



Standard Guide for Describing Shoreline and Inland Response Techniques¹

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1. Scope

1.1 This guide describes methods to clean and remediate stranded oil on marine and lake shorelines, on river banks and other inland water body shorelines, and terrestrial habitats. The primary goal of any countermeasure is to aid recovery while minimizing additional impact.

1.2 This guide describes 22 different tactics that are available for consideration. These options range from natural recovery to active physical or biochemical intervention.

1.3 The tactics listed might not be appropriate under all possible circumstances, and multiple countermeasures could be appropriate on the same shoreline, river bank, lake shore or terrestrial habitat.

1.4 This guide describes technical considerations for selecting appropriate response countermeasures or techniques.

1.5 Selection of specific countermeasures for use during a spill response is guided by properties of the oil, degree of oiling, site accessibility, geomorphology, substrate and vegetation type, mobility of available equipment, hydrologic (coastal and inland) and meteorological conditions, and the presence of sensitive natural and archeological resources. It is advisable to consult with appropriate regulatory authorities since certain response options may require government authorization or approval, or both.

1.6 This guide does not address response to submerged, sunken or buried oil.

1.7 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.8 *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 appro-*

priate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:²

F1686 Guide for Surveys to Document and Assess Oiling Conditions

F1687 Guide for Terminology and Indices to Describe Oiling Conditions on Shorelines

F1872 Guide for Use of Chemical Shoreline Cleaning Agents: Environmental and Operational Considerations

F2205 Guide for Ecological Considerations for the Use of Chemical Dispersants in Oil Spill Response: Tropical Environments

F2532 Guide for Determining Net Environmental Benefit of Dispersant Use

3. Key Terms

3.1 *Shoreline and Inland Habitats*—For the purpose of this guide, marine and estuarine shorelines, river banks, and lake shores will be collectively referred to as shorelines, shores, or shore-zones. Shore types include a range of impermeable (bedrock, ice, and man-made structures), permeable (flats, beaches, and man-made), and coastal wetland (marshes, mangroves,) habitats. Other non-shoreline, inland habitats include wetlands (pond, fen, bog, swamp, tundra, and shrub) and drier terrains (grassland, desert, forests), and will be collectively referred to as either wetlands or terrains, respectively.

3.2 *Mixed Sediment Substrates*—These are described based on the size of the inorganic sediments (Guide **F1687**). The penetration and retention of oil is largely controlled by sediment size. Only light oils (for example, a diesel) can penetrate sand, whereas all but the more viscous oils can easily penetrate into pebbles and cobbles (“coarse sediment”). Substrates composed of mixed sands, pebbles, and cobbles are sometimes referred to as “gravel.” The surface layer often has predominantly coarse sediments with increasing amounts of sand in the subsurface. In mixed-sediment substrates, coarser fractions

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

(pebbles and cobbles) are infilled with the finer sediments (sands and granules) so that these substrates are permeable only for some medium oils and all light oils. Pebble-cobble (“coarse sediment”) substrates have open interstitial spaces, so oil typically penetrates them, but can be easily remobilized by wave flushing, tidal pumping, or by river currents.

3.3 Debris—Scattered organic or inorganic materials that have washed up onto shorelines, wetlands, or accumulated in rivers and streams, or a combination thereof. These materials are not part of a natural habitat, such as sediments, attached animals (for example, mussels or barnacles), live sea grasses, or aquatic plants. Accumulations of large logs that have washed ashore on sedimentary coasts or mid-channel islands can provide protection against wave action and, in some areas, are considered to be a critical element of the shore zone. Likewise, log jams or beaver dams in rivers and streams can provide critical habitat. A decision to remove oiled logs and other debris may require approval from regulatory agencies.

3.4 Hot versus Warm Water Washing—Washing oil from a substrate (solid or otherwise) typically uses ambient (unheated) water pumped from the adjacent water body. The removal of sticky or weathered stranded oil can require an increase in pressure or temperature, or both, to be effective. Conventional water heaters raise water temperatures up to 160°F [70°C]. An operational example is the successful use of warm washing during the *Exxon Valdez* response. Hot water washing involves heating water to temperatures greater than 160°F [70°C]. Hot water heaters are occasionally combined with high-pressure spray systems, require more energy than warm-water heaters, and are only applicable for removal of small amounts of oil (“spot washing”) on man-made structures.

3.5 Waste Generation—Each spill response technique, generates different volumes and types of waste depending on the amount and type of spilled oil and the substrate materials. The types of waste generated during spill response include: oily water or liquids, oiled sediments, or oiled debris. Recovered oil and oil-water mixtures are usually temporarily stored prior to recycling, treatment or disposal, or a combination thereof. Operational waste is generated by cleanup or treatment activities and can include personal protective equipment, sorbents, and packaging. Waste management can be an issue during response, particularly in remote areas where disposal options are limited and travel distances to approved sites are long. Estimates of the types and volumes of potential waste should be included in the countermeasure selection process. **(1)**³

3.6 Response Techniques—For the purpose of this guide, the term, “response techniques,” will be used to generically refer to response countermeasures, clean-up techniques, tactics, or methods, or a combination thereof.

4. Significance and Use

4.1 Once the extent and type of oiling has been defined and documented using proper procedures (see Guides **F1686** and **F1687**), decisions are made on the appropriate course of action

for site cleaning and restoration. In some cases, natural recovery (accompanied by monitoring) can be the preferred approach whereas in other cases, active response may be preferred and appropriate. This guide summarizes the principal response techniques available for shoreline, wetland, and terrain habitats.

