Northwest Area
Shoreline Countermeasures Manual and Matrices

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Northwest Area Committee

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Introduction

Shoreline countermeasures following an oil spill are a critical element in determining the ultimate environmental impact and cost resulting from a spill. As with most aspects of spill response, careful planning can significantly increase the effectiveness of treatment operations. Local response organizations need to develop mechanisms for identifying shorelines requiring treatment, establishing treatment priorities, monitoring the effectiveness and impacts of treatment, and for identifying and resolving problems as the treatment progresses.

The National Oceanic and Atmospheric Administration (NOAA) developed this manual as a tool for shoreline countermeasure planning and response by Regional Response Teams, Area Planning Committees, and State response agencies. The manual is presented as a template that can be tailored for each region or area.

Each section of the manual should be adapted to the specific environments, priorities, and treatment methods appropriate to the planning area. These elements provide the information needed to select cleanup methods for specific combinations of shoreline and oil types. Adapting and completing the template creates a better manual that meets the specific needs of the area. At a minimum, the shoreline environments and special resources need to be revised to reflect those found in the area of concern. Local information on shoreline types (discussed in Chapter 2) can be obtained from Environmental Sensitivity Index (ESI) atlases prepared by NOAA for most of the U.S. shorelines, including the Great Lakes. These atlases describe the shoreline types in each area; these descriptions can be used to replace those included in this template, if appropriate. The section on Special Considerations only lists those resource issues that are potentially of concern. Each region or area should identify those issues of greatest concern and provide guidance on how to best minimize impacts from oil spills. More importantly, the pre-spill process of adapting this manual should allow response agencies the opportunity to discuss and resolve shoreline treatment issues prior to a spill emergency. This tool also outlines a process of documenting and recommending cleanup options for a section of a shoreline after it has been oiled.

1 Shoreline Evaluation and Mapping

STILL TO BE DEVELOPED:

Objectives:

1. **Assess the need for shoreline cleanup.**
2. **Select the most appropriate cleanup method**
3. **Determine priorities for shoreline cleanup.**
4. **Document the spatial oil distribution over time.**
5. **Internally consistent historical record of shoreline oil distribution.**

A. Shoreline Evaluation Process

B. Guidelines for Shoreline Surveys

1. **Joint participation in ground surveys**
2. **Selecting and Naming Segments**
3. **Shoreline Survey Evaluation Forms with accepted common shoreline oiling terminology**

2 Shoreline Types and Sensitive Resources

The type of shoreline, degree of exposure to waves and currents, and associated biological sensitivity are the main criteria for selecting appropriate treatment techniques. Prediction of the behavior and persistence of oil on intertidal habitats is based on an understanding of the coastal environment, not just the substrate type and grain size. The vulnerability of a particular intertidal habitat is an integration of the:

1) Shoreline type (substrate, grain size, tidal elevation, origin)
2) Exposure to wave and tidal energy
3) Biological productivity and sensitivity
4) Ease of cleanup

All of these factors are used to determine the relative sensitivity of shorelines. Key to the sensitivity ranking is an understanding of the relationships between: physical processes, substrate, shoreline type, product type, sediment transport, and product fate and effect. Thus, the intensity of energy expended upon a shoreline by wave action, tidal currents, and river currents directly affects the persistence of stranded oil. The need for shoreline cleanup activities is determined, in part, by the lack or slowness of natural processes in removal of oil stranded on the shoreline.

These concepts were used in the development of the Environmental Sensitivity Index (ESI), which ranks shoreline environments as to their relative sensitivity to oil spills, potential biological injury, and ease of cleanup. ESI maps have been prepared for most areas of the coastline of the United States. Generally speaking, areas exposed to high levels of physical energy, such as wave action and tidal currents, and low biological activity rank low on the scale, while sheltered areas with associated high biological activity have the highest ranking. The shoreline types used in this manual are the rankings, on a scale of 1 to 10, used on most ESI maps (NOAA, 1992). Each atlas has a legend that defines the shoreline ranking scale, describes the nature and distribution of each shoreline type in the area, predicts the behavior of oil on that shoreline type, and makes general cleanup recommendations.

The descriptions, predicted oil impact, and recommended response activity listed in the following sections were updated from existing ESI Atlases for the following areas: the Strait of Juan de Fuca

and Northern Puget Sound (NOAA 1984), Central and Southern Puget Sound (NOAA 1985), Oregon and Washington (NOAA 1986) and Columbia River (NOAA 1991). It should be noted that the description of riverine shoreline in the Columbia River ESI Atlas uses different names and includes only six types. Based on the predicted oil impact and response considerations, these six Columbia River shoreline types correspond to the coastal shoreline types in the following way:

• CR ESI Unvegetated steep banks and cliffs	• ESI-3 Fine and medium grain sand beach, eroding scarp and unvegetated steep river bank
• CR ESI Sand/gravel beaches	• ESI-5 Mixed sand and gravel beaches
• CR ESI Rip rap	• ESI-6C Exposed rip rap
• CR ESI Flats	• ESI-7 Exposed tidal flat
• CR ESI Vegetated banks	• ESI-9B Sheltered vegetated low bank
• CR ESI Marsh/swamp	• ESI-10 Marshes

Shoreline Types

ESI 1. Exposed Rocky Cliff Face & Vertical Sea Walls or Piers

Description

- Exposed rocky shores are most common along the Washington and Oregon outer coasts, but also present along the outer Strait of Juan de Fuca and the San Juan Islands.
- Composed of steeply dipping to vertical bedrock; intertidal zone is steep (< 30˚ slope), with very little width.
- Exposed to high waves, sediment accumulations are uncommon and ephemeral, since waves remove debris that has slumped from eroding cliffs.
- Frequently found interspersed with other shoreline types.
- Rock surfaces are colonized by barnacles, mussels, snails and algae; many of the cliffs are used by marine birds and mammals.
- Manmade seawalls and piers are common along inlets, urbanized areas and developed beachfront sites.
- They are composed of concrete and stone, wooden, or metal bulkheads and wooden pilings.
- Organisms, such as barnacles, shellfish, and algae may be common on pilings; biota on concrete structures along the upper intertidal or supratidal zones is sparse.

Predicted Oil Impact

- Oil typically held offshore by waves reflecting off the steep cliff; on less steep shores, oil may come onshore.
- Oil persistence will be short and will be function of the wave energy during the spill; during high wave energy, oil will be removed in days.
- Marine birds (especially diving birds) and mammals using these rocky shores maybe affected.
- Impacts to intertidal communities are expected to be of short duration; an exception would be where heavy concentrations of a light refined product (e.g., No. 2 fuel oil) came ashore very quickly.
- Oil would percolate between the joints of manmade structures and coat the narrow intertidal area of solid structures.
- Biota would be damaged or killed under heavy accumulations.

Response Considerations

- On most shores, no cleanup is necessary.
- Access is usually very difficult and may pose significant safety issues to response personnel.
- Monitoring for impacts to marine birds and mammals is advised.
- Cleanup of recreational areas may be necessary; high-pressure water flushing is effective while oil is still fresh.

ESI 2. Exposed Wave-Cut Platforms

Description

- The intertidal zone consists of a flat rock bench of highly variable width; along the Oregon and Washington coasts the platform surface is irregular and tidal pools are common.
- The shoreline may be backed by a steep scarp or low bluff. In Puget Sound these areas are usually made up of low-lying bedrock or glacial till.
- There may be a narrow, perched beach of gravel- to boulder-sized sediments at the base of the scarp; pockets of sandy "tidal flats" can occur on the platform in less exposed settings.
- Small accumulations of gravel can be found in the tidal pools and crevices in the platform.

- These habitats can support large populations of encrusting animals and plants, with rich tidal pool communities.

Predicted Oil Impact

- Oil will not adhere to the rock platform, but rather be transported across the platform and accumulate along the high-tide line.
- Oil can penetrate and persist in the beach sediments, if present.
- Tide -pool organisms may be killed
- Persistence of oiled sediments is usually short term (on the order of days to weeks), except in wave shadows or larger sediment accumulations.

Response Considerations

- In most wave-exposed areas, cleanup is not necessary.
- High recreational-use areas may be effectively cleaned using high-pressure water flushing if oil is still fresh.
- Removal of organisms should be avoided.
- Monitoring for impacts to marine birds and mammals is advised.

ESI 3. Fine to Medium Grained Sand Beaches & Unvegetated Steep River Banks

Description

- Sand beaches common along the outer coast, but not very common in the Puget Sound Region
- These beaches are generally wide, hard-packed, and flat if fine grained; gentle sloping (slope < 5˚) if medium grained.
- They are commonly backed by dunes or seawalls along the exposed, outer coast.
- Along sheltered bays, they are narrower, often fronted by tidal flats.
- Upper beach fauna are scarce; lower intertidal biota may include clams, worms and amphipods.
- Near vertical scarps in unconsolidated sediments (most often sand and gravel) and bedrock; most common in urban areas and below dams.
- Undergoing active erosion, as indicated by lack of vegetation

Predicted Oil Impact

- Light oil accumulations will be deposited as oily swashes or bands along the upper intertidal zone.
- Heavy oil accumulations will cover the entire beach surface, although the oil will be lifted off the lower beach with the rising tide.
- Maximum penetration of oil into fine-grained sand will be 10 centimeters (cm).
- Burial of oiled layers by clean sand within the first few weeks will be less than 30 cm along the upper beach face.
- Oil will form a band on steep river banks. In unconsolidated sediments the substrate will be removed taking the oil with it.
- Organisms living in the beach sands may be killed either by smothering or by lethal oil concentrations in the interstitial water.
- Shorebirds may be killed if oiled, though they may shift to clean sites.

Response Considerations

- Cleanup not generally recommended on unconsolidated sediments of steep river banks unless in high recreational use areas.
- Cleanup should concentrate on removal of oil from upper swash zone after all oil has come ashore.
- Sand removal should be minimal to avoid erosion problems; use of heavy equipment for oil/sand removal may result in the removal of excessive amounts of sand; manual cleanup may be more efficient.
- Activity through the oiled sand should be limited to prevent grinding oil deeper in the beach.
- Activity through dune areas should be severely limited.

ESI 4. Coarse-Grained Sand Beaches

Description

- Commonly found near headlands and along the southern Oregon coast.
- These beaches are moderate-to-steep, of variable width, and have soft sediments.
- They may be present as pocket beaches or on top of bedrock platforms.
- Coastal beaches are typically inhabited by razor clams, burrowing worms, and mysids.

Predicted Oil Impact

- Light oil will be deposited primarily as a band along the high-tide line.

- Under very heavy accumulations, oil may spread across the entire beach face, though the oil will be lifted off the lower beach with the rising tide.
- Penetration of oil into coarse-grained sand can reach 25 cm.
- Burial of oiled layers by clean sand can be rapid, and up to 60 cm or more.
- Burial over one meter is possible if the oil comes ashore at the start of a depositional period.
- Biological impacts include temporary declines in infaunal populations, which can also affect feeding shorebirds.

Response Considerations

- Cleanup should commence after the majority of the oil has come onshore unless significant burial is expected to occur.
- Cleanup should concentrate on oil removal from the upper swash zone.
- Sand removal should be minimal to avoid erosion problems; use of heavy equipment for oil/sand removal may result in the removal of excessive amounts of sand; manual cleanup may be more efficient.
- Activity through the oiled sand should be limited to prevent grinding oil deeper in the beach.
- Activity through dune areas should be severely limited.

ESI 5. Mixed Sand And Gravel Beaches

Description

- The most common beach type in Puget Sound; found along the coast as extensive beaches along rocky shores, perched beaches on bedrock, and in the vicinity of river mouths along the southern Oregon coastline
- Narrow, moderately sloping beach composed of a mixture of sand (greater than 20 percent) and gravel (greater than 25 percent).
- The high-tide berm area is usually composed of sand or fine gravel (pebbles to cobbles), whereas the lower part of the beach is coarser, with cobbles to boulders.
- Because of the mixed sediment sizes, there may be zones of sand, pebbles, or cobbles.
- Because of sediment mobility and desiccation on exposed beaches, there are low densities of attached animals and plants.
- Upper intertidal zone used extensively by surf smelt and sand lance for spawning.
- The presence of attached algae, mussels, and barnacles indicates beaches that are relatively sheltered, with the more stable substrate supporting a richer biota.

Predicted Oil Impact

- During small spills, oil will be deposited along and above the high-tide swash.
- Large spills will spread across the entire intertidal area.
- Oil penetration into the beach sediments may be up to 50 cm; however, the sand fraction can be quite mobile, and oil behavior is much like on a sand beach if the sand fraction exceeds about 40 percent.
- Burial of oil may be deep at and above the high-tide line, where oil tends to persist, particularly where beaches are only intermittently exposed to waves.
- On sheltered beaches, extensive pavements of asphalted sediments can form if there is no removal of heavy oil accumulations, because most of the oil remains on the surface; once formed, pavements are very stable and can persist for many years.
- Oil can be stranded in the coarse sediments on the lower part of the beach, particularly if the oil is weathered or emulsified.
- Biota present may be killed by the oil, either by smothering or by lethal concentrations in the water column.

