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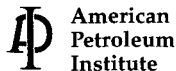
# Options for Minimizing Environmental Impacts of Freshwater Spill Response

API Publication Number 4558  
February 1995



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National Oceanic &  
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Hazardous Materials  
Response & Assessment  
Division

# Options for Minimizing Environmental Impacts of Freshwater Spill Response

API Publication Number 4558

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## ABSTRACT

Selecting appropriate protection, response, and cleanup techniques, both before and following an oil spill, affects the ultimate environmental impact and cost resulting from a spill. The American Petroleum Institute (API) and the National Oceanic and Atmospheric Administration (NOAA) jointly developed this guide as a tool for contingency planners and field responders to identify response techniques that have minimal ecological impacts and also minimize the impact of the oil. The guide provides information on 29 response methods and classifies their relative environmental impact for combinations of four oil types and twelve freshwater environments and habitats. Spill topics of special concern in freshwater settings are also discussed, including public health, conditions under which oil might sink in freshwater, oil behavior in ice conditions, permafrost, and use of firefighting foams.



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# 1.0 INTRODUCTION

## 1.1 SCOPE AND PURPOSE

Selecting appropriate oil spill protection, recovery, and cleanup techniques, before and following an oil spill, is a critical element affecting the ultimate environmental impact and cost resulting from a spill. It is important to identify techniques that in themselves have minimal intrinsic ecological impact and are also effective in reducing the impact of the oil. Furthermore, these response techniques should be considered before a spill, so that little time needs to be spent preparing for the response during a spill.

The American Petroleum Institute (API) and the National Oceanic and Atmospheric Administration (NOAA) jointly developed this guide as a tool to help contingency planners and field responders evaluate response techniques and choose those that will most effectively prevent or minimize adverse ecological impact. Information is provided to help select response techniques for specific combinations of habitat and oil types. Each technique is evaluated individually for a specific habitat; however, during spill response more than one technique may be used at the same time on one or more habitats.

The discussions in this guide reflect primarily the assessment of the environmental *impact* of the response methods. This guide also recognized that the selected techniques should be effective. They must remove a significant amount of oil from the environment or prevent or reduce oil impact, *and* they must have acceptable impact on the habitat as compared to leaving the oil alone (natural recovery). Prolonged use of an inefficient technique may be more ecologically detrimental than short-term use of a potentially more intrusive approach (e.g., frequent entry into a marsh to replace sorbents rather than vacuuming pooled oil).

Reducing the overall ecological impact of a spill event is the primary concern of this guide, and it is applicable for inland, freshwater environments and habitats only. This guide does not address land-only, chemical, or marine spills. It also does not discuss legal or regulatory issues; safety considerations; or guidance on planning, organizing, and conducting a spill response effort. The manual may be customized for specific geographic areas to address special priorities and concerns.

Specific spill conditions will often dictate the response techniques used, and selection always involves tradeoffs. For example, a potentially ecologically damaging, but efficient, cleanup technique could be used to meet site-specific response goals. Also, techniques may be used early in response simply because they can be implemented immediately, rather than



waiting until ones with lower impact can be mobilized. A method that has a significant short-term ecological impact, such as *in situ* burning, may actually produce the lowest long-term ecological impact because it removes the oil quickly.

## 1.2 BACKGROUND

Oil spills into inland waters differ from coastal or marine spills from several perspectives. For instance, inland spills are usually in freshwater habitats. Inland spills are also more frequent than marine spills, and they often involve smaller volumes of oil. Refined product spills are more common in freshwater, while crude oil spills comprise the majority of marine spills. Inland spills have a much higher potential to contaminate water supplies (surface as well as groundwater), to affect areas of concentrated populations, and to impact manmade structures and human activities. In coastal and marine environments, wave and tidal action are important mechanisms for dispersion and transport of oil and in removing oil from shorelines. These mechanisms are less important in freshwater habitats, where currents and floods are more important factors.

The knowledge base for response to oil spills reflects the disparity of information available between marine spill response and freshwater response. The lack of literature and guidelines for inland spill response prompted several efforts to improve this shortcoming. Preparation of this guide began with a workshop sponsored by API on Inland Oil Spills, conducted in Dearborn, Michigan, November 19-21, 1991. The objective of the workshop was to bring together the oil spill response community experienced and/or responsible for responding to freshwater crude oil or petroleum product spills, and to develop strategies through consensus for dealing with spills in different freshwater environments and shoreline habitats. The information from that workshop was the basis for development of this guide. However, the final guidelines presented here are based on the educated and experienced opinions of oil spill experts in industry and government.

### 1.3 ORGANIZATION OF GUIDELINES

The guide identifies response methods for twelve primary freshwater habitats (Table 1), which represent various waterways and shoreline types. Each habitat is treated separately in the guide, although the spill responder will be confronted with a variety of habitats.

**Table 1. Primary freshwater environments and habitats included in this guide.**

| <b><i>Water Environments</i></b> | <b><i>Shoreline Habitats</i></b> |
|----------------------------------|----------------------------------|
| Open Water                       | Bedrock                          |
| Large Rivers                     | Manmade Structures               |
| Small Lakes and Ponds            | Sand                             |
| Small Rivers and Streams         | Mixed Sand and Gravel            |
|                                  | Gravel                           |
|                                  | Vegetated Shorelines             |
|                                  | Mud                              |
|                                  | Wetlands                         |

Section 2 of the guide includes:

- Response method summary matrices for the four primary water environments and eight shoreline habitats for four general oil types.

Section 3, arranged by water environment and shoreline habitat, contains:

- A detailed description of the environment or habitat; and
- Matrices of response methods in terms of recommended use for each of the four general oil types.

Section 4 of the guide contains detailed descriptions of the response methods listed in the matrices. The following headings are used:

- Objective;
- Description;
- Applicable habitats;
- When to use;
- Biological constraints; and
- Environmental impact.

Section 5 discusses the following special issues of concern in freshwater settings:

- Public health concerns;
- Conditions under which oil might sink;
- Oil behavior under ice conditions;
- Oil behavior and response in permafrost habitats; and
- Firefighting foam.



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## 1.4 SENSITIVITY OF ENVIRONMENTS AND HABITATS

Habitat sensitivity is a function of several factors, including degree of exposure to natural removal processes, biological productivity and ability to recover following oil exposure, human use of the habitat, and ease of oil removal. These factors are used to rank the overall sensitivity of shoreline habitats to spilled oil as part of the Environmental Sensitivity Index (ESI). This guide focuses on one element of environmental sensitivity, namely the sensitivity of habitats to impacts resulting from oil removal. ESI shorelines are grouped according to the oil removal considerations used in this guide. The correlation between the shoreline habitat groupings in this guide and the shoreline rankings in the ESI atlases published for the U.S. Great Lakes is shown in Table 2, the summary tables, and Chapter 3. It should be noted that some groupings include both low and high sensitivity habitats, particularly where both sheltered and exposed habitats are grouped, such as bedrock and manmade structures.

**Table 2. Correlation of the shoreline habitats discussed in this guide with the Environmental Sensitivity Index (ESI) shoreline rankings for the Great Lakes.**

| Shoreline Habitats    | ESI Ranking and Description |                                           |
|-----------------------|-----------------------------|-------------------------------------------|
| Bedrock               | ESI = 1A                    | Exposed Rocky Cliffs                      |
|                       | ESI = 2                     | Shelving Bedrock Shores                   |
|                       | ESI = 8A                    | Sheltered Rocky Shores                    |
| Manmade Structures    | ESI = 1B                    | Exposed Solid Seawalls                    |
|                       | ESI = 6B                    | Riprap Structures                         |
|                       | ESI = 8B                    | Sheltered Solid Manmade Structures        |
| Sand                  | ESI = 4                     | Sand Beaches                              |
| Mixed Sand and Gravel | ESI = 3                     | Eroding Scarps in Unconsolidated Sediment |
|                       | ESI = 5                     | Mixed Sand and Gravel Beaches             |
| Gravel                | ESI = 6A                    | Gravel Beaches                            |
| Vegetated Shorelines  | ESI = 9A                    | Sheltered Low Vegetated Banks/Bluffs      |
| Mud                   | ESI = 9B                    | Sheltered Sand/Mud Flats                  |
| Wetlands              | ESI = 10A                   | Fringing Marshes                          |
|                       | ESI = 10B                   | Extensive Marshes                         |



The differences in oil behavior, persistence, and need for cleanup between sheltered and exposed sites are addressed in the discussion of these habitats.

Sensitivity issues of special concern to inland areas include strong seasonal variations in biological productivity and exposure to physical processes, urban areas with extensive manmade structures along the shoreline, and populated areas that are very near shorelines and bodies of water when human-health concerns can dominate cleanup issues. Important seasonal considerations include presence of ice in winter; variations in water level, which greatly influence habitats likely to be exposed to oil, flooding of stranded oil, and natural removal rates; sensitivity of vegetation to direct oiling impact; and use of habitats by migratory birds.