4.2 This guide is intended to minimize the potential for added impact to the environment from use of response techniques in an overly-aggressive manner or in unsuitable conditions or habitats.

4.3 In Section 5, typical considerations, which can limit the applicability of a given technique are addressed in *Constraints*. An example that is applicable to all techniques other the natural recovery, is special permission will likely be needed for any response operations at sites with known culturally or historically important resources. Also, in Section 5, a synopsis of main trade-offs from use of a particular technique is provided in *Environmental Effects*.

5. Onshore Response Techniques

5.1 This section lists and describes those techniques that can be considered for use in an onshore (shoreline, wetland, or terrestrial) oil spill response. Some of these options may require special consideration and authorization prior to work. Also, some of these techniques have greater personnel and equipment requirements or can generate more waste relative to others. Tradeoffs need to be considered when selecting an appropriate option(s), particularly in remote areas. In most cases, government agencies will be involved in the decision-making process. Government approval may be required for some techniques, and these are typically considered on a case-by-case basis. Contingency plans should provide for use of a range of techniques. The response techniques described in this guide are consistent with Environment Canada, US NOAA, and American Petroleum Institute terminology. **(2, 3, 4, 5)**

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A description of each response technique is discussed in separate sections below.

5.2 Natural Recovery:

5.2.1 Objective—Stranded oil is not removed either to minimize environmental impacts from treatment, because no

³ The boldface numbers in parentheses refer to the list of references at the end of this standard.

effective response technique is available, or because predicted impacts from use of a technique are judged to be unacceptable. In some circumstances, safety concerns can preclude cleanup activities. Oil is left to degrade naturally.

5.2.2 Description—Site conditions can be monitored for changes and recovery progress. Prevention of oil remobilization or migration of oil offsite may need active response.

5.2.3 Applicable Habitat Types—Can be used on all shoreline, wetland, or terrestrial habitat types.

5.2.4 When to Use—When natural oil removal rates are acceptable in terms of the resources at risk, when the degree of oiling is light, or when cleanup actions are likely to result in more harm than allowing oil to degrade by natural forces.

5.2.5 Constraints—May be inappropriate for sites used by high numbers of mobile animals (for example, birds, mammals, and crabs) or endangered or threatened species.

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

5.2.7 Waste Generation—None.

5.3 Barriers/Berms:

5.3.1 Objective—To either physically prevent oil from entering into a sensitive area, restrict water movement, or to divert oil towards a collection area, or a combination thereof. **(6)**

5.3.2 Description—A physical barrier is placed across an area in front of encroaching oil to prevent it from entering a sensitive area. Barriers can be earthen berms, trenches, shore-sealing booms, sheet piling, or filter fences. When passage of water is desired, underflow or overflow dams are used. Sheet piles can be driven into substrates and used to restrict oil leaching from land onto shorelines towards adjacent water bodies.

5.3.3 Applicable Habitat Types—On most terrain slopes and at the mouths of creeks, streams, or rivers. For tidal habitats, where a berm can be built above the high-water line to prevent oil from over-washing a low shoreline and entering a sensitive back-beach habitat, such as a lagoon.

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

5.3.5 Constraints—Disturbance to bird nesting areas, beaver dams, wetlands, or other sensitive areas should be minimized. Placement of dams, filter fences and sheet pile barriers can cause physical disruption, especially in wetlands and tundra habitats.

5.3.6 Environmental Effects—Can disrupt or increase localized oiling of substrates and vegetation. Trenching can enhance oil penetration into substrates and increase the degree of substrate oiling.

5.3.7 Waste Generation—Oiled barrier substrates and filter fence materials need to be disposed of as oily wastes. Sheet piles can be removed, cleaned and re-used. Water used for cleaning needs to be collected and treated or disposed. Disposal must be in accordance with all applicable regulations.

5.4 Manual Oil Removal/Cleaning:

5.4.1 Objective—Physically remove oil and oily debris with hand tools and manual labor.

5.4.2 Description—Surface oil and oily debris are removed by manual means (for example, gloved hands, rakes, forks,

shovels, sieves, and sorbents) and placed in containers for removal and subsequent disposal. No mechanized equipment is used except during transfer and transport of waste.

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

5.4.4 When to Use—Generally used on areas where small amounts of 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 oil patches and tar balls.

5.4.5 Constraints—Foot traffic over sensitive areas (for example, wetlands, shellfish beds, bird nesting areas, dunes) should be limited or restricted. There can be time periods when access is not appropriate (for example, bird nesting, seal pupping, and periods when land habitats are inundated).

5.4.6 Environmental Effects—Minimal, if surface disturbance by responders and oily waste management activities are limited.

5.4.7 Waste Generation—Can generate significant amounts of oily substrate and debris, which requires proper disposal or treatment. Decontamination of tools can yield oily waste water which also requires proper treatment. Worker personal protective equipment can be disposed of daily or decontaminated and re-used. Oily waste water resulting from decontamination must be treated properly. Disposal must be in accordance with applicable regulations.