Response Considerations

- Cleanup should commence only after the majority of oil has come ashore.
- Heavy accumulations of oil and oil-soaked debris at the high-tide swash line should be removed to prevent asphalt formation.
- Exposed beaches do not require cleanup unless heavily oiled.
- Removal of sediments should be minimal to prevent erosion.
- Mechanical reworking of sediment into the surf zone can effectively remove fresh oil, especially in sheltered areas of low biological activity; sorbents and booms should be used to contain released oil.

ESI 6A. Gravel Beaches - Pebbles to Cobbles

Description

- Present along coast of Washington.
- Fine grained gravel beaches composed of sediments ranging in size from pebbles to cobbles (from 4 cm to 256 cm in diameter), with boulders a very minor fraction. No sand is on the surface and less than 20 percent is in subsurface.
- Zones of pure pebbles or cobbles may be present, with pebbles forming berms at high-tide line and cobbles and boulders dominating lower beach face.

- The beach slope is intermediate to steep (between 10 and 20 degrees), with multiple wave-built berms forming the upper beach.
- Natural replenishment rate of sediments is extremely slow.
- There is high annual variability in degree of exposure, and thus in frequency of mobilization by waves. Degree of exposure or sediment mobility can be predicted by the amount of rounding or smoothing of the individual pebbles and cobbles.
- Sediment mobility limits the amount of attached algae, barnacles, and mussels to lower tidal levels.

Predicted Oil Impact

- Oil on gravel beaches would coat individual rocks and penetrate up to 60 cm in well-sorted gravels, which may be below the level of annual reworking by the waves.
- Deep penetration and rapid burial of stranded oil is likely on exposed beaches.
- On exposed beaches, oil can be pushed over the high-tide and storm berms, pooling and persisting above the normal zone of wave wash.
- Long-term persistence will be controlled by the depth of penetration versus the depth of routine reworking by storm waves. Oil may persist for years in low wave energy areas.
- In low energy areas, buried oil will tend to seep out, generating sheens that can recontaminate the shoreline.
- On relatively sheltered beaches, formation of asphalt pavements is likely where accumulations are heavy and oil is left uncleaned.

Response Considerations

- Heavily oiled wrack and debris should be removed.
- Due to extremely slow natural replenishment, there should be no permanent removal of sediments.
- High-pressure flushing of gravel may help in cleaning exposed surfaces, but will have little effect on oil penetrated deeply into gravel without extensive reworking.
- In heavily oiled, sheltered areas, sediments may have to be removed and replaced.

ESI 6B. Gravel Beaches - Cobbles to Boulders

Description

- Gravel beaches are composed of sediments ranging in size from cobbles to boulders. (larger than 256 cm in diameter)
- The beach slope is intermediate to steep (between 10 and 20 degrees), with multiple wave-built berms forming the upper beach.
- Boulders dominate the lower intertidal zone. Boulder and cobble armoring of the surface of the middle to lower intertidal zone may also be present.
- Slowest natural replenishment rate of sediments of all beaches.
- There is high annual variability in degree of exposure, and thus in frequency of mobilization by waves.
- Higher amount of attached algae and epifauna due to increased stability of larger boulders.

Predicted Oil Impact

- Oil on gravel beaches would coat individual rocks and penetrate up to 100 cm in the poorly sorted larger cobble and boulder.
- The presence of armor may significantly extend persistence of oil; oil located beneath armored surface will remain longer because of the higher velocities required to mobilize the armor.
- On exposed beaches, oil can be pushed over the high-tide and storm berms, pooling and persisting above the normal zone of wave wash.
- Long-term persistence will be controlled by the depth of penetration versus the depth of routine reworking by storm waves. Oil may persist for years in low wave energy areas.
- In low energy areas, buried oil will tend to seep out, generating sheens that can recontaminate the shoreline.
- On relatively sheltered beaches, formation of asphalt pavements is likely where accumulations are heavy and oil is left uncleaned.

Response Considerations

- Heavily oiled wrack and debris should be removed.
- Due to extremely slow natural replenishment, there should be no permanent removal of sediments.

- High-pressure flushing of gravel may help in cleaning exposed surfaces, but will have little effect on oil penetrated deeply into gravel without extensive reworking.
- In heavily oiled, sheltered areas, sediments may have to be removed and replaced.

ESI 6C. Rip-Rap

Description

- Rip rap is angular rock similiar in size to that described by EIS 6B, used for shoreline protection and inlet stabilization.
- Rip rap structures have a slope which is generally steep, are located at the high tide line where the heaviest concentration of oil usually impact and are made up of boulders too large to be reworked by waves.
- Due to stability of rip rap, biota on the lower levels may be plentiful and varied.
- No natural replenishment of sediments
- Generally located in areas exposed to higher wave energy..
- Higher amount of attached algae and epifauna may be present due to increased stability of larger boulders.

Predicted Oil Impact

- With heavy oiling, individual boulders will be heavily coated and penetration to the bottom of the rip rap structure is likely.
- Pools of oil would collect inside the rip rap structure, and potentially be a source of sheens for a long period.
- Biota would be damaged or killed under heavy accumulations.

Response Considerations

- Heavily oiled wrack and debris should be removed.
- High-pressure flushing of rip rap may help in cleaning exposed surfaces, but will have little effect on oil penetrated deeply into gravel without extensive reworking.
- Heavily oiled rip rap may need to be removed and replaced.

ESI 7. Exposed Tidal Flats

Description

- Particularly common in the eastern portion of Puget Sound and at the entrance to bays, estuaries and river mouths along the coast.
- They are composed primarily of sand and mud.
- The presence of sand indicates that tidal or wind-driven currents and waves are strong enough to mobilize the sediments.
- They are always associated with another shoreline type on the landward side of the flat.
- The sediments are water-saturated, with only the topographically higher ridges drying out during low tide.
- Biological utilization can be very high, with large numbers of infauna and heavy use by birds for roosting and foraging. Clams and worms are the most common species.

Predicted Oil Impact

- Oil does not usually adhere to the surface of exposed tidal flats or penetrate the water saturated sediments, but rather moves across the flat and accumulates at the high-tide line.
- Deposition of oil on the flat may occur on a falling tide if concentrations are heavy, but will frequently be refloated by the next high tide.
- Biological impacts may be severe, especially to burrowing bivalves and worms since oil can penetrate into burrows; this can significantly decrease food for foraging birds and fish in the area.

Response Considerations

- Cleanup of tidal flat generally not recommended due to likelihood of mixing oil deeper into the sediments during cleanup effort.
- Access usually very poor due to shallow water and soft sediments.
- Passive removal of oil lifted off tidal flat by high tide may be advisable if activity can be accomplished without mixing oil into the sediments.
- Use of heavy machinery should be restricted to prevent mixing oil into the sediments and cannot be used in soft, muddier areas.
- Removal of heavily oiled debris stranded in tidal flat may be advisable if activity can be accomplished without mixing surface oil into the sediments.

ESI 8A. Sheltered Vertical Rocky Shores & Solid, Vertical, Man-Made Structures

Description

- Located in calm , interior environments, especially common within interior portion of the San Juan Islands.
- Bedrock shore of variable slope (from vertical cliffs to wide, rocky ledges) which is sheltered from exposure to most wave and tidal energy..
- Uncommon along coast; may occur along the inside of bays and coves.
- Species density and diversity vary greatly, but barnacles, snails, mussels, clams, periwinkles, amphipods, polychaetes, rockweed, and crabs are often very abundant.
- Sheltered solid, vertical, man-made structures consisting of short segments of seawalls, docks and bulkheads are commonly found along the high tide line in harbors, industrial sites and other developed areas.
- Biota on man-made structures along the upper intertidal or supratidal zones are sparse

Predicted Oil Impact

- On rocky shores, oil will adhere readily to the higher rock surfaces, particularly along the high-tide line, forming a distinct oil band.
- The lower intertidal zone usually stays wet (particularly when algae covered), preventing oil from adhering to the rock surface.
- Oil will not penetrate, except in fractures in the rock where oil can pool and persist.
- Oil will penetrate into joints and voids of man-made structure, and with heavy concentrations will coast the intertidal areas.
- Because of the low energy setting, even light accumulations can persist for years, especially between rocks.
- Fresh oil and light refined products have high acute toxicity that can affect attached organisms after even short exposures.

Response Considerations

- Cleanup is difficult, oiled shoreline may pose long-term leaching problem.
- High- and low-pressure water flushing of man-made structures and rocky shores is effective while oil is still fresh.
- Cutting of oiled algae is generally not recommended.

ESI 8B. Sheltered Rubble Slope

Description

- Shoreline commonly found in industrial waterways of northwest ports.
- Relatively steep (greater than 15 degrees) and short rocky shore which is covered with a thin-to-thick veneer of angular rubble without any evidence of rounding or sorting by sediment transport.
- Sheltered from wave energy or strong tidal currents.
- The surface rubble is highly variable in packing, but there is always some permeability in the surface material.
- Species density and diversity vary greatly, but barnacles, snails, mussels, clams, periwinkles, amphipods, polychaetes, rockweed, and crabs are often very abundant.

Predicted Oil Impact

- Oil will adhere readily to the rough rocky surface, particularly along the high-tide line, forming a distinct oil band.
- Where the rubble is loosely packed, oil will penetrate deeply, causing long-term contamination of the subsurface sediments.
- Fresh oil and light refined products have high acute toxicity that can affect attached organisms after even short exposures.

Response Considerations

- Cleanup is difficult, oiled shoreline may pose long-term leaching problem, especially from subsurface contamination.
- High- and low-pressure water flushing is effective for surface contamination while oil is still fresh, but generally does nothing for subsurface contamination.
- Heavly contaminated subsurface sediment may need to be removed and replaced to prevent long term leaching and sheening.
- Cutting of oiled algae is generally not recommended.

ESI 9A. Sheltered Tidal Flats of Sand and Mud

Description

- This shoreline is very common in bays and estuaries in Grays Harbor, Willapa Bay, Tillamook Bay, Columbia River estuary and upper Puget Sound.

- They are present in calm-water habitats, sheltered from major wave activity, and frequently fronted by marshes.
- Although wave energy is very low, flats may be exposed to moderate tidal or river currents.
- Substrate slope is flat (less than 3 degrees) and can vary in width from a few meters to nearly one kilometer..
- Sediment is composed of water-saturated mud or muddy sand, so permeability is very low, except where burrowed.
- The sediments are very soft and cannot support even light foot traffic.
- There are usually large populations of clams, crabs, oysters worms, amphipods and snails; many of these flats are commercially harvested.
- May be used heavily by birds for feeding and as staging areas during migration.
- Eelgrass beds may be present and are an important nursery area for juvenile salmonids, dungeness crab, and various marine fish species.

Predicted Oil Impact

- Oil does not usually adhere to the surface of sheltered tidal flats, but rather moves across the flat and accumulates at the high-tide line.
- Deposition of oil on the flat may occur on a falling tide if concentrations are heavy, but may refloat with the next high tide.
- Oil will not penetrate the water-saturated sediments, however persistent contamination can occur if oil penetrates into burrows of organisms in the mud.
- In areas of high suspended sediments, sorption of oil can result in contaminated sediments that can be deposited on the flats and persist for years.
- Biological impacts may be severe.

Response Considerations

- These areas require high priority for protection during oil spills .
- Cleanup of sheltered tidal flats is generally not recommended due to likelihood of mixing oil deeper into the sediments during cleanup effort.
- Access is very limited due to shallow water and soft substrate; restrict any active cleanup to upper reaches of high-tide swash or conduct from boats.
- Removal of heavily oiled debris stranded along the high tide line may be advisable if activity can be accomplished without mixing surface oil into the sediments.

ESI 9B. Sheltered Vegetated Low Bank

Description

- Either low bank with grasses or low eroding banks with trees and tree roots exposed to the water.
- Found at river mouths in the Puget Sound area, very common throughout the lower Columbia river and above the dams.
- Flooded occasionally by high water.

Predicted Oil Impact

- At low water there is little impact, with oil coating a narrow band of sediment at the water level.
- At high water the oil will cover and coat grasses at base of the trees, oil may also coat low hanging branches and foliage.
- May cause loss of the grasses, but the trees should survive unless oil penetrates and persists in the substrate.

Response Considerations

- Low pressure flushing of oiled areas is effective in removing moderate to heavy accumulations of oil from along the banks.
- Sorbent and containment boom should be placed on the water side of the cleanup operations to contain and collect oil outflow.
- Low- to moderate-pressure flushing can be used to remove oil from tree roots and trunks.