## 1.5 IMPACT OF RESPONSE METHODS IN THE ABSENCE OF OIL

The following criteria were used to evaluate the *relative impact* of each technique in the absence of oil, primarily due to physical disturbances of mechanical methods and toxic impacts from chemical and biological methods. The results are shown in Table 3. Impacts from use of individual products and equipment types vary. The information provided to evaluate impacts in the absence of oil addresses generic characteristics of the response techniques and does not consider those variations. Additional information on environmental impacts is provided in the discussions of each technique in Section 4.

- *Low* Physical damage to the substrate and vegetation is minimal. Toxic impact is likely to be of limited areal extent and short duration. Restabilization or repopulation of the habitat is likely within six months.
- *Moderate* Physical damage to the substrate and vegetation may occur, with increased erosion potential in sedimentary habitats. Toxic impact is such that restabilization or repopulation of the habitat may take six to twelve months.
- *High* Physical damage to the substrate and vegetation is expected. Erosion potential may be high for the technique. The ecosystem may be adversely affected. Restabilization or repopulation of the habitat may take more than twelve months.

Those techniques that are clearly ineffective or inapplicable for a habitat are indicated with a dash (—). For cases where there is insufficient information to evaluate impact in the absence of oil, an "I" is used.

Table 3. Relative impact of response methods in the absence of oil.

| Response Method                    | WATER ENVIRONMENT |                   |              |                      | SHORELINE HABITAT |          |      |                  |                 |        |     |          |
|------------------------------------|-------------------|-------------------|--------------|----------------------|-------------------|----------|------|------------------|-----------------|--------|-----|----------|
|                                    | Open Water        | Small Lakes/Ponds | Large Rivers | Small Rivers/Streams | Bedrock           | Man-Made | Sand | Vegetated Shores | Sand and Gravel | Gravel | Mud | Wetlands |
| <b>PHYSICAL RESPONSE METHODS</b>   |                   |                   |              |                      |                   |          |      |                  |                 |        |     |          |
| Natural Recovery                   | -                 | -                 | -            | -                    | -                 | -        | -    | -                | -               | -      | -   | -        |
| Booming                            | L                 | L                 | L            | L                    | -                 | -        | -    | -                | -               | -      | -   | -        |
| Skimming                           | L                 | L                 | L            | L                    | -                 | -        | -    | -                | -               | -      | -   | -        |
| Barriers/Berms                     | -                 | -                 | -            | H                    | -                 | -        | -    | -                | -               | -      | -   | -        |
| Physical Herding                   | L                 | L                 | L            | L                    | -                 | -        | -    | -                | -               | -      | -   | -        |
| Manual Oil Removal/Cleaning        | L                 | H                 | L            | M                    | L                 | L        | L    | H                | M               | M      | H   | H        |
| Mechanical Removal                 | L                 | H                 | H            | H                    | -                 | M        | M    | H                | M               | M      | H   | H        |
| Sorbents                           | L                 | L                 | L            | L                    | L                 | L        | L    | L                | L               | L      | M   | M        |
| Vacuum                             | L                 | L                 | L            | L                    | L                 | L        | L    | M                | L               | L      | H   | M        |
| Debris Removal                     | -                 | L                 | L            | L                    | L                 | L        | L    | L                | L               | L      | M   | M        |
| Sediment Reworking                 | -                 | H                 | -            | H                    | -                 | -        | M    | H                | M               | M      | H   | H        |
| Vegetation Removal                 | L                 | H                 | M            | H                    | -                 | -        | -    | H                | -               | -      | -   | H        |
| <i>In Situ</i> Burning             | L                 | M                 | L            | M                    | L                 | L        | M    | M                | M               | M      | H   | M        |
| Flooding                           | -                 | -                 | -            | -                    | L                 | L        | L    | L                | M               | L      | L   | L        |
| Low-Pressure, Cold-Water Flushing  | -                 | -                 | -            | -                    | L                 | L        | M    | L                | L               | M      | H   | L        |
| High-Pressure, Cold-Water Flushing | -                 | -                 | -            | -                    | L                 | L        | H    | H                | H               | H      | H   | H        |
| Low-Pressure, Hot-Water Flushing   | -                 | -                 | -            | -                    | M                 | L        | H    | H                | M               | M      | H   | H        |
| High-Pressure, Hot-Water Flushing  | -                 | -                 | -            | -                    | M                 | L        | H    | H                | H               | H      | H   | H        |
| Steam Cleaning                     | -                 | -                 | -            | -                    | M                 | L        | H    | H                | M               | M      | H   | H        |
| Sand Blasting                      | -                 | -                 | -            | -                    | H                 | M        | -    | -                | -               | -      | -   | -        |
| <b>CHEMICAL RESPONSE METHODS</b>   |                   |                   |              |                      |                   |          |      |                  |                 |        |     |          |
| Dispersants                        | L                 | H                 | L            | H                    | -                 | -        | -    | -                | -               | -      | -   | -        |
| Demulsifiers                       | L                 | L                 | L            | M                    | -                 | -        | -    | -                | -               | -      | -   | -        |
| Visco-Elastic Agents               | L                 | M                 | L            | L                    | -                 | -        | -    | -                | -               | -      | -   | -        |
| Herding Agents                     | L                 | M                 | L            | H                    | -                 | -        | -    | -                | -               | -      | -   | -        |
| Solidifiers                        | L                 | L                 | L            | L                    | L                 | L        | M    | M                | M               | L      | M   | M        |
| Chemical Shoreline Pretreatment    | -                 | -                 | -            | -                    | L                 | L        | L    | L                | L               | L      | L   | L        |



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## 1.6 CLASSIFICATION OF OIL RESPONSE METHODS

The classifications developed for this guide compare the relative environmental impact of specific response methods for a given environment or habitat and oil type. It should be noted that the methods were compared among themselves, and no one method was used as a standard. The relative effectiveness of a response technique's ability to protect a habitat or remove oil is not explicitly considered. Relative effectiveness is only incorporated into the classification where less effective methods could result in longer application and thus greater ecological impacts, or leave higher oil residues in the habitat.

The classification categories are defined as follows:

- A May cause the least adverse habitat impact
- B May cause some adverse habitat impact
- C May cause significant adverse habitat impact
- D May cause the most adverse habitat impact
- I Insufficient Information - impact or effectiveness of the method could not be evaluated at this time

Those techniques that are clearly ineffective (e.g., herding agents on heavy oils) or inapplicable for an oil type or habitat (e.g., sand blasting of mud habitats) are indicated with a dash (—).

## 1.7 ASSUMPTIONS USED IN THE DISCUSSION OF METHODS

This guide was prepared with several assumptions:

### *Proper Application of Methods*

It is assumed that methods will be properly applied by trained personnel. For example, if booms are recommended, these guidelines assume that the booms will be effectively located and correctly deployed. Improper application of almost any technique can render it ineffective or cause additional damage. For general guidance on application, see the publications listed in Appendix A. In cases where instruction for using a protection or cleanup method may be habitat-specific, see Section 4.

### *Evaluation of Relative Impact of Methods*

Each method was evaluated independently for each habitat. In an actual response, however, the methods cannot be evaluated in isolation from each other. Specific spill conditions will often dictate the need for different techniques for the same water environment or shoreline habitat. For example, a high degree of oiling or low exposure to natural removal processes may require a more intrusive technique to accelerate recovery in specific areas. The sensitivity of adjacent habitats may lead to the decision not to use an appropriate method because of the likelihood of secondary impact caused by cleanup of nearby sites. Finally, from an operational perspective, it may be necessary to use available methods early during a spill, rather than waiting for equipment or materials to arrive or teams to be trained in use of a less damaging technique.

### *Relative Effectiveness of Methods*

The relative effectiveness of response methods to protect habitats and remove oil is a key consideration when selecting from various response methods. Although this guide attempts to consider only the environmental impact, effectiveness was incorporated into the discussion of methods in three ways.

First, those methods thought to be totally ineffective or inapplicable for an environment or habitat were not even listed in the habitat-specific matrices. For example, barrier/berms are not listed on the open-water matrices, and mechanical removal is not listed on the bedrock matrices.

Second, those methods that were clearly ineffective or inapplicable for a specific oil type within a habitat matrix were designated with a dash (—). Examples include using solidifiers on heavy oils in open water and emulsion-treating agents on gasoline products.