5.5 Mechanical Oil Removal:

5.5.1 Objective—To physically remove oil and oily debris using mechanical equipment. **(7)**

5.5.2 Description—Surface oil, oiled substrate, and oily debris are removed using mechanical equipment (such as front-end loaders, back-hoes, graders, bulldozers, elevating scrapers, dredges, and beach cleaning machines). This technique necessitates that response resources be provided for temporary storage, transportation, treatment, and disposal of recovered oil, oily debris, and oily waste.

5.5.3 Applicable Habitat Types—Locations where surface substrates are amenable to and accessible by mechanical equipment.

5.5.4 When to Use—When large quantities of oiled materials are to be removed. Care should be taken to remove substrates only to the depth of oil penetration. This technique should be used sparingly where removal of large volumes of substrate can lead to erosion. Buried oil recovery can include the temporary removal of clean overburden, removal of oiled substrates, and subsequent replacement of clean overburden. Vehicle traffic should be controlled to minimize further oil penetration.

5.5.5 Constraints—Special restrictions should be established for sites where traffic and equipment operations could be damaging. It could be useful to check soils in advance for vehicular load tolerances. Heavy equipment use should be restricted in sensitive habitats during breeding or nesting seasons and in areas containing endangered or threatened species. Noise generated by mechanical equipment can be locally disruptive during certain seasons.

5.5.6 Environmental Effects—Can be detrimental if excessive substrate volumes are removed without replacement. Organisms in removed substrates might be impacted.

5.5.7 Waste Generation—Can generate significant amounts of oiled substrate and oily debris, which requires treatment or disposal, or both. Mechanical equipment can be decontaminated, which yields oily waste water. Oily wastewater from decontamination must be properly collected and treated. Disposal must be in accordance with applicable regulations. The potential impacts from the high volume of oily waste, debris, and substrates should be considered when selecting this technique.

5.6 Sorbents:

5.6.1 Objective—Physically remove surface oil from substrates by application of oil-attracting (oleophilic) materials.

5.6.2 Description—The term, sorbent, applies to both absorbent and adsorbent materials. The material is placed on an oiled surface to sorb oil that is refloated or mobilized by tidal, wave, or river current action. Sorbents can be used manually to wipe oil directly from a substrate. Sorbent types include boom, pads, rolls, sweeps, snares, and granules. Removal efficiency is dependent on the capacity of a sorbent material, degree of oiling, wave, tidal or water current energy available to free oil from a substrate, and the oil type and its degree of weathering. Recovery of sorbent material is preferred.

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

5.6.4 When to Use—When the oil is floating on water (for example a pond or wetland), or has stranded on a shoreline or spilled to land. The oil should readily adhere to the sorbent. Sorbents are often used as a secondary treatment method after bulk oil has been removed or in sensitive habitats where access is restricted. Sorbents are typically not appropriate on or near high energy or steep shorelines. Some sorbents can break apart in high energy conditions. Steep shorelines make recovery of used sorbents difficult.

5.6.5 Constraints—Recovery of sorbent material is recommended. Loose granular sorbents should be selected to be readily recoverable or biodegradable. Deploying and retrieving sorbents should be conducted to avoid adversely affecting local wildlife. Sorbents should not be placed in a manner that could endanger or trap wildlife. Sorbents can be slow-acting on viscous oils.

5.6.6 Environmental Effects—Deployment and retrieval can cause physical disturbance to habitats. Improperly deployed or tended sorbents can harm or smother sensitive organisms. Some sorbents, when left in place too long, can break apart and present an ingestion hazard to wildlife.

5.6.7 Waste Generation—Can generate large volumes of oiled substrate and oily debris, which requires proper treatment and or disposal. Generation of large amounts of lightly oiled sorbents should be avoided; sorbent types and application should be monitored to maximize performance. Some sorbent types can be de-oiled and reused. Equipment used for retrieval of loose sorbent in terrestrial habitats can be decontaminated and reused, but yields oily wastewater which requires proper treatment or disposal, or both. Disposal must be in accordance with applicable regulations.

5.7 Vacuums:

5.7.1 Objective—To physically remove mobile oil which is pooled.

5.7.2 Description—A vacuum unit with a suction head is used to recover mobile oil. The size of equipment can range from small portable units used to fill 55-gal [202 liter] drums to large truck-mounted devices which can lift large cobbles. Oil removal rates can be extremely slow with this technique. Water spray systems can be used to flush mobile oil toward a suction head.

5.7.3 Applicable Habitat Types—Vacuums can be used on any accessible habitat. Vacuums can be mounted on barges, onshore on trucks, or deployed as individual units from boats or onshore at low tide.

5.7.4 When to Use—When liquid oil is pooled, concentrated in trenches, or trapped amongst accessible vegetation.

5.7.5 Constraints—Special restrictions should be established for areas where foot traffic and equipment operation could 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.

5.7.6 Environmental Effects—Effects can be minimal if foot and vehicular traffic are controlled and minimal areas of substrate are affected.

5.7.7 Waste Generation—Recovered oil and oil-water mixtures are usually stored temporarily prior to recycling, treatment or disposal. Large amounts of water are often collected with vacuums, which then requires separation and treatment. Oil recycling and disposal must be in accordance with applicable regulations.

5.8 Debris Removal:

5.8.1 Objective—Physically remove un-oiled debris in the path of spilled oil prior to stranding. (7)

5.8.2 Description—Manual or mechanical removal of un-oiled debris (for example, wood, seaweed, trash, wreckage). Removal includes the cutting and removal of large oiled logs. Refer to “debris” in 3.3.