ESI 10. Salt & Fresh-Water Marshes (Herbaceous & Woody Vegetation)

Description

- Common along the coast and in Puget Sound at the head of many bays; extensive marches are found in the Skagit River and Nisqually River delta areas, as well as the Columbia River estuary and river below Portland.
- Marshes are low energy, protected wetlands containing emergent, herbaceous and/or woody vegetation, generally associated with river systems, bays and estuaries.
- Width of the marsh can vary widely, from a narrow fringe to extensive; substrate is generally silt and mud, with variable amounts of organic matter.

- The moderate tidal range of coastal and estuarine marshes results in presence of numerous tidal channels; frequently they are fronted by tidal flats.
- Resident flora and fauna are abundant and consist of numerous species.
- Marshes provide a nursery ground for numerous fish species and are heavily used by birds for nesting and feeding.

Predicted Oil Impact

- Oil adheres readily to marsh vegetation.
- The band of coating will vary widely, depending upon the tidal stage at the time oil slicks are in the vegetation. There may be multiple bands.
- Large slicks will persist through multiple tidal cycles and coat the entire stem from the high-tide line to the base.
- If the vegetation is thick, heavy oil coating will be restricted to the outer fringe, with penetration and lighter oiling to the limit of tidal influence.
- Medium to heavy oils do not readily adhere or penetrate the fine sediments, but they can pool on the surface and in burrows.
- Light oils can penetrate the top few centimeters of sediment and deeply into burrows and cracks (up to one meter); once incorporated into the sediment, oil can persist for years.

Response Considerations

- Marshes are very sensitive environments and highly vulnerable to mechanical damage from clean up activities; highest priority for shoreline protection.
- Cleanup is generally not recommended for light oiling, or oiling confined to the outer fringe; natural flushing, especially in higher energy areas, is best strategy.
- Activities in marsh should be kept at minimum to prevent damage to marsh plants and mixing oil into the soft sediments.
- With heavy oiling, combination of manual removal of oiled wrack and debris, low-pressure flushing, passive absorption, and vacuum collection using small boats can be effective; due to the potential for stirring up the sediment and mixing it with the oil, these activities are generally limited to the edge of the marsh.

Special Considerations

The above shoreline types may also have associated sensitive biological resources and human-use areas, which include:

Subtidal Habitats

- Submerged aquatic vegetation
- Kelp beds
- Worm beds

Birds

- Rookeries and nesting sites
- Waterfowl overwintering concentration areas
- High concentration migration stopovers
- High concentration resident bird colonies

Marine Mammals

- Migration corridors
- Population concentration areas

Terrestrial Mammals

- Concentration areas

Terrestrial Plants

- Threatened and endangered plants adjacent to the shoreline

Fish and Shellfish

- Anadromous fish spawning streams
- Sites important to beach- and kelp-spawning fish
- Estuarine areas that are important fish nursery areas
- Special concentration areas for estuarine and demersal fish
- Shellfish seed beds, leased beds, high concentration areas
- Crab and shrimp nursery areas

Recreation

- High-use recreational beaches
- Marinas and boat ramps
- High-use boating, fishing, and diving areas

Management Areas

- Nature preserves and reserves
- Privately developed lands/facilities (Nature Conservancy Areas)
- Research natural areas
- State marine parks/Federal marine sanctuaries
- Wildlife management areas and refuges

Resource Extraction

- Commercial fishing areas, including finfish, crabs, and mollusks
- Water intakes
- Aquaculture sites
- Intertidal and subtidal mining leases
- Subsistence harvest sites
- Log storage sites

Cultural Resources

- Archaeological and other historically significant sites
- Native American reservations

3 Shoreline Countermeasure Methods Using Conventional Response Technology

The following section lists and describes those shoreline countermeasure methods that utilize conventional response technology to mitigate the environmental impact and enhance the recovery of a shoreline or habitat resulting from stranded oil. Methods and equipment currently in use for these conventional shoreline treatment methods are described in some detail below. These methods, when used according to the guidelines in this manual, may be used on most sites as part of the OSC-directed response. It should be noted that some of these methods may require other authorizations or permits before work begins.

1 No Action
2 Manual Removal of Oil
3 Passive Collection of Oil(Sorbents)
4 Oiled Debris Removal
5 Trenching/Recovery Wells
6 Oiled Sediment Removal
7 Ambient-Water Flooding (Deluge)
8a Ambient-Water/Low-Pressure Washing < 50psi
8b Ambient-Water/High-Pressure Washing < 100psi
9 Warm-Water < 90°/Moderate-to-High-Pressure Washing 50-100psi
10 Hot-Water > 90°/Moderate-to-High-Pressure Washing 50-100psi
11 Vacuum Removal of Oil
12 Sediment Reworking
13 Sediment Removal, Cleansing, and Replacement
14 Cutting Oiled Vegetation

1. No Action

Objective

No attempt is made to remove stranded oil, because there is no proven effective method for cleanup, there is unacceptable risk to response workers, or presence of extremely sensitive environment or resource.

Description

No action is taken. However, the OSC continues to monitor the incident.

Applicable Shoreline Types

Can be used on all shoreline types.

When To Use

If the shoreline is extremely remote or inaccessible, the amount and type of oil does not justify a clean-up effort, when natural removal rates are very fast, or cleanup actions will do more harm than leaving the oil to be removed naturally.

Biological Constraints

This method may be inappropriate for areas where high numbers of mobile animals (birds, marine mammals, crabs, etc.) use the intertidal zone or adjacent nearshore waters.

Environmental Effects

Intertidal — The same as the oil.

Subtidal — The same as the oil.

2. Manual Removal of Oil

Objective

Removing stranded surface oil with hand tools and manual labor.

Description

Removing surface oil accumulations with a minimum of sediment by manual means (hands, rakes, shovels, etc.) and placing in containers for removal from the shoreline. No mechanized equipment is used.

Applicable Shoreline Types

Can be used on most shoreline types; not generally recommened on soft mud substrates where mixing of oil deeper in the sediment might occur.

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. Method may need to be closely monitored or may not be appropriate in archaeological and/or culturally sensitive areas.

Biological Constraints

Foot traffic over sensitive areas (shellfish beds, alga mats, bird nesting areas, dunes, etc.) is to be restricted. May be periods when shoreline access is restricted (e.g., bird nesting, mammal pupping).

Environmental Effects

Intertidal — Minimal if surface disturbance by cleanup activities and work force movement is limited.

Subtidal — None.

3. Passive Collection of Oil (Sorbents)

Objective

Removal of oil by adsorption onto oleophilic material placed in the intertidal zone.

Description

Sorbent material is placed on the surface of the shoreline substrate allowing it to absorb oil as it is released by tidal or wave action. Oiled sorbent material is then collected and removed from the shoreline. Oil removal is dependent on the capacity of the particular sorbent, energy available for lifting oil off the shoreline, and degree of oil weathering.

Applicable Shoreline Types

Can be used on any shoreline type.

When to Use

When the shoreline oil is mobile and transport of oil is expected on or off the site. The oil must be of a viscosity and thickness to be released by the substrate and absorbed by the sorbent. Often used as a secondary treatment method after gross oil removal, and along sensitive shorelines where access is restricted.

Biological Constraints

None, although this method can be slow, thus allowing oil to remain in critical habitats during sensitive periods of time.

Environmental Effects

Intertidal — There may be physical impact of placing the sorbent material in a sensitive area. If all absorbents are not recovered, they will become non degradable, oily debris. Passive absorbents in the mid or lower intertidal should be monitored for entrapment of small crustaceans.

Subtidal — None.

4. Oiled Debris Removal

Objective

Removal of contaminated debris and logs.

Description

Manual or mechanical removal of debris from the upper beach face and the zone above high tide beyond the normal wash of waves. Can include cutting and removal of oiled logs. Care should be taken to prevent any possible erosion of beach area and oil penetration into substrate due to foot traffic.

Applicable Shoreline Types

Can be used on most shoreline types where safe access is allowed; not generally recommend on soft mud substrates where mixing of oil deeper in the sediment might occur.

When to Use

When driftwood and debris is heavily contaminated and either a potential source of chronic oil release, an aesthetic problem, or a source of contamination for other organisms on the shoreline.

Biological Constraints

Disturbance to adjacent upland areas should be minimized. Foot traffic over sensitive intertidal areas (shellfish beds, alga mats, bird nesting areas, dunes, etc.) is to be restricted. May be periods when shoreline access is restricted (e.g., bird nesting, mammal pupping).

Environmental Effects

Intertidal — Reduction of habitat's structural complexity.

Subtidal — None.

5. Trenching/Recovery Wells

Objective

Remove subsurface oil from permeable substrates.

Description

Dig trenches or wells (pits) to the depth of the oil and remove oil floating on the water table by vacuum pump or skimmer. Water flooding or high-pressure spraying at ambient temperatures can be used to flush oil to the trench.

Applicable Shoreline Types

Can be used on beaches ranging in grain size from fine sand to gravel.

When To Use

When large quantities of oil penetrate deeply into permeable sediments and cannot be removed by surface flooding. The oil must be liquid enough to flow at ambient temperatures. Method may need to be closely monitored or may not be appropriate in archaeological and/or culturally sensitive areas.

Biological Constraints

Trenches should not be dug in the lower intertidal where attached algae and organisms are abundant.

Environmental Effects

Intertidal — On gravel beaches, there may be a period of beach instability as the sediments are redistributed after the trenches are filled in.

Subtidal — None.

6. Oiled Sediment Removal

Objective

Removal of surface oiled sediments (without replacement).

Description

Oiled sediments are removed by either manual use of hand tools or mechanical use of various kinds of motorized equipment. The oiled material must be transported and disposed of off-site.

Applicable Shoreline Types

Can be used on any shoreline with surface sediments; not generally recommend on soft mud substrates where mixing of oil deeper in the sediment might occur. On rocky coasts, only manual removal is feasible. Heavy equipment should only be used with special supervision to minimize sediment removal.

When to Use

When only very limited amounts of oiled sediments have to be removed. Should not be considered in areas of low natural replenishment and where beach erosion may result. Care should be taken to limit siltation and to remove the sediments only to the depth of oil penetration, which can be difficult with heavy equipment. Method may not be appropriate in archaeological and/or culturally sensitive areas.

Biological Constraints

Excavating equipment must not intrude upon sensitive habitats. Only the upper intertidal and supratidal areas should be considered for sediment removal to minimize disturbance of biological communities in the lower intertidal and subtidal. There may be site-specific constraints limiting placement of equipment and temporary sediment storage piles. Such operations would generally be restricted in fish-spawning areas. Adjacent sensitive areas potentially impacted by released oil sheens must be protected during operations.

Environmental Effects

Intertidal — The equipment is heavy, and required support personnel is extensive. May be detrimental if excessive sediments are removed without replacement. All organisms resident in the beach will be affected, though the need for removal of the oil may be determined to be the best overall alternative.

Subtidal — Release of oil and fine-grained oily sediments to the water during sediment removal activities and tidal flushing of the excavated beach surface.

7. Ambient-Water Flooding (Deluge)

Objective

To wash surface oil and oil from crevices and rock interstices to water's edge for collection.

Description

A large diameter header pipe is placed parallel to the shoreline above the oiled area. A flexible perforated header hose is used during deluge of intertidal shorelines to better conform to their profiles. Ambient seawater is pumped through holes in the header pipes and flows down the beach face to the water. On porous beaches, water flows through the substrate pushing loose oil ahead of it (or floats oil to the water's surface) then transports the oil down slope for pickup. Flow is maintained as long as necessary to remove the majority of free oil. Oil is trapped by booms and picked up with a skimmer or other suitable equipment.

Applicable Shoreline Types

Beaches with sediments coarser than sand, and gently sloping rocky shorelines. Generally not applicable to mud, sand, vegetated, or steep rocky shorelines.

When to Use

On heavily oiled shorelines when the oil is still fluid and loosely adhering to the substrate; and where oil has penetrated into cobble or boulder beaches. This method is frequently used in combination with other washing techniques (low or high pressure, ambient or warm water).

Biological Constraints

Not appropriate at creek mouths. Where the lower intertidal contains rich biological communities, flooding should be restricted to tidal stages when the rich zones are under water, to prevent secondary oiling.

Environmental Effects

Intertidal — Habitat may be physically disturbed and smothered as sand and gravel components are washed down slope. Organisms may be flushed into lower tidal zones.

Subtidal — Oiled sediment may be transported to shallow subtidal areas, contaminating them and burying benthic organisms.

8a. Ambient-Water/Low-Pressure Washing < 50psi

Objective

Mobilize liquid oil that has adhered to the substrate or man-made structures, pooled on the surface, or become trapped in vegetation to water's edge for collection.