Third, those methods that are feasible, but likely to leave a significant amount of oil at the end of treatment, are given a lower classification. Often this change in effectiveness is associated with oil type, e.g., low-pressure, cold-water flushing is given a lower classification for heavy oil than medium oil because of its lower efficiency at oil removal. Similarly, methods such as manual and mechanical oil removal and sediment reworking that would have little effect on gasoline, which tends to evaporate quickly, are given lower classifications because the impact of the methods are not balanced by benefits from removing the oil.

### *Restrictions for Using Response Methods*

Restrictions related to safety, weather, spill size, or regulatory constraints cover a wide spectrum of scenarios. It is thus impractical to discuss every possible situation or combination of factors in a set of guidelines. Some of this information, if appropriate, is included in the discussion under each habitat (Section 3) or in the descriptions of each method (Section 4). Many other considerations can come into play, such as worker safety and aesthetic, social, and economic impacts. Specific safety issues dealing with responding to gasoline spills are reflected in the tables. It should be noted that using chemical methods will require approvals from state and/or Federal regulatory agencies.

## 1.8 CLASSIFICATION OF OIL TYPES

Inland oil spills can involve a wide range of crude oils and refined products. The type of oil spilled is a key consideration in developing response and cleanup strategies. Oil properties important in characterizing oil types include:

*Flash point* Highly volatile oils, which evaporate rapidly after a release, may pose significant fire risks to responders. Often, the safest option is to allow the product to evaporate. Evaporation is an important mechanism for removing the spill from the water or shore because it lessens the need for cleanup and concern for associated impacts. Highly volatile oils completely evaporate in one to two days.

*Specific gravity/API gravity* Oils with a specific gravity greater than 1.00 (API gravity of less than 10) will sink in freshwater. However, those with a specific gravity of 0.95 or higher (API gravity less than 17.5) are also at risk of sinking once they become mixed with suspended sediments. When these oils have stranded on a shoreline, sediment incorporated from the shoreline can cause sinking if it is eroded from the shoreline.

*Viscosity* Viscosity controls both the rate that oil spreads on water and its likely depth of penetration into the substrate once on shore. Low-viscosity oils spread rapidly into thin sheens, increasing the surface area and making recovery difficult. They readily penetrate into sediments and debris. Viscous oils can be so thick that they do not spread, particularly when spilled on cold water. They are more likely to coat rather than penetrate shorelines.

*Emulsion formation* Under certain conditions, oil slicks will form a water-in-oil emulsion often called “chocolate mousse.” This material can contain up to 80 percent water and can be many orders of magnitude more viscous than the spilled oil. There is no simple qualitative measure of the tendency to form emulsions. Emulsions are stabilized by natural or added surfactants, or compounds that act like surfactants, in the spilled oil. Gasoline does not emulsify, while diesel can quickly emulsify. Many crude oils can form stable emulsions. When an emulsion is formed, the oil changes in appearance and viscosity, becoming much more difficult to address from a spill-response perspective: the fluid is more viscous and hard to pump, and the volume has increased by a factor of four to five.

*Adhesion* The ease with which spilled oil can be physically removed from surfaces, usually by water flushing or vacuum, is an important factor in planning cleanup operations. The range of response methods needed for shoreline cleanup will depend largely on whether stranded oil adheres to substrate and response equipment. However, adhesion is a poorly defined parameter that is difficult to predict.

We use an oil classification scheme based on these properties to define four categories of oil. Characteristics of the four general types are provided below (Table 4), along with representative oils. Weathering tends to change the physical and chemical properties of oil, usually making it more viscous and cleanup techniques less effective. Methods used during the initial response should be re-evaluated as time elapses and as the oil changes in character. To some extent, this re-evaluation may be achieved by using the four tables for oil types in sequence, thus simulating the weathering process. Extremely heavy oils or those that are solid at ambient temperatures, such as asphalt, are not addressed below but are discussed as a special consideration in Section 5.

**Table 4. The four types of oil used in this guide and their characteristics.**

*Gasoline Products*

- Very volatile and highly flammable (flash point near 100°F/40°C)
- High evaporation rates
- Narrow cut fraction with no residues
- Low viscosity; spread rapidly to a thin sheen
- Specific gravity less than 0.80
- High acute toxicity to biota
- Do not emulsify
- Will penetrate substrate; nonadhesive

*Diesel-like Products and Light Crude Oils*

*(No. 2 fuel oil, jet fuels, kerosene, West Texas crude, Alberta crude)*

- Moderately volatile (flash point varies 100-150°F/40-65°C)
- Refined products can evaporate to no residue
- Crude oils do have a residue after evaporation is completed
- Low to moderate viscosity; spread rapidly into thin slicks
- Specific gravity of 0.80-0.85; API gravity of 35-45
- Moderate to high acute toxicity to biota; product-specific toxicity related to type and concentration of aromatic compounds
- Can form stable emulsions
- Tend to penetrate substrate; fresh spills are not adhesive
- Stranded light crudes tend to smother organisms

*Medium-grade Crude Oils and Intermediate Products*

*(North Slope crude, South Louisiana crude, No. 4 fuel oil, IFO 180, lube oils)*

- Moderately volatile (flash point higher than 125°F/50°C)
- Up to one-third will evaporate in the first 24 hours
- Moderate to high viscosity
- Specific gravity of 0.85-0.95; API gravity of 17.5-35
- Variable acute toxicity, depending on amount of light fraction
- Can form stable emulsions
- Variable substrate penetration and adhesion
- Stranded oil tends to smother organisms

*Heavy Crude Oils and Residual Products*

*(Venezuela crude, San Joaquin Valley crude, Bunker C, No. 6 fuel oil)*

- Slightly volatile (flash point greater than 150°F/65°C)
- Very little product loss by evaporation
- Very viscous to semisolid; may become less viscous when warmed
- Specific gravity of 0.95-1.00; API gravity of 10-17.5
- Low acute toxicity relative to other oil types
- Can form stable emulsions
- Little penetration of substrate likely, but can be highly adhesive
- Stranded oil tends to smother organisms



## 2.0 SUMMARY OF RESPONSE METHODS AND HABITATS

Tables 6 through 13 provide overviews of the physical, chemical, and biological response methods for four different oil types as applied to all water environments and shoreline habitats. Detailed information regarding specific habitats is provided in Section 3. Users of this guide should consult the matrices and summaries in Section 3 for descriptions of assumptions and circumstances applicable to the various methods. We encourage you to refer to Section 4 for more information on each response method. Also, the references listed in Appendix A can provide valuable, detailed information on specific topics or applications.

It is important to note that the classifications primarily reflect the likely relative environmental impact resulting from properly implementing a response method within each habitat. However, when there are overriding effectiveness or safety issues associated with a specific oil type or habitat, these methods have been classified as “not applicable” and are denoted with a dash (—) on the matrices. In the case of response to gasoline-type spills, many methods have been classified as “not applicable” because of the fire hazard to the responders. Although responders have used many of these methods at gasoline spills to protect resources or clean up the spill, discussion of the spill-specific circumstances that made their use possible are beyond the scope of this document.

Natural recovery is included in the tables since natural processes can be adequate, on their own, to remediate impact from an oil spill. It also presents no added environmental stress due to human spill response activities. Therefore, natural recovery is often classified as having the least adverse habitat impact in the summary tables.

Since there is little information regarding the environmental impact of *in situ* burning, chemical treatment, and biodegradation enhancement in freshwater habitats, the evaluation and discussion are based on the best available knowledge on how they work and any past use. In most cases this knowledge results from past experience with marine spills. Where there is too little information to evaluate a technique (e.g., chemical shoreline pretreatment), an “I”, for insufficient information, is used in the tables.

Spill response techniques described in this guide for inland water habitats include protection, recovery, and cleanup methods. The main objective of protection is keeping oil out of a habitat, or reducing the amount of oil that enters. Recovery consists of removal of floating oil from the water surface. Cleanup consists of removal of stranded oil. Frequently, these methods may be used for several response phases, such as deploying boom for protection or for containing oil washed off a river bank during cleanup.

