Ambient temperature water is pumped through the header pipe at low pressure and flows down to the water. This action simulates tidal flushing. On porous substrates, water flows through the substrate pushing loose oil ahead of it (or floats oil to the surface) then transports the oil down slope for pickup. On saturated, fine-grained substrates, the operation resembles surface flushing. Flow is maintained as long as necessary to remove the majority of free oil. Oil is trapped by booms and picked up using a skimmer or other suitable equipment.

4.11.3 *Applicable Habitat Types*—Most shorelines where the equipment can be effectively deployed. This method is not effective in steep intertidal areas.

4.11.4 *When to Use*—On heavily oiled shorelines when the oil is still fluid and loosely adhering to the substrate or where oil has penetrated into gravel, cobble, or boulder beaches. This method is frequently used in combination with other washing techniques.

4.11.5 *Biological Constraints*—Where the lower intertidal area contains rich biological communities, flooding should be restricted to tidal stages when these areas are under water. Special care should be taken to recover oil in biologically rich communities. Avoid using on muddy substrates. Not appropriate at mouths of streams and creeks.

4.11.6 *Environmental Effects*—Habitat may be impacted by foot traffic and smothered by substrate washed down a slope. If containment is not adequate, oil and oiled substrate may be flushed to adjacent areas. Flooding may cause substrate loss and shoreline erosion. Oiled substrate may be transported to nearshore areas, resulting in contamination and smothering.

4.11.7 *Waste Generation*—Dependent on effectiveness of collection method. Disposal must be in accordance with all applicable regulations.

4.12 *Low Pressure, Ambient Water Flushing*:

4.12.1 *Objective*—To remove liquid oil that has adhered to substrates (including man-made structures), pooled on the surface, or trapped in vegetation.

4.12.2 *Description*—Low pressure (< 10 psi) washing with ambient temperature water sprayed by hoses is used to flush oil to the water's edge for collection. Oil is contained in booms and picked up with skimmers, vacuum, or sorbents. Typically used with a flooding system to prevent released oil from re-adhering to the substrate downstream of the treatment area.

4.12.3 *Applicable Habitat Types*—On substrates and man-made structures such as seawalls and riprap, where the oil is still liquid. In wetlands and along vegetated banks where oil is trapped in vegetation.

4.12.4 *When to Use*—Where fluid oil is stranded onshore.

4.12.5 *Biological Constraints*—Flushing may need to be restricted so that the oil/water mixture does not enter sensitive intertidal habitats, and that mobilized substrates do not impact rich subtidal communities. Flushed oil must be recovered to prevent further oiling of adjacent areas. Flushing from boats will minimize foot traffic in soft substrates and vegetation. In marshes, flush only at high tide and either from boats or at the high tide line to prevent foot traffic in vegetation.

4.12.6 *Environmental Effects*—If containment is not adequate, oil and oily substrate may be flushed in adjacent areas. Flooding may cause loss of substrate and shoreline erosion. Trampling of substrate and attached biota is likely to occur.

4.12.7 *Waste Generation*—Dependent on collection

method. Disposal must be in accordance with all applicable regulations.

4.13 *High Pressure, Ambient Water Flushing*:

4.13.1 *Objective*—Remove oil that has adhered to hard substrates or man-made structures.

4.13.2 *Description*—Similar to low pressure flushing except that water pressure is 100 to 1000 psi (720 to 7200 kPa). High-pressure washing is more effective in removing sticky or viscous oil than low-pressure washing. If low volumes of water are used, sorbents are placed directly below treatment areas.

4.13.3 *Applicable Habitat Types*—On bedrock, man-made structures (riprap, seawalls), and gravel substrates.

4.13.4 *When to Use*—When low pressure flushing is not effective and when a directed water jet can remove oil from hard-to-reach sites. To remove oil for aesthetic reasons or to prevent continued oil release.

4.13.5 *Biological Constraints*—May need to restrict flushing so that oil does not enter sensitive habitats. Flushed oil must be recovered to prevent further oiling of adjacent areas. Should not be used directly on algae or rich intertidal areas.

4.13.6 *Environmental Effects*—All attached biota in the direct spray zone will be removed, even when used properly. Oil may be driven deeper in the substrate or fine substrate may be eroded from shorelines if water jet is improperly applied. If containment is not adequate, oil and oily substrates may be flushed into adjacent areas. Trampling of substrate and biota will occur.

4.13.7 *Waste Generation*—Dependent on effectiveness of collection method. Disposal must be in accordance with all applicable regulations.