Description

Low-pressure washing (<50 psi) with ambient seawater sprayed with hoses is used to flush oil to the water's edge for pickup. Oil is trapped by booms and picked up with skimmers or sorbents. Can be used with a deluge system on beaches to prevent released oil from re-adhering to the substrate. Care must be taken not to drive the oil into the substrate and to prevent erosion and siltation.

Applicable Shoreline Types

On heavily oiled rock shores, gravel beaches, rip rap, and seawalls where the oil is still fresh and liquid. Also, in marshes and mangroves where free oil is trapped.

When to Use

Where adhered oil is still fresh and must be removed due to continued release of oil. Need to closely monitor for excessive siltation and erosion when flushing mixed sand and gravel beaches.

Biological Constraints

May need to restrict use of flushing to certain tidal elevations so that the oil/water effluent does not drain across sensitive low tide habitats. In marshes, use only at high tide under conditions where sediments will not be disturbed and either from boats or the high-tide line to prevent foot traffic in vegetation.

Environmental Effects

Intertidal — If containment methods are not sufficient, contamination may be flushed into lower intertidal zone. Foot traffic, hoses and the need for compressors will increase the physical impact to the environment.

Subtidal — Oiled sediment may be transported to shallow subtidal areas, contaminating them and burying benthic organisms.

8b. Ambient-Water/High-Pressure Washing <100psi

Objective

Mobilize oil that has adhered to hard substrates or man-made structures to water's edge for collection.

Description

Similar to low-pressure washing except that water pressure is up to 100 psi. High-pressure spray will better remove oil that has adhered to rocks. Because water volumes are typically low, may require placement of sorbents directly below treatment areas or use deluge to carry oil to water's edge for collection.

Applicable Shoreline Types

Rock shores, rip rap and vertical hard manmade structures. Can be used to flush floating oil or loose oil out of tide pools and between crevices on rip rap.

When To Use

When low-pressure washing is not effective for removal of adhered oil, which must be removed due to continued release of oil. When directed water jet can remove oil from hard-to-reach sites. To remove oil from man-made structures for aesthetic reasons.

Biological Constraints

May need to restrict use of flushing to certain tidal elevations so that the oil/water effluent does not drain across sensitive low-tide habitats.

Environmental Effects

Intertidal — May dislodge many organisms from the substrate surface. May drive oil deeper into the substrate if water jet is improperly applied. Foot traffic, hoses and the need for compressors will increase the physical impact to the environment. If containment methods are not sufficient, contamination may be flushed into lower intertidal zone.

Subtidal — Oiled sediment and dislodged organisms may be transported to shallow subtidal areas, contaminating them and burying benthic organisms.

9. Warm-Water < 90°F/Moderate Pressure Washing 50- 100psi

Objective

Mobilize thick and weathered oil adhered to rock surfaces prior to flushing it to the water's edge for collection.

Description

Heated seawater (ambient to 90°F) is applied at moderate pressure to mobilize weathered oil that has adhered to rocks. If the warm water is not sufficient to flush the oil down the

beach, "deluge" flooding or additional low- or high-pressure washing can be used to float the oil to the water's edge for pickup. Oil is trapped by booms and picked up with skimmers or sorbents.

Applicable Shoreline Types

Heavily oiled gravel beaches, rip rap and hard, vertical, manmade structures such as seawalls, bulkheads, and docks.

When To Use

When the oil has weathered to the point that low-pressure washing with ambient water is not effective for removal of adhered oil, which must be removed due to continued release of oil. To remove oil from man-made structures for aesthetic reasons.

Biological Constraints

Must restrict use to certain tidal elevations so that the oil/water effluent does not drain across sensitive low-tide habitats (damage can result from exposure to oil, oiled sediments, and warm water). Should be restricted adjacent to stream mouths, tide pool communities, and similar rich intertidal communities.

Environmental Effects

Intertidal — Temperature change can kill attached organisms. May drive oil deeper into substrate if water jet is not properly applied. Foot traffic, hoses and the need for compressors and heaters will increase the physical impact to the environment. If containment methods are not sufficient, contamination may be flushed into lower intertidal zones that would otherwise not be oiled.

Subtidal — Oiled sediment may be transported to shallow subtidal areas, contaminating them and burying benthic organisms.

10. Hot-Water > 90°F/Moderate Pressure Washing 50-100psi

Objective

Dislodge and mobilize trapped and weathered oil from inaccessible locations and surfaces not amenable to mechanical removal prior to flushing oil to water's edge for collection.

Description

Water heaters mounted offshore on barges or small land-based units heat water to temperatures from 90°F up to 170°F, which is usually sprayed by hand with moderate-pressure wands. Used without water flooding, this procedure requires immediate use of vacuum (vacuum trucks or super suckers) to remove the oil/water runoff. With a deluge system, the oil is flushed to the water's surface for collection with skimmers or sorbents.

Applicable Shoreline Types

Heavily oiled manmade, vertical structures such as seawalls, bulkheads and docks.

When To Use

When the oil has weathered to the point that even warm water at high pressure is not effective for removal of adhered oil, which must be removed due to continued release of oil. To remove oil from man-made structures for aesthetic reasons.

Biological Constraints

Restrict use to certain tidal elevations so that the oil/water effluent does not drain across sensitive low-tide habitats (damage can result from exposure to oil, oiled sediments, and hot water). Should be restricted near stream mouths, tide pool communities, etc.

Released oil must be recovered to prevent further oiling of adjacent environments.

Environmental Effects

Intertidal — All attached organisms in the direct spray zone will be dislodged or killed, and significant mortality (temperature impact) of the lower intertidal communities may result even when used properly. May drive oil deeper into substrate if water jet is improperly applied. Foot traffic, hoses and the need for compressors will increase the physical impact to the environment . Where the intertidal community is rich, the tradeoff between damage to the intertidal community from the hot-water washing versus potential damage from leaving the oil has to be weighed.

Subtidal — Oiled sediment may be transported to shallow subtidal areas, contaminating them and burying benthic organisms.

11. Vacuum Removal of Oil

Objective

Remove free oil pooled on the substrate or from the water's surface in sheltered areas.

Description

Use of a vacuum unit with a suction head to recover free oil. The equipment can range from small portable units that fill individual 55-gallon drums to large supersuckers that are truck-mounted and can lift large rocks. Can be used with water spray systems to flush the oil towards the suction head.

Applicable Shoreline Types

Can be used on any shoreline type if accessible; not generally recommend on soft mud substrates where mixing of oil deeper in the sediment might occur. May be mounted offshore on barges, onshore on trucks, or as individual units on boats or ashore at low tide.

When to Use

When free, liquid oil is stranded on the shoreline (usually along the high-tide line) or trapped in vegetation that is readily accessible.

Biological Constraints

Special restrictions should be identified for areas where foot traffic and equipment operation should be limited, such as rich intertidal communities. Operations in wetlands are to be very closely monitored, with a site-specific list of restrictions.

Environmental Effects

Intertidal — Minimal impacts if used properly and minimal substrate is removed.

Subtidal — None.

12. Sediment Reworking

Objective

Rework oiled sediments to break up the oil deposits, increase its surface area, and mix deep subsurface oil layers that will expose the oil to natural removal processes and enhance the rate of oil degradation.

Description

Beach sediments are rototilled or otherwise mechanically mixed with the use of heavy equipment on gravel beaches. The oiled sediments in the upper beach area may also be relocated lower on the beach to enhance natural cleanup during reworking by wave activity (berm relocation).

Applicable Shoreline Types

Should be used only on beaches exposed to significant wave activity. Tilling-type activities work best on beaches with a significant sand fraction; large equipment can be used to relocate sediments up to boulder size.

When to Use

On beaches with significant amounts of subsurface oil, where sediment removal is unfeasible (due to erosion concerns or disposal problems); also where surface oil deposits have started to form pavements or crusts. Method may not be appropriate in archaeological and/or culturally sensitive areas.

Biological Constraints

Should not be used on beaches near shellfish-harvest or fish-spawning areas, or near bird nesting or concentration areas because of the potential for constant release of oil and oiled sediments. Sediment reworking should be restricted to the upper part of the beach, to prevent disturbance of the biological communities in the lower intertidal area.

Environmental Effects

Intertidal — Due to the mixing of oil into sediments, this process could further expose organisms living below the original layer of oil. Repeated mixing over time could delay the re-establishment of organisms. Relocated sediments would bury and kill organisms. There may be a period of beach instability as the relocated sediments are redistributed. Subtidal — There is a potential for release of contaminated sediments to the nearshore subtidal habitats.

13. Sediment Removal, Cleansing, and Replacement

Objective

To remove oiled sediment and replace them with cleaned or new material.

Description

Oiled sediments are excavated using heavy equipment on the beach at low tide. The sediments are loaded into a container for washing. Cleansing methods include hot water wash or physical agitation with a cleansing solution. After the cleansing process, the rinsed materials are returned to the original area. Cleaning equipment must be placed close to beaches to reduce transportation problems. If not possible to clean oiled sediment replace with new material of similar composition.

Applicable Shoreline Types

Sand- to boulder-sized beaches including rip rap. The beaches must be exposed to wave activity, so that the replaced sediments can be reworked into a natural distribution.

When to Use

Applicable on beaches with large amounts of subsurface oil, where permanent removal of sediment is undesired and other cleanup techniques are likely to be ineffective. Method may not be appropriate in archaeological and/or culturally sensitive areas.

Biological Constraints

Excavating equipment must not intrude upon sensitive habitats. Only the upper and supratidal areas should be considered. Generally restricted in spawning areas. There may be site-specific constraints limiting placement of temporary sediment storage piles. Replaced material must be free of oil and toxic substances. The washing must not change the grain size of the replaced material, either by removal of fines or excessive breakage of friable sediments. If new material is used, it must have a similar composition and grain size distribution as removed sediment.

Environmental Effects

Intertidal — All resident organisms will be affected, though the need for removal of the oil may be determined to be the best overall solution. Equipment can be heavy, large, and noisy; disrupting wildlife. Transportation to site may entail aircraft, land vehicles, or barges, contributing to environmental disruption. There may be a period of beach instability as the replaced sediments are redistributed.

Subtidal — May release oil and fine-grained oily sediments into the water during excavation. This is a concern due to tidal flushing of beach sediments and exposed excavations.

14. Cutting Vegetation

Objective

Removal of oiled vegetation to prevent oiling of wildlife.

Description

Manual cutting of oiled vegetation and removal of cut vegetation with rakes. The cut vegetation is bagged immediately for disposal.

Applicable Shoreline Types

Marshes, protected rock, boulder beaches, and low vegetated river bank.

When to Use

Use when large quantities of potentially mobile oil is trapped in vegetation or when the risk of oiled vegetation contaminating wildlife is greater than 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.

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. For plants attached to rock boulder or cobble beaches sources of population recruitment must be considered. Access to bird nesting areas should be restricted during nesting seasons.

Environmental Effects

Intertidal — Removal of the vegetation will result in loss of habitat for many animals. Cut areas will have reduced plant growth for up to two years. Along exposed section of shoreline, the vegetation may not regrow, resulting in erosion and permanent loss of the habitat. Trampled areas (which are inevitable) will recover much slower.

Subtidal — Long-term impacts would include increased sediment load in the subtidal area as a result of increased erosion in the intertidal area.

4 Shoreline Countermeasure Methods Using Alternative Technology

Shoreline counterneasure based on conventional technology are not always successful in effectively minimizing impacts or speeding up recovery of shorelines impacted by stranded oil. Research and development is ongoing for both new and improved oil spill treatment methods. Various chemical, thermal and biological techniques are currently being tested for effectiveness and toxicity, and may be approved for use in certain situations. Methods considered to be of potential use in this area are described below.

15 In-situ Burning on Shoreline
16a Chemical Oil Stabilization with Elastomizers
16b Chemical Protection of Beaches
16c Chemical Cleaning of Beaches
17 Nutrient Enhancement
18 Microbial Addition

15. *In Situ* Burning on Shorelines

Objective

Removal of oil from the shoreline by burning.

Description

Oil on the shoreline is burned, usually when it is on a combustible substrate such as vegetation, logs, and other debris. Oil can be burned off of nonflammable substrates with the aid of a burn promoter. Appropiate air quality agencies must be notified prior to burn.

Applicable Shoreline Types

On any shoreline type except tidal flats.

When to Use

Early in the spill event, after ensuring that the product is ignitable. Must comply with Northwest Area Plan *In Situ* Burning Policy.

Biological Constraints

Should only be considered for use in the upper intertidal or supratidal zones since destruction of plants and animals from heat and burn promoters will be extensive. This

technique is subject to restrictions and permit requirements established by federal, state and local laws. It should not be used to burn PCBs, wastes containing more than 1,000 parts per million (ppm) of halogenated solvents, or other substances regulated by the U. S. Environmental Protection Agency (EPA).