**Table 5. Key to ESI codes used in Tables 7, 9, 11, and 13.**

| <b>ESI No.</b> | <b>Shoreline Type</b>                            |
|----------------|--------------------------------------------------|
| <b>1A</b>      | Exposed rocky cliffs                             |
| <b>1B</b>      | Exposed solid seawalls                           |
| <b>2</b>       | Shelving bedrock shores                          |
| <b>3</b>       | Eroding scarps in unconsolidated sediments       |
| <b>4</b>       | Sand beaches                                     |
| <b>5</b>       | Mixed sand and gravel beaches                    |
| <b>6A</b>      | Gravel beaches                                   |
| <b>6B</b>      | Riprap structures                                |
| <b>7</b>       | Exposed tidal flats (not present in Great Lakes) |
| <b>8A</b>      | Sheltered rocky shores                           |
| <b>8B</b>      | Sheltered, solid, manmade structures             |
| <b>9A</b>      | Sheltered vegetated low banks/bluffs             |
| <b>9B</b>      | Sheltered sand/mud flats                         |
| <b>10A</b>     | Freshwater marshes (herbaceous vegetation)       |
| <b>10B</b>     | Freshwater swamps (woody vegetation)             |

**Table 6. GASOLINE PRODUCTS: Summary of relative environmental impact from response methods for spills in water environments.**

| Response Method                    | WATER ENVIRONMENT |              |                   |                      |
|------------------------------------|-------------------|--------------|-------------------|----------------------|
|                                    | Open Water        | Large Rivers | Small Lakes/Ponds | Small Rivers/Streams |
| <b>PHYSICAL RESPONSE METHODS</b>   |                   |              |                   |                      |
| Natural Recovery                   | A                 | A            | A                 | A                    |
| Booming - Containment              | -                 | -            | -                 | -                    |
| Booming - Deflection/Exclusion     | A                 | A            | A                 | A                    |
| Skimming                           | -                 | -            | -                 | A                    |
| Barriers/Berms                     | -                 | -            | -                 | B                    |
| Physical Herding                   | B                 | B            | C                 | B                    |
| Manual Oil Removal/Cleaning        | -                 | -            | -                 | -                    |
| Mechanical Oil Removal             | -                 | -            | -                 | -                    |
| Sorbents                           | -                 | -            | -                 | -                    |
| Vacuum                             | -                 | -            | -                 | -                    |
| Debris Removal                     | -                 | -            | -                 | -                    |
| Sediment Reworking                 | -                 | -            | -                 | -                    |
| Vegetation Removal                 | -                 | -            | -                 | -                    |
| In Situ Burning                    | -                 | -            | B                 | C                    |
| Flooding                           | -                 | -            | -                 | -                    |
| Low-Pressure, Cold-Water Flushing  | -                 | -            | -                 | -                    |
| High-Pressure, Cold-Water Flushing | -                 | -            | -                 | -                    |
| Low-Pressure, Hot-Water Flushing   | -                 | -            | -                 | -                    |
| High-Pressure, Hot-Water Flushing  | -                 | -            | -                 | -                    |
| Steam Cleaning                     | -                 | -            | -                 | -                    |
| Sand Blasting                      | -                 | -            | -                 | -                    |
| <b>CHEMICAL RESPONSE METHODS</b>   |                   |              |                   |                      |
| Dispersants                        | D                 | D            | D                 | D                    |
| Emulsion Treating Agents           | -                 | -            | -                 | -                    |
| Visco-Elastic Agents               | -                 | -            | -                 | B                    |
| Herding Agents                     | D                 | D            | B                 | D                    |
| Solidifiers                        | D                 | D            | D                 | B                    |
| Chemical Shoreline Pretreatment    | -                 | -            | -                 | -                    |
| Shoreline Cleaning Agents          | -                 | -            | -                 | -                    |
| <b>BIOLOGICAL RESPONSE METHODS</b> |                   |              |                   |                      |
| Nutrient Enrichment                | -                 | -            | -                 | -                    |
| Natural Microbe Seeding            | -                 | -            | -                 | -                    |

The following categories are used to compare the relative environmental impact of each response method for the specific environment or habitat for each oil type, using the following definitions:

- A = May cause the least adverse habitat impact.
- B = May cause some adverse habitat impact.
- C = May cause significant adverse habitat impact.
- D = May cause the most adverse habitat impact.
- I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this time.
- = Not applicable for this oil type.

**Table 7. GASOLINE PRODUCTS: Summary of relative environmental impact from response methods for spills in shoreline habitats.**

| Response Method                    | SHORELINE HABITAT |          |      |                  |                 |        |     |          |
|------------------------------------|-------------------|----------|------|------------------|-----------------|--------|-----|----------|
|                                    | Bedrock           | Man-Made | Sand | Vegetated Shores | Sand and Gravel | Gravel | Mud | Wetlands |
| <b>PHYSICAL RESPONSE METHODS</b>   | 1,2,8*            | 1,8      | 3,4  | 9                | 5               | 6      | 7,9 | 10       |
| Natural Recovery                   | A                 | A        | A    | A                | A               | A      | A   | A        |
| Booming                            | -                 | -        | -    | -                | -               | -      | -   | -        |
| Skimming                           | -                 | -        | -    | -                | -               | -      | -   | -        |
| Barriers/Berms                     | -                 | -        | -    | -                | -               | -      | -   | -        |
| Physical Herding                   | -                 | -        | -    | -                | -               | -      | -   | -        |
| Manual Oil Removal/Cleaning        | -                 | -        | D    | D                | D               | D      | D   | D        |
| Mechanical Oil Removal             | -                 | -        | D    | D                | D               | D      | D   | D        |
| Sorbents                           | B                 | B        | -    | -                | -               | -      | B   | C        |
| Vacuum                             | -                 | -        | -    | -                | -               | -      | -   | -        |
| Debris Removal                     | -                 | -        | -    | -                | -               | -      | -   | -        |
| Sediment Reworking                 | -                 | -        | D    | D                | D               | D      | D   | D        |
| Vegetation Removal                 | -                 | -        | -    | D                | -               | -      | -   | D        |
| In Situ Burning                    | -                 | -        | -    | -                | -               | -      | C   | B        |
| Flooding                           | B                 | B        | B    | B                | A               | A      | B   | B        |
| Low-Pressure, Cold-Water Flushing  | B                 | B        | B    | B                | B               | A      | D   | B        |
| High-Pressure, Cold-Water Flushing | B                 | B        | D    | D                | C               | C      | D   | D        |
| Low-Pressure, Hot-Water Flushing   | -                 | -        | D    | D                | D               | D      | D   | D        |
| High-Pressure, Hot-Water Flushing  | -                 | -        | D    | D                | D               | D      | D   | D        |
| Steam Cleaning                     | -                 | -        | -    | -                | -               | -      | -   | -        |
| Sand Blasting                      | -                 | -        | -    | -                | -               | -      | -   | -        |
| <b>CHEMICAL RESPONSE METHODS</b>   |                   |          |      |                  |                 |        |     |          |
| Dispersants                        | -                 | -        | -    | -                | -               | -      | -   | -        |
| Emulsion Treating Agents           | -                 | -        | -    | -                | -               | -      | -   | -        |
| Visco-Elastic Agents               | -                 | -        | -    | -                | -               | -      | -   | -        |
| Herding Agents                     | -                 | -        | -    | -                | -               | -      | -   | -        |
| Solidifiers                        | -                 | B        | -    | -                | -               | -      | D   | D        |
| Chemical Shoreline Pretreatment    | -                 | -        | -    | -                | -               | -      | I   | I        |
| Shoreline Cleaning Agents          | -                 | -        | -    | -                | -               | -      | -   | -        |
| <b>BIOLOGICAL RESPONSE METHODS</b> |                   |          |      |                  |                 |        |     |          |
| Nutrient Enrichment                | -                 | -        | -    | -                | -               | -      | -   | -        |
| Natural Microbe Seeding            | -                 | -        | -    | -                | -               | -      | -   | -        |

\*Key to ESI codes in Table 5 on page 12.

The following categories are used to compare the relative environmental impact of each response method for the specific environment or habitat for each oil type, using the following definitions:

- A = May cause the least adverse habitat impact.
- B = May cause some adverse habitat impact.
- C = May cause significant adverse habitat impact.
- D = May cause the most adverse habitat impact.
- I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this time.
- = Not applicable for this oil type.