4.14 *Low Pressure, Hot Water Flushing*:

4.14.1 *Objective*—To remove non-fluid oil that has adhered to substrate or man-made structures (seawalls, riprap) or has pooled on substrate.

4.14.2 *Description*—Hot water (90°F (32°C) up to 171°F (77°C) is sprayed with hoses at low pressures (<10 psi (<72 kPa) to liquefy and mobilize oil that has adhered to substrate. Oil is floated to the water's edge and recovered with skimmers, vacuum, or sorbents. Can be used with flooding to prevent re-adherence of oil.

4.14.3 *Applicable Habitat Types*—Rocky shorelines, sand to gravel beaches, man-made structures.

4.14.4 *When to Use*—When heavy, but relatively fresh oil has stranded onshore. Heating the oil above its pour point will cause the oil to flow. This method is less effective on sticky oils.

4.14.5 *Biological Constraints*—Wetlands and rich intertidal communities should be avoided so that the hot oil/water mixture does not enter sensitive habitats. Flushing from boats will help minimize foot traffic in soft substrates and vegetation. Flushed oil must be recovered to prevent further oiling of adjacent areas. This method should not be used directly on algae or in rich intertidal areas and should be restricted near stream mouths.

4.14.6 *Environmental Effects*—Hot water can cause mortality of biota. If containment is inadequate, oil may be flushed in adjacent areas. Flooding may cause loss of substrate and shoreline erosion. Trampling of substrate and biota will occur.

4.14.7 *Waste Generation*—Dependent on effectiveness of collection method. Disposal must be in accordance with all applicable regulations.

4.15 *High Pressure, Hot Water Flushing*:

4.15.1 *Objective*—Mobilize weathered, viscous oil that is strongly adhered to surfaces or trapped.

4.15.2 *Description*—Hot water (90°F (32°C) up to 171°F (77°C) is sprayed with hand-held wands at pressures greater than 100 psi (720 kPa). If used without water flooding, this option requires immediate use of vacuum or sorbents to remove the oil/water runoff. If a flooding system is used, the oil is flushed to the water surface for collection with skimmers, vacuum, or sorbents.

4.15.3 *Applicable Habitat Types*—Rocky shorelines, gravel beaches, man-made structures (riprap, seawalls).

4.15.4 *When to Use*—When the oil has weathered to the point that warm water at low pressure is not effective at removal of adhered oil. Often used to remove oil from man-made structures for aesthetic reasons.

4.15.5 *Biological Constraints*—Restrict use so that the oil/water mixture does not enter sensitive habitats (damage can result from exposure to oil, oiled substrate, and hot water). This method should not be used directly on algae or in sensitive intertidal areas. Should be restricted near stream mouths and tide pool communities. Released oil must be recovered to prevent further oiling of adjacent areas.

4.15.6 *Environmental Effects*—Attached biota in the direct spray zone will be removed or killed even when method is used properly. Oil may be driven into the substrate. Oiled substrate may be mobilized to shallow nearshore areas resulting in contamination and smothering.

4.15.7 *Waste Generation*—Dependent on effectiveness of collection method. Disposal must be in accordance with all applicable regulations.

4.16 *Steam Cleaning*:

4.16.1 *Objective*—To remove heavy oil from solid substrates or man-made structures.

4.16.2 *Description*—Steam or very hot water 171°F (77°C) to 212°F (100°C) is sprayed with hand-held wands at high pressure (2000 + psi (14 400 kPa)). Water volumes are considerably less compared to flushing methods.

4.16.3 *Applicable Habitat Types*—Man-made structures including seawalls and riprap.

4.16.4 *When to Use*—Removal of heavy oil for aesthetic reasons and when hot-water flushing is not effective and no living resources are present.

4.16.5 *Biological Constraints*—This method is not to be used in soft substrate areas, vegetation, or areas of high biological abundance directly on or below the man-made structure.

4.16.6 *Environmental Effects*—Complete mortality of all biota in the spray zone. Recovery of all released oil is difficult. If containment is inadequate, oil may be flushed into nearshore areas.

4.16.7 *Waste Generation*—Dependent on effectiveness of collection method. Sorbents are typically used and generate significant volumes of waste. Disposal must be in accordance with all applicable regulations.

4.17 *Sand Blasting*:

4.17.1 *Objective*—Remove heavy oil from solid substrates or man-made structures.

4.17.2 *Description*—Use of sandblasting equipment to remove oil from substrate. May include the recovery of used (oiled) sand. Equipment can be operated from boat or land.