Environmental Effects

Little is known about the relative effects of burning oiled wetlands compared to other techniques or natural recovery. Burning may cause significant air pollution, which must be considered when weighing the potential benefits and risks of the technique. The combustion products may travel great distances before deposition.

16a. Chemical Oil Stabilization with Elastomizers

Objective

Solidify or gelatinize oil on the water's surface or a beach to keep it from spreading or escaping, and to speed recovery rate and efficiency.

Description

Chemical agent enhancing polymerization of the hydrocarbon molecules applied by semi-liquid spray or as a dry chemical onto the oil in the proper dosage. Depending on the nature and concentration of the polymerizing agent, the oil can be rendered viscoelastic, but still fluid, gelatinous, or semisolid. The primary purpose is to stabilize the oil, keeping it from spreading or escaping, causing oiling elsewhere. May reduce the solubility of the light (and more toxic) fractions, by locking them into the polymer. This reduces both air and water exposure. Depending on the beach type and equipment used, recovery may be enhanced.

Applicable Shoreline Types

Suitable on shorelines of low permeability where heavy oil has pooled on the surface, except vegetated shorelines.

When to Use

When heavy concentrations of liquid oil are on the substrate and adjacent water body, and physical removal can not be completed prior to the next tide so that the oil is likely to move to a more sensitive shoreline type. Should be used in conjunction with booming or other physical containment. Must comply with National Contingency Plan and Northwest Area Plan.

Biological Constraints

Not suitable for vegetated or rip rap shore types. Should be avoided when birds or other wildlife that may be more adversely impacted by the congealed oil can not be kept away

from the treated shoreline. The congealed oil may stick to vegetation and wildlife, increasing physical damage to both. On rip rap the congealed oil may remain in crevices where it may hamper recovery and prolong the release of sheens.

Environmental Effects

May enhance the smothering effect of oil on intertidal organisms. Thus, the treatment should be considered only for heavily oiled beaches where smothering effects are already maximal. The congealed oil may stick to vegetation and wildlife increasing physical damage, such as impaired flight in birds or impaired thermoregulation in mammals and birds whose feathers or fur become oiled.

16b. Chemical Protection of Beaches

Objective

Pretreat shoreline to prevent oil from adhering to the substrate.

Description

Certain types of water-based chemicals, some of which are similar in composition to dispersants, are applied to beaches in advance of the oil.

Applicable Shoreline Types

Coarse- and fine-grained sand beaches, seawalls and piers (particularly piers or waterfront facilities that are of historical significance), eroding bluffs, wave-cut platforms, and rip rap.

When to Use

When oil is projected to impact an applicable shoreline, particularly those that have high recreational or aesthetic value. Must comply with National Contingency Plan and Northwest Area Plan.

Biological Constraints

May not be suitable for nutrient-rich environments, particularly in confined waters. The toxicity of shoreline treatment products is reportedly much less than that of oil, but the toxicity of each product should be evaluated prior to consideration for use.

Environmental Effects

The long-term environmental effects of these procedures are unknown. A toxic effect of the chemical can be anticipated. Additionally, the nutrient load to nearshore and interstitial waters may lead to eutrophication. Whether the predicted reduced residence time of the oil on the beach will increase the survival rate for sessile and interstitial organisms is unknown.

16c. Chemical Cleaning of Beaches

Objective

To increase the efficiency of oil removal from contaminated areas.

Description

Special formulations, which can be characterized as weak dispersants, are applied to the substrate, as a presoak and/or flushing solution, to soften weathered or heavy oils to aid in the efficiency of flushing treatment methods. The intent is to be able to lower the temperature and pressure required to mobilize the oil from the substrate.

Applicable Shoreline Types

On any shoreline where deluge and water flushing procedures are applicable.

When to Use

When the oil has weathered to the point where it will not flow using warm to hot water. This approach may be most applicable where flushing decreases in effectiveness as the oil weathers. Must comply with National Contingency Plan and Northwest Area Plan.

Biological Constraints

Will require extensive biological testing for toxicity and water quality sampling prior to receiving approval for use. The concern is that the treated oil will be dispersed in the water column, and thus impact water column and subtidal organisms. Field tests will be required to show that use of a beach cleaner does not reduce overall recoverability of the oil. Use may be restricted where suspended sediment concentrations are high, adjacent to wetlands and tidal flats, and near sensitive subtidal resources.

Environmental Effects

If more oil is dispersed into the water column, there could be more oil sorbed onto suspended sediments and transferred to subtidal habitats, particularly along sheltered shorelines. Intertidal habitats might survive better, if cooler water temperatures are possible.

17. Nutrient Enhancement

Objective

To speed the rates of natural microbial degradation of oil by addition of nutrients (specifically nitrogen and phosphorus). Microbial biodegradation is the conversion by microorganisms of dissolved and dispersed hydrocarbons into oxidized products via various enzymatic reactions. Some hydrocarbons are converted to carbon dioxide and cell material, while others are partially oxidized and/or left unaltered as a residue.

Description

Nutrients are applied to the shoreline in one of several methods: soluble inorganic formulations that are dissolved in water and applied as a spray at low tide, requiring frequent applications; slow-release formulations that are applied as a solid to the intertidal zone and designed to slowly dissolve; and oleophilic formulations that adhere to the oil itself, thus they are sprayed directly on the oiled areas.

Applicable Shoreline Types

Could be used on any shoreline type where safe access is allowed.

When to Use

On moderately to heavily oiled shorelines, after other techniques have been used to remove as much oil as possible; on lightly oiled shorelines where other techniques are not effective; and where nutrients are a limiting factor in natural degradation. Potentially for the treatment of subsurface oil. Must comply with National Contingency Plan and Northwest Area Plan.

Biological Constraints

Not applicable in shallow water, poorly flushed, restricted embayments where nutrient overloading may lead to eutrophication, or where toxicity of nutrients, particularly ammonia, is of concern. There must be no risk of oxygen depletion. Use is to be restricted adjacent to stream mouths, tide pools, etc. Contact toxicity of oleophilic formulations may restrict areas of direct application. Bioassay test results should be carefully evaluated, as other chemicals in the formulations could be toxic to aquatic organisms.

Environmental Effects

Tests in Alaska showed that interstitial oxygen concentrations did not decrease to such an extent that it limited the supply of oxygen available to the bacteria. The fertilizer applications that increased nutrient concentrations and microbial activity did not harm the nearshore environment. About 99 percent of butoxyethanol, a toxic component of the Inipol formulation, (the fertilizer commonly used in Alaska) degraded to nontoxic compounds within 24 hours after Inipol treatments of cobble shorelines. Inipol was initially toxic to intertidal organisms directly contacted during application. Researchers also found no evidence that the nutrients released from the treated shorelines stimulated algal blooms.

18. Microbial Addition

Objective

To speed the rates of natural microbial degradation of oil by addition of nutrients and microbial products. Microbial biodegradation is the conversion by microorganisms of dissolved and dispersed hydrocarbons into oxidized products via various enzymatic reactions. Some hydrocarbons are converted to carbon dioxide and cell material, while others are partially oxidized and/or left untouched as a residue.

Description

Formulations containing hydrocarbon-degrading microbes and fertilizers are added to the oiled area. The argument is made that indigenous organisms will be killed by the oil, so new microbial species need to be added to begin the process of biodegradation. To date, microbial addition has not been shown to work better than fertilizer alone in field tests.

Applicable Shoreline Types

Could be used on any shoreline type where safe access is allowed.

When to Use

On moderately to heavily oiled shorelines, after other techniques have been used to remove as much oil as possible; on lightly oiled shorelines where other techniques are not effective; and where oil degrading bacteria are a limiting factor in natural degradation. Potentially for the treatment of subsurface oil. Must comply with National Contingency Plan and Northwest Area Plan.

Biological Constraints

Not applicable in shallow water, poorly flushed, restricted embayments where nutrient overloading may lead to eutrophication, or where toxicity of nutrients, particularly ammonia, is of concern. There must be no risk of oxygen depletion. Use is to be restricted adjacent to stream mouths, tide pool communities, etc. Bioassay test results should be carefully evaluated, as other chemicals in the formulation could be toxic to aquatic organisms.

Environmental Effects

Yet to be evaluated for full-scale field applications.

5 Matrices of Recommended Countermeasure Methods by Oil and Shoreline Type

The matrices included in this chapter show which shoreline countermeasure techniques have been considered for the fourteen shoreline types described in Chapter 2. Four matrices have been constructed for the major categories of oil (very light, light, medium, heavy).

Countermeasure methods are described in Chapters 3 and 4. Countermeasures in Chapter 3 are traditional or conventional techniques that the OSC can use without any additional concurrence. However, the cutting of vegetation countermeasure should be used only during specific seasonal windows under specific conditions and with landowner approval. Countermeasures in Chapter 4 are described under a separate section called "Shoreline Countermeasure Methods Using Alternative Technology" may be useful in certain situations,. These methods are considered more experimental and controversial in their application and potential impacts and require more formal review and consultation before implementing. The exact requirements are spelled out in the National Contingency Plan and the Northwest Area Plan. The Shoreline Countermeasures Matrices are a particularly dynamic component of the manual and should continue to be revised as the existing techniques are used and evaluated, and as both old and new techniques are refined.

Each matrix has a written explanation of how it is to be used as a countermeasure advisability matrix. The matrix is only a general guide for removing oil from shoreline substrates. It must be used in conjunction with the entire "Shoreline Countermeasures Manual" plus field observations and scientific advice. The countermeasures listed are not necessarily the best under all circumstances, and any listed technique may need to be used in conjunction with other techniques (including ones not listed herein). The Federal On-Scene Coordinator (FOSC) or the State OSC operating with the FOSC's authorization has the responsibility for and authority to determine which countermeasure(s) are appropriate for the various situations encountered.

Selection of countermeasure techniques to be used in each spill is based upon the degree of oil contamination, shoreline types, and the presence of sensitive resources. Extremely sensitive areas are generally limited to manual cleanup methods. It is important to note that the primary goal of countermeasure implementation is the removal of oil from the shoreline with no further

injury or destruction to the environment. The three categories of guidance used in the matrices are defined as follows:

R	Recommended	May be the preferred method that best achieves the goal of minimizing destruction or injury to the environment
C	Conditional	Viable and possibly useful but may result in limited adverse effects to the environment
	Shaded	Not applicable or not generally recommended.

Shoreline Countermeasures Matrix

Very Light Oil (Jet fuels, Gasoline)

- Highly volatile (should all evaporate within 1-2 days)
- High concentration of toxic (soluble) compounds
- Result: Localized, severe impacts to water column and intertidal resources
- Duration of impact is a function of the resource recovery rate
- No dispersion necessary

SHORELINE TYPES CODES

1- Exposed rock shores and vertical, hard man-made structure (e.g. seawalls)	6B - Gravel beaches - cobbles to boulders
2 - Exposed wave-cut platforms	6C - Exposed rip rap
3 - Fine to medium grained sand beaches & steep unvegetated river banks	7 - Exposed tidal flat
4 - Course grained sand beaches	8A- Sheltered vertical rock shores and vertical, hard man-made structures (e.g. seawalls, docks,
5 - Mixed sand and gravel beaches, including artificial fill containing a range of grain size and material	8B - Sheltered rubble slope
6A - Gravel beaches - pebbles to cobble	9A - Sheltered sand and mud flats
	9B - Sheltered vegetated low bank
	10 - Marshes

COUNTERMEASURES	SHORELINE TYPES 1	2	3	4	5	6A	6B	6C	7	8A	8B	9A	9B	10
CONVENTIONAL METHODS														
No action	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Manual removal of oil														
Passive collection of oil			C	C	C	C	C	C						
Oiled debris removal	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Trenching/recovery wells			C	C	C									
Oiled sediment removal														
Ambient water flooding (Deluge)														C
Amb water flush <50 psi														
Amb water flush <100 psi														
Warm water flush <90°F														
Hot water flush >90°F														
Vacuum removal of oil														
Sediment reworking			C	C	C	C								
Sediment Removal-cleaning-replacement														
Cutting oiled vegetation														
ALTERNATIVE METHODS*														
In-situ burning on shore														
Chemical stabilization, protection, or cleaning														
Nutrient enhancement														
Microbial addition														

R Recommend - May be Preferred Alternative
C Conditional (Refer to NW Shoreline Countermeasures Manual)
Shaded areas are Not Applicable or Not Generally Recommened
***** Follow approved process defined in NCP and NW Area Plan

This countermeasure advisability matrix is only a general guide for removal of oil from shoreline substrates. It must be used in conjunction with the entire Shoreline Countermeasures Manual plus field observations and scientific advice. The countermeasures listed are not necessarily the best under all circumstances, and any listed technique may need to be used in conjunction with other techniques (including ones not listed herein). The Federal On-Scene Coordinator (FOSC) or the state OSC operating with the FOSC's authorization has the responsibility for and the authority to determine which countermeasure(s) are appropriate for various situations encountered. Selection of countermeasures is based on the degree of oil contamination, the shoreline type, and the presence of sensitive resources.