**Table 8. DIESEL-LIKE OILS: Summary of relative environmental impact from response methods for spills in water environments.**

| Response Method                    | WATER ENVIRONMENT |              |                   |                      |
|------------------------------------|-------------------|--------------|-------------------|----------------------|
|                                    | Open Water        | Large Rivers | Small Lakes/Ponds | Small Rivers/Streams |
| <b>PHYSICAL RESPONSE METHODS</b>   |                   |              |                   |                      |
| Natural Recovery                   | A                 | A            | B                 | B                    |
| Booming                            | A                 | A            | A                 | A                    |
| Skimming                           | A                 | A            | A                 | A                    |
| Barriers/Berms                     | —                 | —            | —                 | A                    |
| Physical Herding                   | B                 | B            | B                 | B                    |
| Manual Oil Removal/Cleaning        | —                 | —            | C                 | C                    |
| Mechanical Oil Removal             | —                 | —            | C                 | C                    |
| Sorbents                           | B                 | B            | A                 | A                    |
| Vacuum                             | A                 | A            | A                 | A                    |
| Debris Removal                     | —                 | B            | B                 | B                    |
| Sediment Reworking                 | —                 | —            | —                 | —                    |
| Vegetation Removal                 | B                 | B            | B                 | B                    |
| <i>In Situ</i> Burning             | A                 | B            | B                 | B                    |
| Flooding                           | —                 | —            | —                 | —                    |
| Low-Pressure, Cold-Water Flushing  | —                 | —            | —                 | —                    |
| High-Pressure, Cold-Water Flushing | —                 | —            | —                 | —                    |
| Low-Pressure, Hot-Water Flushing   | —                 | —            | —                 | —                    |
| High-Pressure, Hot-Water Flushing  | —                 | —            | —                 | —                    |
| Steam Cleaning                     | —                 | —            | —                 | —                    |
| Sand Blasting                      | —                 | —            | —                 | —                    |
| <b>CHEMICAL RESPONSE METHODS</b>   |                   |              |                   |                      |
| Dispersants                        | B                 | C            | D                 | D                    |
| Emulsion Treating Agents           | B                 | B            | I                 | I                    |
| Visco-Elastic Agents               | B                 | B            | B                 | B                    |
| Herding Agents                     | B                 | D            | B                 | D                    |
| Solidifiers                        | B                 | B            | B                 | B                    |
| Chemical Shoreline Pretreatment    | —                 | —            | —                 | —                    |
| Shoreline Cleaning Agents          | —                 | —            | —                 | —                    |
| <b>BIOLOGICAL RESPONSE METHODS</b> |                   |              |                   |                      |
| Nutrient Enrichment                | —                 | —            | I                 | I                    |
| Natural Microbe Seeding            | —                 | —            | I                 | I                    |

The following categories are used to compare the relative environmental impact of each response method for the specific environment or habitat for each oil type, using the following definitions:

- A = May cause the least adverse habitat impact.
- B = May cause some adverse habitat impact.
- C = May cause significant adverse habitat impact.
- D = May cause the most adverse habitat impact.
- I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this time.
- = Not applicable for this oil type.

Table 9. DIESEL-LIKE OILS: Summary of relative environmental impact from response methods for spills in shoreline habitats.

| Response Method                    | SHORELINE HABITAT |          |      |                  |                 |        |     |          |
|------------------------------------|-------------------|----------|------|------------------|-----------------|--------|-----|----------|
|                                    | Bedrock           | Man-Made | Sand | Vegetated Shores | Sand and Gravel | Gravel | Mud | Wetlands |
| <b>PHYSICAL RESPONSE METHODS</b>   | 1,2,8*            | 1,8      | 3,4  | 9                | 5               | 6      | 7,9 | 10       |
| Natural Recovery                   | A                 | A        | A    | A                | A               | A      | A   | A        |
| Booming                            | -                 | -        | -    | -                | -               | -      | -   | -        |
| Skimming                           | -                 | -        | -    | -                | -               | -      | -   | -        |
| Barriers/Berms                     | -                 | -        | -    | -                | -               | -      | -   | -        |
| Physical Herding                   | -                 | -        | -    | -                | -               | -      | -   | -        |
| Manual Oil Removal/Cleaning        | B                 | A        | B    | B                | B               | B      | D   | D        |
| Mechanical Oil Removal             | -                 | -        | B    | C                | C               | D      | D   | D        |
| Sorbents                           | A                 | A        | A    | A                | A               | A      | A   | A        |
| Vacuum                             | B                 | B        | B    | B                | B               | B      | C   | B        |
| Debris Removal                     | A                 | A        | A    | B                | A               | A      | B   | B        |
| Sediment Reworking                 | -                 | -        | B    | D                | B               | B      | D   | D        |
| Vegetation Removal                 | -                 | -        | -    | B                | -               | -      | -   | C        |
| In Situ Burning                    | B                 | B        | -    | B                | -               | -      | C   | B        |
| Flooding                           | A                 | A        | A    | A                | A               | A      | A   | A        |
| Low-Pressure, Cold-Water Flushing  | A                 | A        | B    | A                | A               | A      | C   | A        |
| High-Pressure, Cold-Water Flushing | B                 | A        | D    | C                | C               | B      | D   | D        |
| Low-Pressure, Hot-Water Flushing   | C                 | B        | C    | D                | C               | C      | D   | D        |
| High-Pressure, Hot-Water Flushing  | D                 | B        | D    | D                | D               | D      | D   | D        |
| Steam Cleaning                     | D                 | C        | -    | -                | D               | D      | -   | -        |
| Sand Blasting                      | D                 | C        | -    | -                | -               | -      | -   | -        |
| <b>CHEMICAL RESPONSE METHODS</b>   |                   |          |      |                  |                 |        |     |          |
| Dispersants                        | -                 | -        | -    | -                | -               | -      | -   | -        |
| Emulsion Treating Agents           | -                 | -        | -    | -                | -               | -      | -   | -        |
| Visco-Elastic Agents               | -                 | -        | -    | -                | -               | -      | -   | -        |
| Herding Agents                     | -                 | -        | -    | -                | -               | -      | -   | -        |
| Solidifiers                        | B                 | B        | B    | D                | -               | -      | D   | D        |
| Chemical Shoreline Pretreatment    | I                 | I        | I    | I                | I               | I      | I   | I        |
| Shoreline Cleaning Agents          | -                 | B        | -    | I                | -               | -      | D   | I        |
| <b>BIOLOGICAL RESPONSE METHODS</b> |                   |          |      |                  |                 |        |     |          |
| Nutrient Enrichment                | C                 | C        | B    | B                | B               | B      | I   | I        |
| Natural Microbe Seeding            | I                 | I        | I    | I                | I               | I      | I   | I        |

\*Key to ESI codes in Table 5 on page 12.

The following categories are used to compare the relative environmental impact of each response method for the specific environment or habitat for each oil type, using the following definitions:

- A = May cause the least adverse habitat impact.
- B = May cause some adverse habitat impact.
- C = May cause significant adverse habitat impact.
- D = May cause the most adverse habitat impact.
- I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this time.
- = Not applicable for this oil type.

**Table 10. MEDIUM OILS: Summary of relative environmental impact from response methods for spills in water environments.**

| Response Method                    | WATER ENVIRONMENT |              |                   |                      |
|------------------------------------|-------------------|--------------|-------------------|----------------------|
|                                    | Open Water        | Large Rivers | Small Lakes/Ponds | Small Rivers/Streams |
| <b>PHYSICAL RESPONSE METHODS</b>   |                   |              |                   |                      |
| Natural Recovery                   | B                 | B            | C                 | C                    |
| Booming                            | A                 | A            | A                 | A                    |
| Skimming                           | A                 | A            | A                 | A                    |
| Barriers/Berms                     | —                 | —            | —                 | A                    |
| Physical Herding                   | B                 | B            | B                 | B                    |
| Manual Oil Removal/Cleaning        | —                 | B            | C                 | C                    |
| Mechanical Oil Removal             | —                 | B            | C                 | C                    |
| Sorbents                           | B                 | B            | A                 | A                    |
| Vacuum                             | A                 | A            | A                 | A                    |
| Debris Removal                     | —                 | B            | B                 | B                    |
| Sediment Reworking                 | —                 | —            | —                 | —                    |
| Vegetation Removal                 | B                 | B            | B                 | B                    |
| <i>In Situ</i> Burning             | A                 | B            | B                 | B                    |
| Flooding                           | —                 | —            | —                 | —                    |
| Low-Pressure, Cold-Water Flushing  | —                 | —            | —                 | —                    |
| High-Pressure, Cold-Water Flushing | —                 | —            | —                 | —                    |
| Low-Pressure, Hot-Water Flushing   | —                 | —            | —                 | —                    |
| High-Pressure, Hot-Water Flushing  | —                 | —            | —                 | —                    |
| Steam Cleaning                     | —                 | —            | —                 | —                    |
| Sand Blasting                      | —                 | —            | —                 | —                    |
| <b>CHEMICAL RESPONSE METHODS</b>   |                   |              |                   |                      |
| Dispersants                        | B                 | C            | D                 | D                    |
| Emulsion Treating Agents           | B                 | B            | I                 | I                    |
| Visco-Elastic Agents               | B                 | B            | B                 | B                    |
| Herding Agents                     | B                 | D            | B                 | D                    |
| Solidifiers                        | B                 | B            | B                 | B                    |
| Chemical Shoreline Pretreatment    | —                 | —            | —                 | —                    |
| Shoreline Cleaning Agents          | —                 | —            | —                 | —                    |
| <b>BIOLOGICAL RESPONSE METHODS</b> |                   |              |                   |                      |
| Nutrient Enrichment                | I                 | I            | I                 | I                    |
| Natural Microbe Seeding            | I                 | I            | I                 | I                    |

The following categories are used to compare the relative environmental impact of each response method for the specific environment or habitat for each oil type, using the following definitions:

- A = May cause the least adverse habitat impact.
- B = May cause some adverse habitat impact.
- C = May cause significant adverse habitat impact.
- D = May cause the most adverse habitat impact.
- I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this time.
- = Not applicable for this oil type.