4.17.3 *Applicable Habitat Types*—Heavily oiled seawalls, riprap, and bedrock.

4.17.4 *When to Use*—When heavy oil needs to be cleaned for aesthetic reasons. When steam cleaning is not effective and chemical cleaning is not permitted.

4.17.5 *Biological Constraints*—Not to be used in areas of soft substrates, vegetation, or high biological abundance directly below or adjacent to area being sand blasted.

4.17.6 *Environmental Effects*—Complete mortality of all biota in sandblasting area. Smothering of biota in adjacent areas is possible. Non-recovery of used sand will introduce oil into adjacent areas. Used oiled sand may be transported to shallow nearshore areas resulting in contamination, smothering, and sinking in near-shore waters.

4.17.7 *Waste Generation*—Used oiled sand must be recovered and disposed in accordance with all applicable regulations.

4.18 *Solidifiers*:

4.18.1 *Objective*—Change the physical state of oil from a liquid to a solid.

4.18.2 *Description*—Chemical products (polymers) are added to oil at 10 to 45 % volume or greater, solidifying the oil in minutes to hours. Broadcast systems such as leaf blowers, water cannons, or fire suppression systems, can be modified to apply the solidifier over large areas. Solidifiers can be placed in sorbent booms.

4.18.3 *Applicable Habitat Types*—All substrates and man-made structures.

4.18.4 *When to Use*—When oil needs to be immobilized to prevent refloating from a shoreline, penetration in a substrate, or further spreading. Due to a requirement for mixing, solidifiers should be administered while the oil is still fluid. The oil may not fully solidify unless well mixed with the product. A mixture of solid and untreated oil may occur. This option is generally not used on heavy oils that are already viscous.

4.18.5 *Biological Constraints*—All treated material must be recovered.

4.18.6 *Environmental Effects*—Available products are insoluble and have very low aquatic toxicity. Unrecovered solidified oil may have longer impact because of slow weathering rates. Physical disturbance of habitat is likely to occur during application and recovery.

4.18.7 *Waste Generation*—Oil treated with solidifiers is usually disposed in land fills. Disposal must be in accordance with all applicable regulations.

4.19 *Shoreline Cleaning Agents (Surface Washing Agents)*:

4.19.1 *Objective*—To increase the efficiency of oil removal from contaminated areas through the use of chemical products. To be able to lower the water temperature and pressure required to mobilize the oil from the substrate.

4.19.2 *Description*—Special low-toxicity formulations are applied to the substrate, as a presoak or flushing solution, or both, to soften weathered or heavy oils and increase the efficiency of flushing methods. Some products will disperse the oil as it is washed off the substrate while other products will not.

4.19.3 *Applicable Habitat Types*—On the same habitats where water flooding and flushing methods are applicable.

4.19.4 *When to Use*—When weathered oil cannot be removed using ambient water temperature and low pressures.

4.19.5 *Biological Constraints*—When the product does not disperse the oil into the water column, the mobilized oil must be recovered from the water surface. Any dispersed oil may impact the water column and subtidal organisms. Use may be restricted in areas where suspended sediment concentrations are high, near wetlands, and near sensitive nearshore resources.

4.19.6 *Environmental Effects*—Surface washing agents will vary in aquatic toxicity and in their dispersability effects on treated oil. Aquatic toxicity should be considered when considering a product for use. In many cases, regulatory approval will be needed.

4.19.7 *Waste Generation*—Treated oil must be recovered. Waste generation is a function of the recovery method, which frequently includes sorbents. Disposal must be in accordance with all applicable regulations.

4.20 *Nutrient Enrichment*:

4.20.1 *Objective*—Accelerate the rates of natural microbial degradation of oil by adding nutrients (specifically nitrogen and phosphorus) to stimulate microbial growth.

4.20.2 *Description*—If analysis of interstitial pore water indicates that nutrients are a limiting factor, water soluble nutrients can be applied to an oiled area using a spray irrigation system. Nutrients are applied daily if oiled area is submerged by tides and waves and if maximum microbial stimulation is desired. If oiled area is submerged only during spring tides the frequency of nutrient addition is determined by the water coverage of the intertidal zone. Use of slow-release granular or encapsulated nutrients or oleophilic fertilizer that adheres to the oil, should require less frequent addition. However time-series monitoring of interstitial pore water nutrient levels is necessary to ensure that target levels are being maintained, particularly throughout the depth of the impacted intertidal zone.