Shoreline Countermeasures Matrix

Light Oil (Diesel, No 2 Fuel Oils, Light Crudes)

- Moderately volatile; will leave residue (up to 1/3 of spilled amount)
- Moderate concentrations of toxic (soluble) compounds
- Long-term contamination of intertidal resources possible
- Potential for subtidal impacts (dissolution, mixing, sorption onto suspended sediments)
- No dispersion necessary
- Cleanup can be very effective

SHORELINE TYPES CODES

1- Exposed rock shores and vertical, hard man-made structure (e.g. seawalls)
2 - Exposed wave-cut platforms
3 - Fine to medium grained sand beaches & steep unvegetated river banks
4 - Course grained sand beaches
5 - Mixed sand and gravel beaches, including artificial fill containing a range of grain size and material
6A - Gravel beaches - pebbles to cobble
6B - Gravel beaches - cobbles to boulders
6C - Exposed rip rap
7 - Exposed tidal flat
8A- Sheltered vertical rock shores and vertical, hard man-made structures (e.g. seawalls, docks, bulkheads)
8B - Sheltered rubble slope
9A - Sheltered sand and mud flats
9B - Sheltered vegetated low bank
10 - Marshes

COUNTERMEASURES	SHORELINE TYPES													
	1	2	3	4	5	6A	6B	6C	7	8A	8B	9A	9B	10
CONVENTIONAL METHODS														
No action	R	R	C	C	C	C	C	C	R	C	C	R	C	R
Manual removal of oil			C	C	C	C	C	C		R	R		C	
Passive collection of oil	C	R	R	R	R	R	R	R	C	R	R	C	R	R
Oiled debris removal	C	C	R	R	R	R	R	R	C	R	R	C	C	C
Trenching/recovery wells			C	C	C									
Oiled sediment removal			C	C	C	C								
Ambient water flooding (Deluge)			C	C	C	R	R	R			C			C
Amb water flush <50 psi		C			C	C	C	C		R	C			C
Amb water flush <100 psi														
Warm water flush <90°F														
Hot water flush >90°F														
Vacuum removal of oil							C	C						C
Sediment reworking			C	C	C	C								
Sediment Removal-cleaning-replacement			C	C	C									
Cutting oiled vegetation							C	C		C	C		C	C
ALTERNATIVE METHODS*														
In-situ burning of shore														
Chemical stabilization, protection, or cleaning														
Nutrient enhancement			C	C	C	C	C	C						C
Microbial addition														

R Recommend - May be Preferred Alternative
C Conditional (Refer to NW Shoreline Countermeasures Manual)
Shaded areas are Not Applicable or Not Generally Recommened
* Follow approved process defined in NCP and NW Area Plan

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Shoreline Countermeasures Matrix

Medium Oil (Most Crude Oils & Some Heavily Weathered Light Crudes)

- About 1/3 will evaporate within 24 hours
- Maximum water-soluble fraction is 10-100ppm
- Oil contamination of intertidal areas can be severe and long-term
- Impact to waterfowl and fur-bearing mammals can be severe
- Chemical dispersion is an option within 1-2 days
- Cleanup most effective if conducted quickly

SHORELINE TYPES CODES

1- Exposed rock shores and vertical, hard man-made structure (e.g. seawalls)
2 - Exposed wave-cut platforms
3 - Fine to medium grained sand beaches & steep unvegetated river banks
4 - Course grained sand beaches
5 - Mixed sand and gravel beaches, including artificial fill containing a range of grain size and material
6A - Gravel beaches - pebbles to cobble
6B - Gravel beaches - cobbles to boulders
6C - Exposed rip rap
7 - Exposed tidal flat
8A- Sheltered vertical rock shores and vertical, hard man-made structures (e.g. seawalls, docks, bulkheads)
8B - Sheltered rubble slope
9A - Sheltered sand and mud flats
9B - Sheltered vegetated low bank
10 - Marshes

COUNTERMEASURES	SHORELINE TYPES													
	1	2	3	4	5	6A	6B	6C	7	8A	8B	9A	9B	10
CONVENTIONAL METHODS														
No action	C	C	C	C	C	C	C	C	R	C	C	R	C	R
Manual removal of oil	C	R	R	R	R	C	C	C		R	R		C	C
Passive collection of oil	R	R	R	R	R	R	R	R	C	R	R	R	R	R
Oiled debris removal	C	R	R	R	R	R	R	R	C	R	R	C	R	C
Trenching/recovery wells			C	C	C									
Oiled sediment removal			C	C	C	C							C	
Ambient water flooding (Deluge)			C	C	C	R	R	R		R	R		C	C
Amb water flush <50 psi	C	C			C	R	C	R		R	R		C	C
Amb water flush <100 psi	C	C					C	C		C				
Warm water flush <90°F	C						C	C		C				
Hot water flush >90°F	C									C				
Vacuum removal of oil	C	C	R	R		C	R	R		C	C		C	C
Sediment reworking			C	C	C	C								
Sediment Removal-cleaning-replacement			C	C	C	C		C			C			
Cutting oiled vegetation							C	C		C	C		C	C
ALTERNATIVE METHODS*														
In-situ burning on shore														
Chemical stabilization, protection, or cleaning														
Nutrient enhancement			C	C	C	C	C	C			C			C
Microbial addition														

R Recommend - May be Preferred Alternative
C Conditional (Refer to NW Shoreline Countermeasures Manual)
Shaded areas are Not Applicable or Not Generally Recommened
***** Follow approved process defined in NCP and NW Area Plan

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Shoreline Countermeasures Matrix

Heavy Oil (Heavy Crude Oils, Intermediate Fuel Oils, Bunker C & Heavily Weathered Medium Crudes)

- Heavy oils with little or no evaporation or dissolution
- Water-soluble fraction likely to be <10ppm
- Heavy contamination of intertidal areas likely
- Severe impacts to waterfowl and fur-bearing mammals (coating and ingestion)
- Long-term contamination to sediments possible
- Weathers very slowly
- Dispersion seldom effective
- Shoreline cleanup difficult under all conditions

SHORELINE TYPES CODES

1- Exposed rock shores and vertical, hard man-made structure (e.g. seawalls)
2 - Exposed wave-cut platforms
3 - Fine to medium grained sand beaches & steep unvegetated river banks
4 - Course grained sand beaches
5 - Mixed sand and gravel beaches, including artificial fill containing a range of grain size and material
6A - Gravel beaches - pebbles to cobble
6B - Gravel beaches - cobbles to boulders
6C - Exposed rip rap
7 - Exposed tidal flat
8A- Sheltered vertical rock shores and vertical, hard man-made structures (e.g. seawalls, docks, bulkheads)
8B - Sheltered rubble slope
9A - Sheltered sand and mud flats
9B - Sheltered vegetated low bank
10 - Marshes

COUNTERMEASURES	SHORELINE TYPES 1	2	3	4	5	6A	6B	6C	7	8A	8B	9A	9B	10
CONVENTIONAL METHODS														
No action	C	C	C	C	C	C	C	C	R	C	C	R	C	R
Manual removal of oil	C	R	R	R	R	C	C	C		R	R		C	C
Passive collection of oil	R	R	R	R	R	R	R	R	C	R	R	C	R	R
Oiled debris removal	C	R	R	R	R	R	R	R	C	R	R	C	R	C
Trenching/recovery wells			C	C	C									
Oiled sediment removal			C	C	C	C		C					C	
Ambient water flooding (Deluge)			C	C	C	R	R	R		R	R		C	C
Amb water flush <50 psi	C	C			C	R	C	R		C	C		C	C
Amb water flush <100 psi	C	C					C	C		C	C			
Warm water flush <90°F	C						C	C		C				
Hot water flush >90°F	C									C				
Vacuum removal of oil	C	C	C	C	C	C	C	C		C	C		C	C
Sediment reworking			C	C	C	C								
Sediment Removal-cleaning-replacement			C	C	C	C		C						
Cutting oiled vegetation							C	C		C	C		C	C
ALTERNATIVE METHODS*														
In-situ burning on shore														
Chemical stabilization, protection, or cleaning														
Nutrient enhancement			C	C	C	C	C	C						C
Microbial addition														

R Recommend - May be Preferred Alternative
C Conditional (Refer to NW Shoreline Countermeasures Manual)
Shaded areas are Not Applicable or Not Generally Recommened
***** Follow approved process defined in NCP and NW Area Plan

This countermeasure advisability matrix is only a general guide for removal of oil from shoreline substrates. It must be used in conjunction with the entire Shoreline Countermeasures Manual plus field observations and scientific advice. The countermeasures listed are not necessarily the best under all circumstances, and any listed technique may need to be used in conjunction with other techniques (including ones not listed herein). The Federal On-Scene Coordinator (FOSC) or the state OSC operating with the FOSC's authorization has the responsibility for and the authority to determine which countermeasure(s) are appropriate for various situations encountered. Selection of countermeasures is based on the degree of oil contamination, the shoreline type, and the presence of sensitive resources.

Appendix A

Guidelines For Treatment Operations

General Guidelines

Ensure familiarity and compliance with approved treatment methods, approved shoreline segment work plans, advisories, and special instructions. Restrict all access to wetlands and tidal flats, except with special authorization.

Conditions to avoid

- Treatment techniques (such as high pressure and hot water) that dislodge intertidal vegetation and invertebrates, e.g., mussels, barnacles, snails
- Clearing marshes and vegetated shorelines (the presence of algae does not characterize a vegetated shoreline)

Actions to encourage

- Boom off mud/grass flat adjacent to treatment areas to prevent further contamination.
- Boom off tidal creeks to prevent further contamination.
- Minimize impact to uncontaminated lower intertidal zones, including:
  - land crews during tides that cover the lower intertidal zone
  - avoid high-/low-pressure washing where possible
  - work heavily oiled upper beach zone hen lower intertidal zones are covered by high tides
  - employ sorbents along riprap and below oiled upper beach to protect lower intertidal zone from oiling

Ensure that all signs of human activity are removed when cleanup is completed. Ensure that all trash and wastes are removed daily:

- Oil trapped in booms must be picked up before the next tide cycle
- All food and associated trash must be removed each day to minimize attracting wildlife into contaminated areas

Guidelines Specific to Biological Resources

Advisories and special instructions may address:

- bird concentration areas (nesting sites, colonies, rookeries, etc.)
- live/dead animal collection policy
- protection of cultural resources
- marine mammal haulouts
- collection of eagle feathers and marine mammal parts
- cutting bull kelp
- cutting oiled fucus

Appendix B includes existing “best management practices” for specific issues addressed during previous spills, which can be used as the basis for developing regional guidelines.

Appendix B

Best Management Practices

Specialized Areas of Concern - National
(The following notices are provided as guidelines.)

Marine Mammal Notice
Collection of Eagle Feathers and Marine Mammal Parts
Protection of Cultural Resources
Cutting of Oiled Bull Kelp
Cutting of Oiled Fucus (Popweed)
Instruction for the Disposition of Dead and Live Wildlife

Marine Mammal Notice

(Developed by NOAA in 1989 during the *Exxon Valdez* oil spill.)

To reduce stress caused by unnecessary disturbance to marine mammal haulouts and improve the changes for wildlife survival, an aircraft advisory is issued for coastal areas affected by the spill. These advisories request that pilots stay at least one-half mile offshore and 1000 feet above ground level from areas of wildlife concentrations and critical habitats. These areas are shown on maps and distributed to pilots. The most critical areas to avoid are: (list critical areas).

No person, except an authorized government official, will approach, molest, or take a seal or sea lion, regardless of whether the animal is oiled, distressed, lethargic, or abandoned. This reminder is necessitated by the widespread activities of oil spill cleanup personnel in areas where seals and sea lions are giving birth to pups. Although casual and distant human/marine mammal interactions may not always be avoidable, they are, to varying degrees, harmful to the animal. The following explanation and guidance with respect to seal pups is offered in the interest of avoiding law violations and minimizing human-induced mortality among marine mammals.

Live seal pups are to be left undisturbed, whether or not they have oil on them. A pup not accompanied by an adult and/or appearing emaciated may not be abandoned. Females commonly leave their pups alone for extended periods during foraging trips. Newborn and young pups appear emaciated before acquiring fat through nursing. It is not possible to distinguish between a normal pup and one that is truly distressed. In the presence of humans, female seals may only approach their pups at night to nurse them, making determination of abandonment difficult to establish. True abandonment is unlikely, barring death or serious injury to the mother.