**Table 11. MEDIUM OILS: Summary of relative environmental impact from response methods for spills in shoreline habitats.**

| Response Method                    | SHORELINE HABITAT |          |      |                  |                 |        |     |          |
|------------------------------------|-------------------|----------|------|------------------|-----------------|--------|-----|----------|
|                                    | Bedrock           | Man-Made | Sand | Vegetated Shores | Sand and Gravel | Gravel | Mud | Wetlands |
| <b>PHYSICAL RESPONSE METHODS</b>   | 1,2,8*            | 1,8      | 3,4  | 9                | 5               | 6      | 7,9 | 10       |
| Natural Recovery                   | A                 | B        | B    | B                | B               | B      | A   | A        |
| Booming                            | —                 | —        | —    | —                | —               | —      | —   | —        |
| Skimming                           | —                 | —        | —    | —                | —               | —      | —   | —        |
| Barriers/Berms                     | —                 | —        | —    | —                | —               | —      | —   | —        |
| Physical Herding                   | —                 | —        | —    | —                | —               | —      | —   | —        |
| Manual Oil Removal/Cleaning        | B                 | B        | A    | B                | A               | B      | C   | C        |
| Mechanical Oil Removal             | —                 | —        | B    | C                | B               | C      | D   | D        |
| Sorbents                           | A                 | A        | A    | B                | A               | A      | A   | A        |
| Vacuum                             | B                 | B        | B    | B                | B               | B      | B   | B        |
| Debris Removal                     | A                 | A        | A    | B                | A               | A      | B   | B        |
| Sediment Reworking                 | —                 | —        | B    | D                | B               | B      | D   | D        |
| Vegetation Removal                 | —                 | —        | —    | B                | —               | —      | —   | C        |
| In Situ Burning                    | B                 | B        | B    | B                | B               | B      | C   | B        |
| Flooding                           | B                 | B        | A    | A                | A               | A      | A   | A        |
| Low-Pressure, Cold-Water Flushing  | A                 | A        | B    | A                | A               | A      | C   | A        |
| High-Pressure, Cold-Water Flushing | B                 | A        | D    | C                | C               | B      | D   | D        |
| Low-Pressure, Hot-Water Flushing   | B                 | B        | C    | D                | C               | C      | C   | D        |
| High-Pressure, Hot-Water Flushing  | C                 | B        | D    | D                | D               | D      | D   | D        |
| Steam Cleaning                     | D                 | C        | —    | —                | D               | D      | —   | —        |
| Sand Blasting                      | D                 | C        | —    | —                | —               | —      | —   | —        |
| <b>CHEMICAL RESPONSE METHODS</b>   |                   |          |      |                  |                 |        |     |          |
| Dispersants                        | —                 | —        | —    | —                | —               | —      | —   | —        |
| Emulsion Treating Agents           | —                 | —        | —    | —                | —               | —      | —   | —        |
| Visco-Elastic Agents               | —                 | —        | —    | —                | —               | —      | —   | —        |
| Herding Agents                     | —                 | —        | —    | —                | —               | —      | —   | —        |
| Solidifiers                        | B                 | B        | B    | D                | B               | B      | C   | D        |
| Chemical Shoreline Pretreatment    | I                 | I        | I    | I                | I               | I      | I   | I        |
| Shoreline Cleaning Agents          | B                 | B        | B    | I                | B               | B      | D   | I        |
| <b>BIOLOGICAL RESPONSE METHODS</b> |                   |          |      |                  |                 |        |     |          |
| Nutrient Enrichment                | C                 | C        | B    | B                | B               | B      | I   | I        |
| Natural Microbe Seeding            | I                 | I        | I    | I                | I               | I      | I   | I        |

\*Key to ESI codes in Table 5 on page 12.

The following categories are used to compare the relative environmental impact of each response method for the specific environment or habitat for each oil type, using the following definitions:

- A = May cause the least adverse habitat impact.
- B = May cause some adverse habitat impact.
- C = May cause significant adverse habitat impact.
- D = May cause the most adverse habitat impact.
- I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this time.
- = Not applicable for this oil type.

**Table 12. HEAVY OILS: Summary of relative environmental impact from response methods for spills in water environments.**

| Response Method                    | WATER ENVIRONMENT |              |                   |                      |
|------------------------------------|-------------------|--------------|-------------------|----------------------|
|                                    | Open Water        | Large Rivers | Small Lakes/Ponds | Small Rivers/Streams |
| <b>PHYSICAL RESPONSE METHODS</b>   |                   |              |                   |                      |
| Natural Recovery                   | B                 | C            | C                 | C                    |
| Booming                            | A                 | A            | A                 | A                    |
| Skimming                           | A                 | A            | A                 | A                    |
| Barriers/Berms                     | —                 | —            | —                 | A                    |
| Physical Herding                   | B                 | B            | B                 | B                    |
| Manual Oil Removal/Cleaning        | B                 | B            | B                 | B                    |
| Mechanical Oil Removal             | B                 | B            | C                 | C                    |
| Sorbents                           | B                 | B            | A                 | A                    |
| Vacuum                             | A                 | A            | A                 | A                    |
| Debris Removal                     | —                 | B            | B                 | B                    |
| Sediment Reworking                 | —                 | —            | —                 | —                    |
| Vegetation Removal                 | B                 | B            | B                 | B                    |
| <i>In Situ</i> Burning             | A                 | B            | B                 | B                    |
| Flooding                           | —                 | —            | —                 | —                    |
| Low-Pressure, Cold-Water Flushing  | —                 | —            | —                 | —                    |
| High-Pressure, Cold-Water Flushing | —                 | —            | —                 | —                    |
| Low-Pressure, Hot-Water Flushing   | —                 | —            | —                 | —                    |
| High-Pressure, Hot-Water Flushing  | —                 | —            | —                 | —                    |
| Steam Cleaning                     | —                 | —            | —                 | —                    |
| Sand Blasting                      | —                 | —            | —                 | —                    |
| <b>CHEMICAL RESPONSE METHODS</b>   |                   |              |                   |                      |
| Dispersants                        | —                 | —            | —                 | —                    |
| Emulsion Treating Agents           | B                 | B            | I                 | I                    |
| Visco-Elastic Agents               | —                 | —            | —                 | —                    |
| Herding Agents                     | —                 | —            | —                 | —                    |
| Solidifiers                        | —                 | —            | —                 | —                    |
| Chemical Shoreline Pretreatment    | —                 | —            | —                 | —                    |
| Shoreline Cleaning Agents          | —                 | —            | —                 | —                    |
| <b>BIOLOGICAL RESPONSE METHODS</b> |                   |              |                   |                      |
| Nutrient Enrichment                | I                 | I            | I                 | I                    |
| Natural Microbe Seeding            | I                 | I            | I                 | I                    |

The following categories are used to compare the relative environmental impact of each response method for the specific environment or habitat for each oil type, using the following definitions:

- A = May cause the least adverse habitat impact.
- B = May cause some adverse habitat impact.
- C = May cause significant adverse habitat impact.
- D = May cause the most adverse habitat impact.
- I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this time.
- = Not applicable for this oil type.

**Table 13. HEAVY OILS: Summary of relative environmental impact from response methods for spills in shoreline habitats.**