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

5.8.4 When to Use—When debris becomes oiled, it becomes a potential source for re-oiling habitats and biota, an aesthetic problem, and can be a safety hazard for responders. Pre-cleaning of an area before stranding of spilled oil can limit these issues during a response. In some cases, removal is only temporary and natural debris, such as rack on a shoreline, can and should be replaced once there is not further threat of oiling.

5.8.5 Constraints—Consultation with appropriate regulatory authorities should take place prior to removal of debris because of its potential wildlife habitat value. Foot traffic over sensitive areas (for example, wetlands, tundra, bird nesting sites, dunes, areas containing endangered plant species) should be restricted. There may be temporary periods when shoreline access is restricted (for example, bird nesting, influx of large numbers of migratory birds, or seal pupping).

5.8.6 Environmental Effects—Removal could affect future habitat use, lower erosion protection, and reduce sources of food from foraging for some species.

5.8.7 Waste Generation—An advantage of collecting debris prior to oiling is that waste disposal requirements would 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 applicable regulations.

5.9 *Mixing:*

5.9.1 Objective—Physically rework oiled sediments in situ to break up oil deposits, increase surface area, and mix deeper subsurface oil layers to expose them to natural removal processes and enhance their rate of natural weathering and degradation. (8)

5.9.2 Description—Oiled substrate is mixed either in the absence of water above the water line (“dry” mixing) or underwater (“wet” mixing) using mechanical equipment or manual tools. In both cases, the intent is to agitate sediment in situ, without sediment removal. This differentiates mixing from sediment relocation (5.10) where sediments are purposely moved from one location to another. Refloated oil from reworked areas can be contained and recovered. “Wet” mixing typically takes place within a boomed area in shallow water (<1 m depth), and can involve the use of high-pressure water jets to agitate underwater sediments. Landfarming, which uses both mixing and bioremediation (5.21) is a common practice and may require regulatory approval.

5.9.3 Applicable Habitat Types—Any habitat which can support mechanical equipment or foot traffic, or both.

5.9.4 When to Use—On sand to coarse-sediment substrates with surface or subsurface oil, where sediment removal is not feasible due to erosion or waste disposal issues, and in remote areas with small amounts of oil. Can be used in later phases of a cleanup program, after bulk oil removal has been completed, to accelerate weathering of oil residues.

5.9.5 Constraints—Might not be applicable on shorelines located immediately adjacent to sensitive habitats (for example, those with shellfish beds, fish-spawning areas, bird nesting or concentration areas) because of the potential for continued release of oil.

5.9.6 Environmental Effects—Mixing of oil into substrate could expose biota which occur beyond the original layer of oil. Repeated reworking could delay re-establishment of biota. Oil released into water, either by “wet” mixing or by rising water levels after “dry” mixing and that cannot be contained at the surface, can flow to adjacent areas. Studies show rates of biodegradation of oil are greatly accelerated when it is released into surface water from mixing. Field experiments show released oil rapidly spreads into a water column, is positively or neutrally buoyant, and is unlikely to sink in quantities which could cause widespread effects.

5.9.7 Waste Generation—Equipment used for mixing sediment, whether dry or wet, can be decontaminated and reused. Decontamination yields oily wastewater which requires proper treatment or disposal, or both. Disposal must be in accordance with applicable regulations.

5.10 *Sediment Relocation:*

5.10.1 Objective—Physically relocate oiled sediments to enhance natural weathering and cleaning rates by wave or river current activity. (8)

5.10.2 Description—Oiled sediments are removed from one location and relocated to another which has a greater potential for weathering processes or exposure to wave or current action.

5.10.3 Applicable Habitat Types—This technique is generally used on sand, coarse-sediment, or cobble shorelines or river bars where sediment removal, potential erosion, or low natural sediment replenishment, or a combination thereof, are of concern. Sediment relocation can also be used at remote sites with small amounts of oil.

5.10.4 When to Use—Appropriate for sites where oil is stranded above the normal waterline or in the upper intertidal zone, swash zone, or river bank. Sediment relocation can be used where remoteness or other logistical limitations make oiled sediment removal impractical or undesirable due to waste management issues. Can be used in later phases of a cleanup program to accelerate the weathering of oil residues after bulk oil removal has been completed.

5.10.5 Constraints—This technique is not usually applicable on shorelines located immediately adjacent to shellfish habitats or fish spawning areas during bird migration due to the potential of introducing oil into these sensitive habitats.

5.10.6 Environmental Effects—Oil released onto surface water can be transported to immediately adjacent areas. Field experiments show the released oil rapidly spreads into the water column, is positively or neutrally buoyant, and is unlikely to sink in quantities which could cause widespread adverse effects. Studies show rates of natural biodegradation of oil, released into water from sediment relocation, are greatly accelerated. Oil recovery efforts (booming and collection) at the site of relocation can limit spreading of oil which could otherwise pose a risk to immediately adjacent sensitive areas or populations. Typically, this technique is not used with oil recovery as an objective.

5.10.7 Waste Generation—Equipment used for sediment relocation can be decontaminated and reused. Decontamination yields oily wastewater which requires proper treatment or disposal, or both. Disposal must be in accordance with applicable regulations.