Pup deaths will greatly increase if oiled animals are picked up and subjected to the stress of handling, transport, and rehabilitation centers. Unlike sea otters and birds, external oiling does not adversely affect a seal's heat conservation ability or indicate a need for human assistance. Persons finding seals, sea lions, whales, or porpoises that appear to be in distress should contact NOAA Fisheries. Do not touch or closely approach these animals.

Collection of Eagle Feathers and Marine Mammal Parts

In response to inquiries about collecting eagle feathers and marine mammal parts by personnel involved in cleanup activities during a spill, the laws and regulations dealing with the collection and possession of such materials are summarized below.

Collection of Eagle Feathers: The Eagle Act (Public Law 95-616, 92 Stat. 3114, 16 U.S. Code 668) prohibits the collection and possession of any eagle parts, including feathers.

Collection of Marine Mammal Parts: The Marine Mammal Protection Act of 1972 (Public Law 92-522, 88 State. 1027, 95 Stat. 979, 16 USC 1372) generally prohibits the collection and possession of any marine mammal parts. Under 50 CFR 18.26, the collection of certain dead marine mammal parts is allowed, as follows:

a. Any bones, teeth or ivory of any (non-endangered) dead marine mammal may be collected from a beach or from land within 1/4 of a mile of the ocean. The term “ocean” includes bays and estuaries.
b. Marine mammal parts so collected may be retained if registered within 30 days with an agent of the National Marine Fisheries Service, or an agent of the U.S. Fish and Wildlife Service.
c. Registration shall include (1) the name of the owner, (2) a description of the article to be registered, and (3) the date and location of collection. Items so collected and registered must be retained in the ownership of the collector. The sale of such items is prohibited.

Protection of Cultural Resources

Shoreline cleanup operations have the potential for damaging important archaeological and cultural resources. Authorized shoreline cleanup procedures may uncover undiscovered archaeological features or artifacts. To assist in their identification, drawings of the types of artifacts that might be found in the intertidal zone and along the shoreline by cleanup crews are included. Cleanup personnel should be aware of the policy that anyone found vandalizing or appropriating cultural materials will be subject to full prosecution under the Archaeological Resources Protection Act. If response personnel find any cultural resources (fossils, archaeological or historical artifacts), the following steps should be taken immediately:

1. Leave the cultural materials in place at the site of discovery and mark with flagging tape.
2. Stop cleanup activities in the surrounding area.
3. Inform a designated state representative.

Cutting of Oiled Bull Kelp (*Nereocystis luetkeana*) as a Technique for Releasing and Recovering Trapped Oil

(Based on research by NOAA conducted during the *Tenyo Maru* oil spill, off the coast of Washington, 1991)

Although bull kelp is an annual, with much of a year's growth typically removed by seasonal storms, Dr. Sandra Lindstrom, a phycologist with the University of British Columbia, cautions that removal of the upper portion of the stipe removes the entire active reproductive area of the plant, which is located in the fronds. Bull kelp reproduces by the production of spore cases, which drop to the bottom and subsequently grow into the following season's plants. If cutting is to take place, it should be limited to the fronds, leaving a portion on the plant, which would permit it to nominally survive. Cutting the stipe effectively kills the plant.

Cutting kelp beds abruptly changes the light regime on the seafloor below. This may have implications in that growth of young kelp plants is light-mediated, and an increase in light reaching the bottom may result in earlier growth than would otherwise occur.

Secondary ecological impacts of kelp removal should be carefully considered before arriving at a decision about cutting the near-surface portions of plants. The canopy provided by the kelp stipes and blades represents important habitat for fish species such as greenlings and rockfishes (a study in California counted 23 species of fish in a bull kelp bed) and substrate for organisms that are important prey items for fish.

Should cutting take place, cutting the upper portion of the plants is preferable to removing the entire plant, and cutting only the blades and leaving the stipe intact is preferable to removing the gas-filled bulb. Decisions will necessarily balance removal of oil from the environment with direct impacts on the plants and alteration of significant nearshore habitat.

Commercial harvesting equipment similar to that routinely employed in California coastal waters is a possibility, but *Nereocystis* is substantially different in nature than *Macrocystis*. If they worked, such harvesting barges would cut through the stipe and kill the plant. Whether they are capable of cutting the stipe is not known. Support logistics for kelp cutting could be expected to be substantial as well: the large biomass of kelp

would require either vessels with considerable hold capacity, or barges on which the plants could be loaded.

Cutting of Oiled Fucus (Popweed)

(Developed by NOAA in 1989 during the *Exxon Valdez* oil spill)

The cutting of heavily oiled fucus still attached to the substrate in the intertidal zone is sometimes suggested during shoreline cleanup efforts. At issue is the benefit derived from removing a source of contamination compared with the costs to intertidal systems from fucus removal. Fucus defines the mid-intertidal zone and provides shelter and attachment for other animals. The spores, primarily the very small plants, are a sources of food for other animals. The plants are prone to breaking loose in exposed settings and may end up on the beach or in the water. The average half-life of fucus plants is six months, with the large, older overstory plants being up to five years old (in Prince William Sound).

Fucus is a particularly hardy species with respect to oiling. Mortality may occur as a result of the oil preventing photosynthesis from occurring, but it is extremely difficult to determine if a plants is dead or alive by looking at it when oiled. Reproduction in fucus is through the release of spores from buoyant reproductive receptacles that look like small air sacs located on the tips of the plant. The presence of mucus coming out of these receptacles when exposed during low tide indicates that the plant is fertile. Recruitment comes primarily from spores released by plants located no more that three to ten feet away and occurs quite readily as long as sufficient numbers of other fucus plants are in the area. In the absence of other fucus plants, drift spores do come along, but recruitment from this source is very haphazard and not at all guaranteed.

Cutting oiled fucus still attached to the rock is generally not recommended. Flushing (ambient water) and other cleanup techniques should be tried first. If it is deemed necessary to remove heavily oiled fucus to prevent redistribution to very sensitive resources, a sufficient number of mature plants should be left in the area to facilitate recruitment (in patches or fringe three to ten feet apart). If this is not done, recruitment may not take place. It is not necessary to leave the holdfasts when cutting plants.

Instruction for the Disposition of Dead and Live Wildlife

(Derived from the Wildlife Protection Guidelines, Alaska RRT, 1991)

Dead Animals

1. Collect all dead animals (except whale and other large forms), including scavenged carcasses, to discourage further scavenging in oiled areas.
2. Wear gloves when handling dead animals.
3. Use a shovel or spade to uncover and remove carcasses partially covered by sand, kelp, wood, or other debris.
4. Place carcasses in double plastic garbage bags. Place all animals from one beach in one bag, if possible. Close securely with masking tape.
5. Complete an animal collection form or provide the following information:
   - beach name or location where carcasses were recovered
   - date
   - name and address of collector
   - species, age, and sex of collected animals .

   If any of this information is not available or questionable, this fact should be recorded so that additional examinations of the animals can be conducted.
6. Place the form or list in a ziplock baggie and place the baggie outside the first garbage bag but inside the second. Bring the dead animals to a designated recovery site

Live Animals

Authorization for animal rescue must be given by the appropriate State or Federal agency prior to the rescue and rehabilitation of oiled wildlife. Long-handled nets, rags, or towels are recommended for capturing live, oiled birds. Wear gloves to keep from getting oiled. Do not wash oiled birds. It is more important to keep them warm. Place them in a covered cardboard box. It is okay to keep more than one bird and multiple species in the same box. Do not attempt to give birds fluids; they should be taken to a rehabilitation center as soon as possible. For live birds, the following information should be reported:

- beach name or location where animal was recovered
- date and name and address of collector
- species, age, and sex of collected animals
- condition of the animal

Do not attempt capture of live sea otters without prior authorization from the appropriate agency. Inexperienced people can cause otters additional injuries. In addition, otters may bite and cause infections. A bite from an otter may result in inflammation of the joints and inability to bend one's fingers. Live, oiled otters are to be reported to the designated agency contact for the spill.

Glossary

Aerobic

Able to live or grow only where free oxygen is present.

Anaerobic

Able to live and grow where there is no air or free oxygen.

Annual

A plant that lives only one year or season.

Aromatic

Organic compounds containing any of a series of benzene ring compounds. They are unsaturated organic ring compounds with low boiling points and are generally toxic to aquatic life.

Benthos

The plants and animals that live in and on the bottom of a water body.

Berm

A wedge-shaped sediment mass built up along the shoreline by wave action. Sand berms typically have a relatively steep seaward face (beach face) and a gently sloping surface (berm top). A sharp crest (berm crest) usually separates the two oppositely sloping planar surfaces on top of the berm. Berms on sand beaches are eroded away during storms, thus a berm may not be present if the beach is visited shortly after a storm. On gravel beaches, however, steep and high storm berms are activated and refurbished during storms.

Biota

Animal and plant life characterizing a given region. Flora and fauna, collectively.

Booms

Both containment and absorbent booms are used for the collection, deflection, and containment of spreading oil. Containment booms are somewhat rigid structures extending both above and below the water acting as barriers to surface oil. Primary containment booms are usually deployed close to oiled shorelines to trap oil being flushed from beaches before it is collected. Secondary containment booms are deployed farther out to trap oil that leaks past primary booms. Absorbent boom is used along the shore-water interface to collect oil dislodged during treatment operations. It is important that absorbent boom be changed once the sorbent capacity is reached. Great care should be taken to seal the shore ends of booms so that no oil can get past. This is particularly difficult at rocky shorelines, or areas strewn with boulders and cobbles. The use of absorbent pads or other materials, such as “pom poms”, can be effective sealants.

Brackish

Intermediate in salinity (0.50 to 17.00 parts per thousand) between sea water and fresh water.

Clam shell

A mechanical device mounted at the end of a crane that picks up soil or mud with a pincer-like movement.

Coagulating agent

Chemical additives applied to oil to form a more cohesive mass.

Contact period

The time required to maximize the efficiency of the sorbent or chemical agent or the time before plant or animal damage occurs.

Dispersant

Chemical agent used to disperse and suspend oil in water leading to enhanced biodegradation.

Distillate

A refined hydrocarbon obtained by collection and condensation of a known vapor fraction of the crude oil.

Drag line

A mechanical device that excavates or transports soil, using a container pulled over earth by cables or chains.

Dredge

A device used to remove sediment from the bottom of a water body.

Emulsification

The process by which oil is mixed with water.

Endless rope

A continuous rope-like oil sorbent device that is pulled across the surface of the water to pick up oil.

Erosion

The wearing away by action of water or wind of unprotected or exposed earth.

Estuary

Classic definition A drowned river valley that has a significant influx of fresh water and is affected by the tides. Most of the coastal water bodies in the mid-Atlantic region are estuaries (e.g., Chesapeake Bay, Delaware Bay).

Evaporation

The conversion of a fluid—including hydrocarbons—to a gaseous state.

Fast ice

Any sea ice that forms along and remains attached to the coast, or that forms between grounded ice bergs, or is attached to the bottom in shallow waters. May form *in situ* from seawater or by freezing of pack ice to the shore. It may extend a few meters to several hundred kilometers from the shore.

Fertilizer

A substance or agent that helps promote plant or seed growth.

Flash point

The lowest temperature at which vapors from a volatile liquid (e.g., oil) will ignite.

Flushing

Use of a water stream to make oil flow to a desired location or recovery device.

Fouling

Accumulation of oil or other materials, such as debris, that makes a device inoperative.

Free oil

See mobile oil.

Gelling agent

See coagulating agents.

Habitat

The chemical, physical, and biological setting in which a plant or animal lives.

Herding agent

Chemical agent that confines or controls the spread of a floating oil film.

Intertidal

The part of the shoreline that lies between high-tide and low-tide water levels.

Lagoon

A shallow, linear, and usually oblong water body, located parallel with and connected to a larger water body by one or more inlet channels.

Landfill

A dump that has progressive layers of waste matter and earth.

Marsh fringe

The edge of the marsh adjacent to the water.

Migration

Seasonal movement of a group of animals from one location to another.

Mobile oil

Oil that can refloat when water is applied (as in high tide).

Mobilization

Movement of oil caused by physical forces, such as gravity, tides, or wind. Mobility of oil is limited by its viscosity.

Mousse

A type of oil/water emulsion.

Non-persistent

Decomposed rapidly by environmental action.

Oil/water separator

A device for separating oil from water.

Oleophilic

A material that has affinity for oil.

Paraffin

The waxy saturated component of crude oil, having relatively high boiling point and low volatility. Any member of the methane series having the general formula $C_nH_{2n}+2$.

Penetration

Downward motion of oil into sediments from the surface driven by gravitational forces.

Perennial

Vegetation that continues to grow for several years.