| Response Method                    | SHORELINE HABITAT |          |      |                  |                 |        |     |          |
|------------------------------------|-------------------|----------|------|------------------|-----------------|--------|-----|----------|
|                                    | Bedrock           | Man-Made | Sand | Vegetated Shores | Sand and Gravel | Gravel | Mud | Wetlands |
| <b>PHYSICAL RESPONSE METHODS</b>   | 1,2,8*            | 1,8      | 3,4  | 9                | 5               | 6      | 7,9 | 10       |
| Natural Recovery                   | B                 | B        | B    | B                | B               | B      | B   | B        |
| Booming                            | -                 | -        | -    | -                | -               | -      | -   | -        |
| Skimming                           | -                 | -        | -    | -                | -               | -      | -   | -        |
| Barriers/Berms                     | -                 | -        | -    | -                | -               | -      | -   | -        |
| Physical Herding                   | -                 | -        | -    | -                | -               | -      | -   | -        |
| Manual Oil Removal/Cleaning        | A                 | A        | A    | B                | A               | A      | C   | C        |
| Mechanical Oil Removal             | -                 | -        | A    | C                | B               | C      | D   | D        |
| Sorbents                           | B                 | B        | B    | B                | B               | B      | B   | A        |
| Vacuum                             | B                 | A        | B    | B                | B               | B      | B   | B        |
| Debris Removal                     | A                 | A        | A    | B                | A               | A      | B   | B        |
| Sediment Reworking                 | -                 | -        | B    | D                | B               | B      | D   | D        |
| Vegetation Removal                 | -                 | -        | -    | B                | -               | -      | -   | C        |
| In Situ Burning                    | B                 | B        | B    | B                | B               | B      | C   | B        |
| Flooding                           | C                 | C        | B    | B                | C               | C      | A   | B        |
| Low-Pressure, Cold-Water Flushing  | C                 | C        | B    | B                | B               | B      | C   | B        |
| High-Pressure, Cold-Water Flushing | B                 | B        | D    | D                | C               | B      | D   | D        |
| Low-Pressure, Hot-Water Flushing   | B                 | B        | B    | D                | B               | B      | C   | D        |
| High-Pressure, Hot-Water Flushing  | C                 | B        | D    | D                | D               | D      | D   | D        |
| Steam Cleaning                     | D                 | C        | -    | -                | D               | D      | -   | -        |
| Sand Blasting                      | D                 | C        | -    | -                | -               | -      | -   | -        |
| <b>CHEMICAL RESPONSE METHODS</b>   |                   |          |      |                  |                 |        |     |          |
| Dispersants                        | -                 | -        | -    | -                | -               | -      | -   | -        |
| Emulsion Treating Agents           | -                 | -        | -    | -                | -               | -      | -   | -        |
| Visco-Elastic Agents               | -                 | -        | -    | -                | -               | -      | -   | -        |
| Herding Agents                     | -                 | -        | -    | -                | -               | -      | -   | -        |
| Solidifiers                        | -                 | -        | -    | -                | -               | -      | -   | -        |
| Chemical Shoreline Pretreatment    | I                 | I        | I    | I                | I               | I      | I   | I        |
| Shoreline Cleaning Agents          | B                 | B        | B    | I                | B               | B      | D   | I        |
| <b>BIOLOGICAL RESPONSE METHODS</b> |                   |          |      |                  |                 |        |     |          |
| Nutrient Enrichment                | D                 | D        | C    | B                | C               | C      | I   | I        |
| Natural Microbe Seeding            | I                 | I        | I    | I                | I               | I      | I   | I        |

\*Key to ESI codes in Table 5 on page 12.

The following categories are used to compare the relative environmental impact of each response method for the specific environment or habitat for each oil type, using the following definitions:

- A = May cause the least adverse habitat impact.
- B = May cause some adverse habitat impact.
- C = May cause significant adverse habitat impact.
- D = May cause the most adverse habitat impact.
- I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this time.
- = Not applicable for this oil type.

## 3.0 SPILL RESPONSE METHODS FOR SPECIFIC INLAND HABITATS

### 3.1 INTRODUCTION

Oil spill protection, recovery, and cleanup methods are described in the following sections for four water environments and eight shoreline habitats. Each section is organized in the following format:

- Description of the environment or habitat;
- Matrices of response methods for four oil types; and
- Short summaries of the key issues considered for each response method.

The inland habitats are presented in order of their sensitivity, from least to most sensitive to oil spill impact, first for water environments, then for shoreline habitats. Accordingly, water environments begin with large rivers and end with small lakes and ponds. Shoreline habitats begin with bedrock and end with wetlands.

Response methods in each matrix are listed in order, generally beginning with those that cause the least adverse habitat impact, to those that can cause the most adverse habitat impact. Methods for which insufficient information is available for some habitats are listed last. Methods that are not applicable for all four oil types are excluded from the tables.

The use of water environments and shoreline habitats generally reflects the distinction between oil on a water body versus oil that is stranded at the land-water interface. Water-based activities consist mostly of containment, protection, and collection methods while onshore response includes protection, recovery, and cleanup. A large spill will likely affect a wide range of habitats and require use of many different methods. However, large spills can be divided into a series of small spills for developing site-specific response strategies. Often, more than one response method can be used with minimal habitat impacts. Spill conditions may dictate selecting a specific method, or combination of methods, over other possible methods.

We encourage you to refer to Section 4 for more information on each response method. Also, the references listed in Appendix A can provide valuable, detailed information on specific topics or applications.



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## 3.2 OPEN WATER

### *Habitat Description*

Open-water environments exist in large water bodies, such as the Great Lakes, Lake Champlain, and Lake Mead. These large water bodies have ocean-like wave and current conditions; however, lake currents are generally weak (less than one knot). Local weather conditions commonly cause sudden changes in sea state. Suspended sediment loads are highly variable, both spatially and over time. River mouths are particularly problematic areas, with high suspended sediment and debris loads, shallow zones, and manmade structures, which create complex water circulation patterns.

Thermal stratification with an upper, warm layer over cool, denser water is a common feature of large lakes during the warmer months. In most temperate lakes, stratification ends in the autumn when surface cooling combines with water mixing from high winds. Ice formation is a common characteristic of interior and northern lakes in winter months. Although all inland waters are surrounded by land, response operations for open-water environments are water-based; that is, protection and recovery equipment must be deployed from vessels.

### *Sensitivity*

Open waters are considered to have low to medium sensitivity to oil spill impact because physical removal rates are high, water-column concentrations of oil can be rapidly diluted, and most organisms are mobile enough to move out of the area affected by the spill.

Enclosed and protected areas of large lakes are more sensitive than offshore and nearshore waters because of slower dilution rates. Oil spills can affect fish in the water column, with the early life stages at greatest risk. Also, many birds (waterfowl, raptors, gulls, terns, and diving birds) feed and rest on the water, and therefore are highly vulnerable. Human use of affected areas may be restricted for a period of time, potentially limiting access for navigation, transportation, water intakes, or recreational activities during the spill.

Free-floating flora or mats can occur in sheltered bays of nutrient-rich lakes. Such mats may be particularly susceptible to oil because of their location in bays where oil may accumulate. Moreover, the plants are at the water surface (where the oil is) and without underground roots to regenerate after being oiled.

**Table 14. Relative environmental impact from response methods for OPEN WATER environments.**

| <i>Response Method</i>           | <i>Gasoline Products</i> | <i>Diesel-Like Oils</i> | <i>Medium Oils</i> | <i>Heavy Oils</i> |
|----------------------------------|--------------------------|-------------------------|--------------------|-------------------|
| Booming - Deflection/Exclusion   | A                        | A                       | A                  | A                 |
| Booming - Containment            | —                        | A                       | A                  | A                 |
| Skimming/Vacuum                  | —                        | A                       | A                  | A                 |
| <i>In Situ</i> Burning           | —                        | A                       | A                  | A                 |
| Natural Recovery                 | A                        | A                       | B                  | B                 |
| Physical Herding                 | B                        | B                       | B                  | B                 |
| Sorbents                         | —                        | B                       | B                  | B                 |
| Vegetation Removal               | —                        | B                       | B                  | B                 |
| Emulsion Treating Agents         | —                        | B                       | B                  | B                 |
| Visco-Elastic Agents/Solidifiers | —                        | B                       | B                  | —                 |
| Dispersants                      | D                        | B                       | B                  | —                 |
| Herding Agents                   | D                        | B                       | B                  | —                 |
| Manual Oil Removal/Cleaning      | —                        | —                       | —                  | B                 |
| Mechanical Oil Removal           | —                        | —                       | —                  | B                 |
| Nutrient Enrichment              | —                        | —                       | I                  | I                 |
| Natural Microbe Seeding          | —                        | —                       | I                  | I                 |

The following categories are used to compare the relative environmental impact of each response method for the specific environment or habitat for each oil type, using the following definitions:

- A = May cause the least adverse habitat impact.
- B = May cause some adverse habitat impact.
- C = May cause significant adverse habitat impact.
- D = May cause the most adverse habitat impact.
- I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this time.
- = Not applicable for this oil type.