5.11 *Vegetation Cutting/Removal:*

5.11.1 Objective—Physical removal of oiled vegetation to prevent oiling of wildlife and secondary oil releases.

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

5.11.3 Applicable Habitat Types—Habitats (such as marshes or wetlands) composed of emergent, herbaceous vegetation, upper shorelines after very high tides, and river and lake shores after flooding. (9)

5.11.4 When to Use—Use when the risk of oiled vegetation affecting wildlife outweighs the value of the vegetation to be cut, and there is no less destructive technique to remove or reduce the risk of oiling to acceptable levels.

5.11.5 Constraints—Cutting only the oiled parts of plants and leaving roots, and as much of the stem as possible, minimizes impacts. Strict monitoring of operations should be conducted to minimize the degree of any root destruction and mixing of any oil deeper into substrates. Access to bird nesting areas should be restricted during nesting seasons.

5.11.6 *Environmental Effects*—Vegetation removal impacts habitat structure and function. Reduced plant growth and plant mortality can occur in cut areas. If the base of a plant stem is cut, then oil could penetrate into a substrate. Cut vegetation might not recover along exposed areas, resulting in loss of habitat and erosion. Recovery might be delayed in trampled areas.

5.11.7 *Waste Generation*—Oiled plant cuttings should be collected and disposed. Equipment used for vegetation cutting and removal can be decontaminated. Decontamination yields oily wastewater which requires proper treatment or disposal, or both. Disposal must be in accordance with applicable regulations.

5.12 *Flooding (Deluge):*

5.12.1 *Objective*—Physically wash (push using the power of flowing water) oil to adjacent waters or pits/trenches for collection and removal.

5.12.2 *Description*—A large diameter (2 to 6 in. [5 to 15 cm]) perforated header pipe is placed above an oiled area. A flexible perforated header hose can be used to better conform to the surface. Ambient temperature water is pumped through the header pipe at low pressure and flows down slope. This action simulates natural flushing. On porous substrates, water flows through substrate materials pushing loose oil ahead of it (or floats oil to the surface), and then transports oil down slope for subsequent recovery. On saturated fine-grained substrates, this technique resembles surface flushing (see 5.13 and 5.15). Flow is maintained as long as necessary to remove the majority of free oil. Oil on water is contained by booms while oil on land is collected in pits/trenches and is then recovered using a skimmer or other suitable equipment.

5.12.3 *Applicable Habitat Types*—Most habitats where the equipment can be effectively deployed. This technique is not effective on steep shorelines, river banks or non-vegetated slopes. Fresh water should not be used for flooding marine or estuarine sites. Saltwater should not be used for flooding freshwater sites.

5.12.4 *When to Use*—On heavily oiled shorelines when oil is still fluid and loosely adhering to substrate or where oil has penetrated into pebble, cobble, or boulder substrates. This technique is frequently used in combination with other washing techniques (see 5.13 through 5.16).

5.12.5 *Constraints*—Where lower intertidal or other habitats contain rich biological communities, then flooding should be restricted to tide or river stages when they are under water. Special care should be taken in biologically rich communities to recover mobilized oil. Avoid using on muddy, adsorbent substrates.

5.12.6 *Environmental Effects*—Habitats can be impacted by foot traffic from responders and smothered by recently deposited substrate washed down slope. If containment is not adequate, oil and oiled substrate could be inadvertently flushed out to adjacent areas. Flooding can cause substrate loss and erosion.

5.12.7 *Waste Generation*—Dependent on effectiveness of collection technique for mobilized oil and subsequent separation of oil and water. Disposal must be in accordance with applicable regulations.

5.13 *Low Pressure, Ambient Water Flushing:*

5.13.1 *Objective*—To physically mobilize and recover liquid oil which has either adhered to substrates (including man-made structures), pooled on a substrate, or has been trapped amongst vegetation.

5.13.2 *Description*—Low pressure (<20 psi [<140 kPa]) ambient temperature water sprayed by hoses is used to flush oil to adjacent water, or to a lined pit/trench on land for collection and recovery. (10) Oil is collected and contained in booms and recovered with skimmers, vacuum, or sorbents. Typically used with a flooding system to prevent released oil from re-adhering to any substrate downstream of a treatment site.

5.13.3 *Applicable Habitat Types*—On substrates and man-made structures, such as seawalls and riprap, where oil is still liquid. In wetlands, mangroves, and along vegetated banks where oil is trapped amongst vegetation. Fresh water should not be used for flooding marine or estuarine sites. Saltwater should not be used for flooding freshwater sites.

5.13.4 *When to Use*—Where oil is mobile or fluid.

5.13.5 *Constraints*—Flushing might need to be restricted so that an oil/water mixture does not enter other sensitive habitats, and that mobilized substrates do not impact biologically rich communities. Flushed oil should be recovered to prevent further oiling of adjacent areas. Flushing from boats can minimize foot traffic in sites with soft substrates and aquatic vegetation. In tidal sites, flush only at high tide either from boats or the high water line to limit foot traffic.

5.13.6 *Environmental Effects*—If containment of mobile oil is not adequate, oil and oily substrate could be inadvertently flushed to adjacent areas. Flooding can cause loss of substrate and erosion. Habitats could be adversely effected by trampling of substrates by responders and response vehicles.

5.13.7 *Waste Generation*—Dependent on effectiveness of collection method for mobilized oil and subsequent oil-water separation. Disposal must be in accordance with applicable regulations.