Permeability

The degree to which fluids can flow through a substance. Measured in Darcys. Permeability is not equal to porosity. High porosity of a material does not insure high permeability. However, a substance cannot be permeable without having some degree of porosity.

Physiography

General term for the shape of the earth's surface.

Pooled oil

Oil thickness exceeds one centimeter. This need not be uniform.

Porosity

The volume of void spaces in a sediment mass, measured in percent.

Riprap

(a) A layer of large, durable fragments of broken rock, specially selected and graded, and thrown together irregularly or fitted together. Its purpose is to prevent erosion by waves or currents and thereby preserve the shape of a surface, slope, or underlying structure. It is used for irrigation channels, river-improvement works, spillways at dams, and revetments for shore protection. (b) The stone used for riprap.

Recontamination

Contamination by oil of an area that was previously cleaned.

Rhizome

A rootlike stem under or along the ground, ordinarily in a horizontal position, which usually sends out roots from its lower surface and leafy shoots from its upper surface.

Salt pan

A pool above high tide, "drained" only by evaporation so that salt is accumulated and concentrated.

Seine

A fish net that can be used to collect sorbent or debris.

Skimmer

A mechanical device that removes an oil film from the water surface.

Oil skimmers collect oil spilled on, or released to, the water's surface. They come in a wide range of shapes and sizes. Skimmers generally have a higher recovery rate than sorbents, providing enough oil is present to justify the costs for its use. Skimmers are usually

equipped with storage space for collected oil. Oil is herded to a collection point along a containment boom located close to shore yet in water of sufficient depth for the skimmer to function. Two types of skimmers currently in use are described below. Other types of skimmers are being tested for possible use at a later date.

Band, or "Rope," skimmers use an oleophilic material such as polypropylene. Oil is collected by a floating, continuous rotating band or "rope" drawn through an oil slick or along the water's edge of a contaminated area. Adhered oil is wrung from the band by a squeeze roller and collected in an oil sump. These bands are used in either static (stationary) or dynamic (towed) modes. Bands can be torn by solids or skimmed debris. Efficiency is high in calm waters, poor in choppy waters and waves.

Belt skimmers use an oleophilic belt mounted on the front of a small vessel. The oleophilic belt pushes the floating oil below the waterline. Oil not adsorbed by the belt is collected into a holding area located behind the belt. Oil carried up the belt is recovered at the top of the system by a squeeze belt or scraper blade. It is then pumped into a storage container. These skimmers can not operate in shallow waters or tight areas.

Slurry

A suspension of particles in water.

Solubility

The amount or fraction of a substance (e.g., oil) that dissolves into the water column, measured in ppm.

Solvent

A chemical agent that will dissolve oil.

Specific gravity

The measure of the density of a substance such as oil or sea water, usually determined at 20°C, compared to the density of pure water at 4°C. Thus, specific gravity varies slightly with temperature.

Sorbent

All sorbent materials work on the same principles—oil adheres to the outside of the material or sorbs into the material by capillary action. There are three basic types of sorbent materials: mineral based, natural organic, and synthetic organic. Currently, only synthetic organic sorbents are being used in the field in the form of booms, pads, and mops. Peat is currently in the testing and demonstration phase.

Stain

Oil that is visibly present but cannot be scraped off with a fingernail.

Substrate

The substance, base, or nutrient on which, or the medium in which, an organism lives and grows, or the surface to which a fixed organism is attached; e.g., soil, rocks, and water.

Substrate penetration

Vertical distance from surface to where oil has percolated into the substrate.

Subtidal

That part of the coastal zone that lies below the lowest low-tide level, so that it is always underwater.

Sump

A pit or reservoir that serves as a drain from which oil can be collected.

Supratidal

Above the normal high-tide line.

Tank barge

A barge for transporting liquids.

Tarballs

Lumps of oil (<10 cm in diameter) weathered to a high density semisolid state.

Tidal variation or range

The vertical distance between high and low tides.

Toxicity

The inherent potential or capacity of a material (e.g., oil) to cause adverse effects in a living organism (Rand and Petrocelli, 1985).

Viscosity

Flow resistance; referring to internal friction of a substance (e.g., oil) that is a function of the oil type and temperature.

Vacuum systems

Used to recover oil collected behind containment booms along the beach face and in the water during shoreline flushing operations. Where equipment access allows, vacuums can be used to remove pools of oil directly from shorelines and surfaces of heavily oiled rocks. Two vacuum systems currently in use are described below.

The first system is classified as a vacuum device, but requires a high-velocity air stream, @ 150 mph, to draw oil, water, and debris into the unit's collection chamber. Due to the 6- to 12-inch diameter of the inlet hose, it rarely becomes clogged by debris. The inlet nozzle should always be placed slightly above (never below) the fluid's surface. The distance at which it is held above the fluid is critical to limit the amount of water intake. This system is suitable for picking up weathered oil, tar balls, and mousse from water or shorelines, and to vacuum oil from skimming vessels, boomed areas, or debris-laden sites. The primary advantage is its ability to pick up oil of any viscosity and, where necessary, lift fluid more than 30 feet. The system can pick up and decant simultaneously. The main disadvantages are that it usually picks up a high water/oil ratio, and can be difficult to repair in the field.

The second system, barge-mounted vacuum trucks, use high-suction pumps and a cylindrical chamber capable of sustaining very low internal pressure, i.e., minus 12 psi. Vacuum is created in the chamber, and a 3- to 4-inch diameter hose is usually placed slightly below the surface of a floating oil slick, allowing a mixture of water and oil to enter the collection chamber. The position of the open end of the vacuum hose is critical. If it is placed too far down into the oil slick, recovered fluid will be mostly water; if not deep enough, air will be sucked into the system, and much of the vacuum will be lost. The primary advantages of the vacuum truck system are: it can recover fluid of nearly any viscosity; it has a rapid pickup rate of thick oil layers; and it can recover a wide variety of small debris. Primary disadvantages are its limited lift, no more than 20

to 30 feet, and the length of time required to reestablish a vacuum if air enters the hose. As with the other vacuum, this one also picks up a high water/oil ratio.

Weathering

Natural influences such as temperature, wind, and bacteria that alter the physical and chemical properties of oil.

Weir

A vertical barrier placed just below the surface of the water so that a floating oil slick can flow over the top.

Wetlands (as defined by the Annotated Code of Maryland Title 9)

State wetlands: Lands below the mean high-tide line affected by the regular rise of tide.
Private wetlands: Lands bordering on state tidal wetlands, below the mean tide line subject to the effects of the regular rise and fall of tide. Lands able to support growth of wetland vegetation.

Lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, and is at least periodically saturated with or covered by water (Cowardin et al., 1979).

Wrack

Accumulations of plant debris that is deposited at or above the high-tide line (e.g., *Spartina* or kelp debris).

Bibliography

American Petroleum Institute. 1982. *Oil Spill Response: Options For Minimizing Adverse Ecological Impacts*. Publication No. 4398. Washington, D.C.: American Petroleum Institute. 98 pp.

Bobra, M., P. Kawamura, M. Fingas, and D. Velicogna. 1987. Laboratory and mesoscale testing of Elastol and Brand M demoussifer. *Proceedings of the 10th Arctic and Marine Oil Spill Program Technical Seminar, June 9-11, 1987.* Edmonton, Alberta, Canada. pp. 223-241.

Breuel, A. 1981. *Oil Spill Cleanup and Protection Techniques for Shorelines and Marshlands*. Park Ridge, New Jersey: Noyes Data Corp. 404 pp.

Cairns, J., Jr. and A.L. Buikema, Jr. (Eds.). 1984. *Restoration of Habitats Impacted by Oil Spills*. Boston: Butterworth Publishers.

CONCAWE. 1987. *A Field Guide To Coastal Oil Spill Control And Clean-up Techniques*. The Hague, The Netherlands: . 112 pp.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. *Classification of wetlands and deepwater habitats of the United States*. Washington, D.C.: U.S. Fish and Wildlife Service. 103 pp.

Environment Canada. 1992. Oilspill SCAT Manual for the Coastlines of British Columbia. Edmonton, Alberta: Technology Development Branch, Conservation and Protection. 245 pp.

DOI. 1991. Wildlife Protection Guideline for Alaska. Tab D to Annex X of the Alaska Region Oil and Hazardous Substances Pollution Contingency Plan. Anchorage: U.S. Department of the Interior. 229 pp.

ERCE and PENTEC. 1991. Evaluation of the condition of intertidal and shallow subtidal biota in Prince William Sound following the *Exxon Valdez* oil spill and subsequent shoreline

treatment. Seattle, Wash. Report HMRAD 91-1. Seattle: Hazardous Materials Response and Assessment Division, National Oceanic and Atmospheric Administration. Two Volumes.
Fiocco, R.J., G.P. Canevari, J.B. Wilkinson, J. Bock, M. Robbins, H.O. Jahns, and R.K. Markarian. 1991. Development of Corexit 9580–A chemical beach cleaner. *Proceedings of the 1991 International Oil Spill Conference, March 4-7, 1991, San Diego, California*. API Publication No. 4529, Washington, D.C.: American Petroleum Institute, pp. 395-400.

Hayes, M.O., E.R. Gundlach, and C.D. Getter. 1980. Sensitivity ranking of energy port shorelines. *Proceedings of the Specialty Conference on Ports '80, May 19-20, 1980, Norfolk, Virginia*, pp. 697-708.

Hayes, M.O., J. Michel, and B. Fichaut. 1991. Oiled gravel beaches: A special problem. *Proceedings of the Specialty Conference on Oil Spills, Management and Legislative Implications*, published by American Society of Civil Engineers pp. 444-457.

Interagency Shoreline Cleanup Committee. 1989. Field Shoreline Treatment Manual. Valdez, Alaska: National Oceanic and Atmospheric Administration, Alaska Department of Environmental Conservation, Alaska Department of Fish and Game, U.S. Fish and Wildlife Service, U.S. Environmental Protection Agency, and Exxon.

Meyers & Associates and RPI, Inc. 1989. *Oil Spill Response Guide*. Park Ridge, New Jersey: Noyes Data Corp. 314 pp.

National Research Council. 1989. *Using Oil Spill Dispersants on the Sea*. Washington, D.C.: National Academy Press. 335 pp.

National Oceanic and Atmospheric Administration. 1992. Introduction to coastal habitats and biological resources for oil spill response. Report HMRAD 92-4. Seattle: Hazardous Materials Response and Assessment Division, NOAA. 384 pp.

Nauman, S.A. 1991. Shoreline Cleanup: Equipment and Operations. *Proceedings of the 1991 International Oil Spill Conference, March 4-7, 1991, San Diego, California*. Washington, D.C.: American Petroleum Institute. pp. 1411-1417.

Owens, E.H. and A.R. Teal. 1990. Shoreline cleanup following the *Exxon Valdez* oil spill–field data collection within the SCAT program. *Proceedings of the 13th Arctic and*

Marine Oil Spill Program Technical Seminar, June 6-8, 1990, Edmonton, Alberta, Canada, pp. 411-421.

Prince, R.C., J.R. Clark, and J.E. Linstrom. 1990. *Bioremediation Monitoring Program*. Anchorage: Exxon, U.S. Environmental Protection Agency, Alaska Department of Environmental Conservation. 85 pp. plus appendices.

Rand, G. M. and S. R. Petrocelli. 1985. *Fundamentals of Aquatic Toxicology*. Washington, D. C.: Hemisphere Publishing Company. 666 pp.

Rooney-Char, A.H., R.W. Middleton, A.T. Fritz, and M.L. Vance. 1983a. *ESI Atlas of Maryland*. Seattle: Hazardous Materials Response and Assessment Division, National Oceanic and Atmospheric Administration. 119 maps.

Rooney-Char, A.H., A.T. Fritz, M.L. Vance, R.W. Middleton, and J. Baker. 1983b. *ESI Atlas of Virginia*. Seattle: Hazardous Materials Response and Assessment Division, National Oceanic and Atmospheric Administration. 113 maps.

Rooney-Char, A.H., M.L. Vance, A.T. Fritz, and R.W. Middleton. 1983c. *ESI Atlas of North Carolina*. Seattle: Hazardous Materials Response and Assessment Division, National Oceanic and Atmospheric Administration. 113 maps.

Sanders, N. and E. Gray. Alaska Oil Spill Bioremediation Project Workshop Summary. Rockville, Maryland: Technical Resources, Inc. 8 pp.

Tetra Tech. 1982. *Ecological Impacts of Oil Spill Cleanup: Review and Recommendations*. Draft report. Washington, D.C.: American Petroleum Institute.

U.S. Congress, Office of Technology Assessment. 1991. Bioremediation for Marine Oil Spills - Background Paper. OTA-BP-0-70. Washington, D.C.: U.S. Government Printing Office. 31 pp.