4.20.3 *Applicable Habitat Types*—Can be used on any habitat where access is allowed and nutrients are deficient.

4.20.4 *When to Use*—On moderate to heavily oiled substrates, after other methods have been used to remove as much of the oil as possible. On lightly oiled substrates where other methods are destructive or not effective; and, where nutrients are a limiting factor in natural degradation.

4.20.5 *Biological Constraints*—Use of ammonia–based fertilizers at highly elevated concentrations should be avoided because un-ionized ammonia is toxic to aquatic biota. Nitrate is a good nitrogen source and does not have the toxicity of ammonia. Sodium tripolyphosphate is recommended over orthophosphates as it is more soluble in seawater. If nutrients are properly applied with adequate monitoring, eutrophication is not expected to occur. Only nutrients shown to be nontoxic and effective should be used. Contact toxicity of oleophilic nutrients may restrict their use, as other components in the

product could be more toxic to aquatic organisms in the presence of oil. Only registered or approved products whose toxicity is known should be used, as some formulations could be toxic to aquatic organisms. There must be no risk of excessive oxygen depletion. Use is not recommended adjacent to stream mouths and tide pools.

4.20.6 *Environmental Effects*—Foot or vehicle traffic resulting from nutrient application may be detrimental. Nutrients may be sprayed from a vessel or aircraft.

4.20.7 *Waste Generation*—None.

4.21 *Natural Microbial Seeding (Bioaugmentation)*:

4.21.1 *Objective*—To increase the rates of natural microbial degradation of oil by addition of high numbers of oil-degrading microorganisms.

4.21.2 *Description*—Formulations containing hydrocarbon-degrading microbes are added to the oiled area. Microorganisms are added because indigenous hydrocarbon degrading microbes are low in number or the microbes present cannot degrade the oil effectively. Formulations containing oil degrading microbes must also contain adequate nitrogen and phosphorous. Research has not demonstrated conclusively that bioaugmentation is effective.

4.21.3 *Applicable Habitat Types*—Insufficient information on impact or effectiveness to determine applicable habitats.

4.21.4 *When to Use*—Insufficient information on impact or effectiveness to determine when to use it.

4.21.5 *Biological Constraints*—Avoid using products containing ammonia-containing fertilizers at elevated concentrations since un-ionized ammonia is toxic to aquatic biota. If the product is applied properly with adequate monitoring, eutrophication should not be a problem. Aquatic toxicity data should be carefully evaluated, as other components in the formulation could be toxic to aquatic organisms.

4.21.6 *Environmental Effects*—This is not a common option, so adverse effects, if any, are yet to be evaluated in full-scale field applications. Foot or vehicle traffic during application may cause impact. Product may be applied from vessels or aircraft.

4.21.7 *Waste Generation*—None.

4.22 *In Situ Burning*:

4.22.1 *Objective*—To removal oil from the shorelines by igniting and burning it.

4.22.2 *Description*—Oil on the shoreline is removed by burning, particularly when it is on a combustible substrate such as vegetation, logs, and other debris. Oil can also be burned on non-flammable substrates with the aid of a burn promoter. On certain substrates it may be necessary to dig trenches for oil to accumulate to a thickness that will sustain burning. Heavy oils are hard to ignite but can sustain burning. Emulsified oil may not ignite or sustain a burn.

4.22.3 *Applicable Habitat Types*—On most habitats. Except dry, muddy substrates where heat may impact biological productivity. May increase oil penetration in permeable substrates. Not suitable for mangroves or other woody vegetation.

4.22.4 *When to Use*—Early in the spill event, after ensuring that the product is ignitable. Onshore where heavy oil is present in sites neither amenable nor accessible to physical removal and the oil must be removed quickly. There are potential applications for oil spilled on ice. Consult with regulatory authorities, as there are many operational and public health constraints.

4.22.5 *Biological Constraints*—Possible effects of large volumes of smoke on wildlife and populated areas should be evaluated.

4.22.6 *Environmental Effects*—Temperature and air quality effects are likely to be localized and temporary. Toxicological effects from burn residues have not been evaluated. Removal of burn residues is often necessary. Removal of residue may cause physical impact to sensitive habitats such as wetlands. Limited data indicate recovery of wetland vegetation will depend on the season of burn, vegetation type, and water level in the wetland at the time of burning.

4.22.7 *Waste Generation*—Burn residues need to be collected. Residues from an efficient burn will be a small fraction of the original oil volume. Disposal of burn residues must be in accordance with all applicable regulations.

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