5.14 *High Pressure, Ambient Water Flushing:*

5.14.1 *Objective*—Physically mobilize and recover oil that has adhered to hard substrates or man-made structures.

5.14.2 *Description*—Similar to low pressure flushing except water pressure is increased to greater than 100 psi (700 kPa). High-pressure flushing is more effective than low-pressure flushing in removing sticky or viscous oils. If low volumes of water are used, then sorbents can be placed directly below treatment sites to collect mobilized oil.

5.14.3 *Applicable Habitat Types*—On shoreline and inland bedrock, man-made structures (for example, riprap and seawalls), and coarse sediment substrates (for example, cobble and boulders). Fresh water should not be used for flooding marine or estuarine sites. Saltwater should not be used for flooding freshwater sites.

5.14.4 *When to Use*—When low pressure flushing (5.13 and 5.15) 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.

5.14.5 *Constraints*—Might need to restrict flushing so oil does not enter sensitive, adjacent habitats. Flushed oil should

be recovered to prevent further oiling of adjacent habitats. Should not be used directly on biologically-rich areas or on sensitive vegetation.

5.14.6 Environmental Effects—Attached biota in the direct spray zone could be removed even when flushing is conducted properly. If a water jet is improperly applied, then oil could be driven deeper in substrates or fine substrates could be eroded. If containment of mobilized oil is not adequate, then both oil and oily substrates could be inadvertently flushed into adjacent areas. Trampling of substrate and biota can occur.

5.14.7 Waste Generation—Dependent on effectiveness of collection method for mobilized oil and subsequent oil-water separation. Disposal must be in accordance with applicable regulations.

5.15 Low Pressure, Warm Water Flushing:

5.15.1 Objective—To physically mobilize and recover non-fluid oil, which has either adhered to substrates, man-made structures (for example, seawalls and riprap) or pooled on a substrate.

5.15.2 Description—Heated water at temperatures of up to 160°F [70°C] is sprayed with hoses at low pressure (<10 psi [<72 kPa]) to liquefy and mobilize oil which has adhered to substrate. **(10)** Oil is floated to adjacent waters or inland to a lined pit/trench and recovered with skimmers, vacuum, or sorbents. Can be used with flooding (see 5.12) to prevent re-adherence of mobilized oil.

5.15.3 Applicable Habitat Types—Bedrock surfaces, sand to gravel substrates, and man-made solid structures. Fresh water should not be used for flooding marine or estuarine sites. Saltwater should not be used for flooding freshwater sites.

5.15.4 When to Use—When heavy, but relatively fresh or mobile oil has stranded. Heating oil above its pour point causes the oil to flow. This technique is less effective on sticky oils.

5.15.5 Constraints—Wetlands and rich intertidal communities should be avoided, so heated oil/water mixture does not enter them. Flushing from boats minimizes foot traffic in soft substrates and on vegetation. Flushed oil should be recovered to prevent oiling of adjacent areas. This technique should not be used directly on algae or rich intertidal areas and should be restricted near stream mouths.

5.15.6 Environmental Effects—Heated water can cause mortality of biota. If containment of mobilized oil is inadequate, then oil could be flushed towards adjacent areas. Flooding could cause loss of substrate and erosion. Trampling of substrate and biota can occur from foot and vehicular traffic.

5.15.7 Waste Generation—Dependent on effectiveness of collection method for mobilized oil and subsequent oil-water separation. Disposal must be in accordance with applicable regulations.

5.16 High Pressure, Warm Water Flushing:

5.16.1 Objective—Physically mobilize and recover weathered or viscous oil that has strongly adhered to surfaces or been trapped in coarse substrates.

5.16.2 Description—Heated water to temperatures up to 160°F [70°C] is sprayed with hand-held wands at pressures greater than 100 psi [700 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 in

conjunction, then oil is flushed down slope to for collection with skimmers, vacuum, or sorbents.

5.16.3 Applicable Habitat Types—Bedrock shorelines, man-made structures (riprap, seawalls) seawalls). Fresh water should not be used for flooding marine or estuarine sites. Saltwater should not be used for flooding freshwater sites.

5.16.4 When to Use—When oil has weathered to the point that use of ambient water at low pressure (5.13) is not effective at removal of adhered oil. Often used to remove oil for aesthetic reasons from man-made structures. This technique is generally not applicable for spills of gasoline, diesel, or light crude oil.

5.16.5 Constraints—Restrict use so the released oil/water mixtures do not inadvertently enter adjacent sensitive habitats (damage can result from exposure to oil, oiled substrate, and heated water). This technique should not be used directly on sensitive areas (for example, intertidal biota, tundra, marshes). This technique should be restricted near stream mouths and tide pool communities. Released oil should be recovered to prevent further oiling of adjacent areas.

5.16.6 Environmental Effects—Attached biota within a direct spray zone can be removed or killed even when this technique is used properly. Oil can be driven into a substrate. Oiled substrate can be mobilized towards shallow near shore areas resulting in additional oiling and smothering of biota.

5.16.7 Waste Generation—Dependent on effectiveness of collection method and oil-water separation. Disposal must be in accordance with applicable regulations.

5.17 Hot Water, High Pressure Cleaning:

5.17.1 Objective—To physically mobilize and recover heavy oil from solid substrates and man-made structures.

5.17.2 Description—Hot water at temperatures above 160°F [70°C] is sprayed with hand-held wands at high pressure (2000+ psi [14 000+ kPa]). Water volumes are considerably less compared to flushing methods (see Sections 5.13 – 5.16). Use may require regulatory approvals.

5.17.3 Applicable Habitat Types—Man-made structures, including seawalls and riprap. Fresh water should not be used for flooding marine or estuarine sites. Saltwater should not be used for flooding freshwater sites.

5.17.4 When to Use—Removal of heavy oil primarily for aesthetic reasons, and when warm water flushing is not effective and no valuable living resources are present.

5.17.5 Constraints—This technique is not applicable to soft substrates, on vegetation, or areas of high biological abundance directly on or below the man-made structure.

5.17.6 Environmental Effects—Mortality of biota in the direct spray zone is expected. Warmed and mobilized oil and oiled substrate could be inadvertently transported to adjacent habitats.

5.17.7 Waste Generation—Dependent on effectiveness of collection method for released oil and subsequent oil-water separation. Sorbents are typically used in conjunction with this technique, and recovered oiled sorbents can generate large volumes of waste. Disposal must be in accordance with applicable regulations.

5.18 Sand Blasting:

5.18.1 *Objective*—Physically mobilize and recover heavy oil from solid substrates or man-made structures.

5.18.2 *Description*—Use of sandblasting equipment to remove oil from substrate. Should include recovery of used (oiled) sand. Equipment can be operated from a boat or on land. Use may require regulatory approvals.

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

5.18.4 *When to Use*—When oil needs to be removed for aesthetic reasons and when high-pressure hot water is not effective and use of surface washing agents (5.20) is not permitted.

5.18.5 *Constraints*—Not applicable in soft substrates, vegetation, or habitats with high biological abundance or where these types of habitats occur directly below or adjacent to area being sand blasted.

5.18.6 *Environmental Effects*—Mortality of biota directly in a sandblasting area is expected. Used sand could introduce oil into adjacent areas which had been unoiled or smother biota, or both.

5.18.7 *Waste Generation*—Dependent on effectiveness of collection method and removal of sand blast material. Extensive sandblasting can generate high volumes of used sand for subsequent treatment or disposal, or both. Disposal must be in accordance with applicable regulations.

5.19 Solidifiers:

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

5.19.2 *Description*—Chemical products (polymers in powder or granular form) are added to oil at 10 to 45 % volume or greater to solidify the oil in minutes to hours. Broadcast systems (such as leaf blowers, water cannons, or fire suppression systems) can be modified to apply solidifiers over large areas. On water, solidifiers can be broadcast within sorbent booms, which help contain solidified oil for subsequent recovery. Use may require regulatory approvals.

5.19.3 *Applicable Habitat Types*—Most substrates and man-made structures. Use of solidifiers on riprap can be problematic as oil is less likely to be naturally flushed or be removed by washing, or both (see Sections 5.12 – 5.17).

5.19.4 *When to Use*—When it is appropriate to immobilize oil to prevent refloating from a shoreline, penetration in a substrate, or further spreading. Due to a requirement for mixing, solidifiers should be administered while oil is still fluid. The oil might not fully solidify unless well mixed with the solidifier product. A mixture of solid and untreated oil can occur. This technique is generally not used on heavy oils that are already viscous. Use during colder weather slows the function of the solidifier.

5.19.5 *Constraints*—Consult with appropriate regulatory authorities regarding product approvals prior to use. Treated material should be recovered.

5.19.6 *Environmental Effects*—Available products are insoluble and have very low aquatic toxicity. Unrecovered solidified oil can have slow weathering rates and so could have longer times during which oil exposure could occur. Physical disturbance of habitat is likely during application and recovery.

5.19.7 *Waste Generation*—Oil treated with solidifiers is usually disposed in landfills. Equipment used for collecting solidified oil could be decontaminated and reused. Decontamination yields oily wastewater which requires proper treatment and disposal. Disposal must be in accordance with applicable regulations.

5.20 Surface Washing Agents (SWAs):

5.20.1 *Objective*—To increase the efficiency of oil removal by using chemical products which minimize stranding of spilled oil on a shore or river bank (Guide F1872). To lower the water temperature and pressure required to mobilize oil from a substrate.

5.20.2 *Description*—SWAs are applied to a substrate as a presoak or flushing solution (or both) to soften weathered or heavy oils and increase the efficiency of flushing techniques (see Sections 5.12 – 5.16). Chemical dispersants (Guides F2205 and F2532) are excluded from this technique as they are designed for application on water to disperse spilled oil into a water column and accelerate natural biodegradation. SWAs are designed to create a barrier between the oil and a substrate to enhance flushing and enable subsequent mechanical recovery. However, some SWAs can disperse oil as it is washed off a substrate into a waterbody. Response personnel and decision makers should test an SWA's ability before use. Use may require regulatory approvals.

5.20.3 *Applicable Habitat Types*—On the same habitats where water flooding and flushing methods are applicable (Sections 5.12 – 5.16).

5.20.4 *When to Use*—When weathered oil cannot be removed using ambient water temperature and low pressures. Consult manufacturer's instructions for proper application of SWAs.

5.20.5 *Constraints*—Consult with appropriate regulatory authorities prior to use. For SWAs that do not disperse oil, then the mobilized oil should be recovered from the water surface. Use may be restricted in areas where concentrations of organic suspended materials are high, near sensitive near shore resources (such as wetlands), and in some enclosed water bodies (smaller lakes and ponds).

5.20.6 *Environmental Effects*—SWAs vary in their aquatic toxicity and in their dispersibility of treated oil. Any dispersed oil can impact water column or benthic organisms if concentrations are high and the dilution potential is low. In many cases, regulatory approval for use of SWAs will be required.

5.20.7 *Waste Generation*—Waste generation is a function of the released oil recovery method, which frequently includes use of sorbents and skimmers. Treated oil should be recovered. Disposal must be in accordance with applicable regulations.

5.21 Nutrient Enrichment:

5.21.1 *Objective*—Accelerate natural microbial degradation of oil by adding key nutrients (specifically, nitrogen and phosphorus) to stimulate microbial growth and degradation of oil. (11)

5.21.2 *Description*—If analysis of interstitial pore water indicates nutrients levels are a limiting factor to microbial growth, then key water-soluble nutrients can be applied to an oiled area using a spray irrigation system. Use of slow-release granular or encapsulated nutrients or oleophilic fertilizers that

adhere to oil requires less frequent application compared to use of water soluble nutrients. Nutrients can be sprayed from a vessel or aircraft. Time-series monitoring of interstitial pore water nutrient levels is appropriate to ensure target levels are maintained, particularly throughout the depth of an oiled zone. Can be used in combination with mixing (see Section 5.9) and use may require regulatory approvals.

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

5.21.4 When to Use—On moderate to heavily oiled substrates, after other techniques have removed as much oil as possible. On lightly oiled substrates, when other techniques are destructive or not effective; and, where nutrients are a limiting factor.

5.21.5 Constraints—Consult with appropriate regulatory authorities regarding product approvals prior to use. Use is not recommended adjacent to stream mouths, on river or stream bars, and intertidal zones or tide pools because products can be easily washed away. Nitrate is a good nitrogen source and does not have the toxicity of ammonia. Orthophosphates are recommended for freshwater habitat application, while sodium tripolyphosphate is recommended for marine and estuarine habitat applications.

5.21.6 Environmental Effects—Foot or vehicle traffic from nutrient application operations can be detrimental. Only nutrients shown to be nontoxic and effective should be used. Avoid using ammonia-based fertilizers adjacent to water bodies because un-ionized ammonia is toxic to aquatic biota. Contact toxicity of oleophilic nutrients may restrict their use, as other components in a 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.

5.21.7 Waste Generation—Equipment used for applying nutrients could become oiled. Decontamination yields oily wastewater which requires proper treatment and disposal.

5.22 In Situ Burning:

5.22.1 Objective—To remove oil by igniting and burning it.

5.22.2 Description—Oil is removed from a substrate (for example, ponds, wetlands, bedrock, soil/sediments, ice, and snow) by burning. (12) Fresh oil, which has higher evaporation rates, can be more easily ignited. Heavier or weathered oil can be ignited with the aid of a burn promoter (for example, diesel fuel). Emulsified oil can be more difficult to ignite and may not be able to sustain a burn. On certain substrates it could be necessary to dig trenches for oil to accumulate to a thickness that sustains burning. Wetting a future burn site can increase soil water saturation, limit oil penetration into substrate and

possibly float oil on a surface, plus augment fire control steps. Fire breaks of cut vegetation or tilled substrate or hardscape around the perimeter of a burn site are often required to aid fire control.

5.22.3 Applicable Habitat Types—On most habitats, except dry substrates where heat can impact soil microbes and plant roots or contribute to fire control concerns. Can increase oil penetration in permeable substrates when oil is heated and able to flow more easily. In-situ burning can be beneficial for oiled wetlands depending on season. Fire ecologists can provide useful information on the suitability of burning oil in different habitats. Not suitable for mangroves.

5.22.4 When to Use—Early in a spill event after ensuring that an oil can be ignited. Use where pooled oil is present at sites which are neither amenable nor accessible to physical removal and when oil must be removed quickly. For oil spilled onto ice or in snow. Use may require regulatory approvals. Consult with regulatory authorities regarding potential operational and public health constraints.

5.22.5 Constraints—Possible effects of large volumes of smoke on nearby wildlife and populated areas during large burns should be evaluated. Wetting a future burn site can increase soil water saturation, limit substrate penetration by oil, and possibly float oil on a surface, plus augment fire control steps. The presence and mobility of endangered/threatened species in an area should be assessed. Fire breaks of cut vegetation or tilled substrate or hardscape around the perimeter of a burn site are often required to aid fire control.

5.22.6 Environmental Effects—Temperature and air quality effects are usually very localized and temporary. Burn residue has low reactivity and low acute toxicity. Effects from residue are primarily physical (for example, smothering). Removal of burn residues is often necessary. Removal of residue by mechanical equipment can cause physical impact to sensitive habitats such as wetlands. Recovery of a burn site depends on degree of oiling, season of burn, vegetation types, and substrate saturation at the time of burning. If plant cover is greatly reduced, then erosion could occur, and erosion control measures may be necessary. Animals could be attracted to new plant growth at a burn site, therefore protection from overgrazing could be needed.

5.22.7 Waste Generation—Burn residues need to be collected and disposed. Residues from an efficient burn are a small fraction of the original oil volume. Equipment used for collecting residue could become oiled. Decontamination yields oily wastewater which requires proper treatment and disposal. Disposal must be in accordance with applicable regulations.



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