## RESPONSE METHODS: OPEN WATER ENVIRONMENTS

### *Least Adverse Habitat Impact*

#### *Booming*

- Most effective in low-wave conditions and slow currents
- Safety concerns limit the containment of gasoline spills; however, booms can be used to exclude or deflect the spill away from sensitive resources

#### *Skimming/Vacuum*

- Effectiveness limited by current velocities and widely spread, thin sheens
- Not applicable to gasoline spills because of safety concerns

#### *In Situ Burning*

- Most appropriate in offshore, rather than nearshore, areas
- More difficult to ignite emulsified and heavy oils and sustain the burn
- Safety issues for workers, vessels, and aircraft must be addressed
- Not applicable to gasoline spills due to safety concerns and containment difficulties

#### *Natural Recovery*

- Low impact except for medium- to heavy-category oils, which are persistent and would eventually strand on shorelines

### *Some Adverse Habitat Impact*

#### *Physical Herding*

- May be needed under calm conditions to move oil toward recovery devices
- Water spray onto gasoline likely to mix the product into the water column

#### *Sorbents*

- Not a stand-alone technique except for very small spills
- Inhibit the evaporation of gasoline spills

#### *Vegetation Removal*

- May be appropriate if oil is trapped in floating vegetation

### *Emulsion-Treating Agents*

- Not applicable to oils that do not form emulsions, such as gasoline

### *Visco-Elastic Agents/Solidifiers*

- Not appropriate to gasoline spills because of safety concerns during application and inhibition of evaporation
- The recovery of treated oil must be considered
- Most are not very effective on heavy oils, which are too viscous to allow the product to mix into the oil

### *Dispersants*

- Inhibit the evaporation of gasoline spills
- Use requires comparing the impact of dispersed versus undispersed oil
- Not effective on heavy or weathered oils

### *Herding Agents*

- Most effective under calm conditions
- Not applicable to heavy oils because oil must be fluid
- Inhibit the evaporation of gasoline spills

### *Manual Oil Removal/Cleaning and Mechanical Oil Removal*

- Effective only when heavy oils have solidified into large masses
- Complete removal of heavy oil is rarely achieved

### *Insufficient Information*

#### *Nutrient Enrichment and Natural Microbe Seeding*

- Not applicable to gasoline and diesel-like oils because they rapidly evaporate
- There is insufficient information on impact and effectiveness for other oil types, particularly for open-water applications in freshwater

### 3.3 LARGE RIVERS

#### *Habitat Description*

Large rivers have varying salinities, meandering channels, and high flow rates (currents usually greater than one knot). These rivers are not necessarily navigable to large vessels. If they are, the environment can include associated locks, dams, pools, and other manmade structures. Examples of large rivers include the Mississippi River and its major tributaries, the Hudson River, the Delaware River, and the Columbia River. Water levels vary seasonally, with potential for reversal of water flow up tributaries and into backwater lakes during high water. Floodplains are common characteristics of large rivers. Floods generate high suspended sediment and debris loads. In northern regions, ice covers the surface in winter. River banks or bars are discussed in the sections on shore habitats (Sections 3.6 to 3.13), and backwater lakes are discussed in Section 3.4.

#### *Sensitivity*

Large rivers have medium sensitivity to oil spill impact because, even though they have high natural removal rates, they also have extensive biological and human use. Biological resources of concern include concentrations of migratory waterfowl and shorebirds, fish, and endangered mussel beds. Under flood conditions, river floodplains contain highly sensitive areas that are important habitats for many valuable species. Floating vegetation is present in areas of low flow. Recreational use of rivers is very high, and many are major transportation corridors. Drinking, industrial, and cooling water intakes are quite vulnerable to oil spills in this environment because of turbulent mixing, and they often shut down when slicks are present.

High currents, eddies, mid-river bars, ice formation, and flooding may complicate response measures in this habitat. Water flow across weirs and dams is of special concern because it is often turbulent and likely to emulsify oil slicks as they pass over these structures. Emulsified oil has a density close to water; it can readily suspend beneath the surface and remain in the water column as it moves through a series of locks and dams. Also, oil can adsorb onto sediment particles, which then settle out in quiet backwaters, potentially contaminating these habitats.

LARGE RIVER

The diagram illustrates the following features and components:

- Water Levels:**
  - Flood Water Level:** Indicated by a dashed line at the top of the channel.
  - Normal Water Level:** Indicated by a dashed line in the middle of the channel.
- Channel Features:**
  - Scour Channel:** A deepened area on the left bank.
  - Bar:** A sand and gravel deposit on the right bank.
  - Slough:** A side channel or area of standing water on the right bank.
- Substrates and Deposits:**
  - Mud:** Deposited in the scour channel and near the slough.
  - Sand, Gravel:** Found in the main channel and along the banks.
- Flow and Water States:**
  - Flowing Water:** Indicated by arrows in the main channel.
  - Standing Water:** Located in the slough.
- Channel and Flood Plain:**
  - Channel:** The central area where the river flows.
  - Flood Plain:** The areas on either side of the channel that are inundated during floods.

**Table 15. Relative environmental impact from response methods for LARGE RIVER environments.**

| <i>Response Method</i>           | <i>Gasoline Products</i> | <i>Diesel-Like Oils</i> | <i>Medium Oils</i> | <i>Heavy Oils</i> |
|----------------------------------|--------------------------|-------------------------|--------------------|-------------------|
| Booming - Deflection/Exclusion   | A                        | A                       | A                  | A                 |
| Booming - Containment            | —                        | A                       | A                  | A                 |
| Skimming/Vacuum                  | —                        | A                       | A                  | A                 |
| Natural Recovery                 | A                        | A                       | B                  | C                 |
| Physical Herding                 | B                        | B                       | B                  | B                 |
| Sorbents                         | —                        | B                       | B                  | B                 |
| <i>In Situ</i> Burning           | —                        | B                       | B                  | B                 |
| Emulsion Treating Agents         | —                        | B                       | B                  | B                 |
| Vegetation Removal               | —                        | B                       | B                  | B                 |
| Debris Removal                   | —                        | B                       | B                  | B                 |
| Visco-Elastic Agents/Solidifiers | —                        | B                       | B                  | —                 |
| Manual Oil Removal/Cleaning      | —                        | —                       | B                  | B                 |
| Mechanical Oil Removal           | —                        | —                       | B                  | B                 |
| Dispersants                      | D                        | C                       | C                  | —                 |
| Herding Agents                   | D                        | D                       | D                  | —                 |
| Nutrient Enrichment              | —                        | —                       | I                  | I                 |
| Natural Microbe Seeding          | —                        | —                       | I                  | I                 |

The following categories are used to compare the relative environmental impact of each response method for the specific environment or habitat for each oil type, using the following definitions:

- A = May cause the least adverse habitat impact.
- B = May cause some adverse habitat impact.
- C = May cause significant adverse habitat impact.
- D = May cause the most adverse habitat impact.
- I = Insufficient Information - impact or effectiveness of the method could not be evaluated at this time.
- = Not applicable for this oil type.

## RESPONSE METHODS: LARGE RIVER ENVIRONMENTS

### *Least Adverse Habitat Impact*

#### *Booming*

- Used primarily for diverting slicks towards collection points in low-current areas
- Safety concerns limit the containment of gasoline spills; however, booms can be used to exclude or deflect the spill away from sensitive resources

#### *Skimming/Vacuum*

- Not applicable to gasoline spills because of safety concerns

### *Some Adverse Habitat Impact*

#### *Natural Recovery*

- For small gasoline and diesel-like spills, evaporation and natural dispersion would rapidly remove surface slicks
- For all other types and sizes of spills, oil recovery and/or protection of sensitive resources should be attempted

#### *Physical Herding*

- May be needed to flush oil trapped in debris, eddies, etc. toward recovery devices
- Water spray onto gasoline spills will likely enhance mixing of the product into the water column

#### *Sorbents*

- Not applicable to gasoline spills because of safety concerns and inhibition of evaporation
- May not be practical for large rivers because oil will spread and drift rapidly
- Overuse results in excess waste generation

#### *In Situ Burning*

- May not be practical in rivers because oil will spread rapidly
- Containment and maintenance of minimum thickness for burning (1-3 millimeters) is difficult in fast currents

#### *Emulsion-Treating Agents*

- Not applicable for gasoline products, which do not emulsify



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### *Vegetation Removal*

- May be considered where oil is trapped in floating vegetation along shore and in eddies
- Removal of oiled vegetation may be required to prevent secondary oiling of wildlife or chronic sheening

### *Debris Removal*

- River debris can trap persistent oils, causing chronic sheening and exposure of aquatic resources

### *Visco-Elastic Agents/Solidifiers*

- Not applicable to gasoline spills because of safety concerns during application and inhibition of evaporation
- Recovery of treated oil may be difficult
- May not be practical in rivers because oil will spread and drift rapidly
- Not effective on heavy oils, which are too viscous to allow the product to mix into the oil

### *Manual Oil Removal/Cleaning*

- Concentrations of heavy oils that have hardened into solid or semi-solid masses can be manually picked up, from boat or shore
- Hand tools can be used to pick up small accumulations of oiled debris
- Operations conducted from boats minimize potential for habitat disruption by trampling onshore

### *Mechanical Oil Removal*

- May be needed to recover large amounts of oil/oily debris trapped in booms or along shore
- Equipment can be operated from barges with less impact; shore-based operations are likely to cause localized disruption of shoreline habitat

### *Probable Adverse Habitat Impact*

#### *Dispersants*

- Inhibit the evaporation of gasoline spills
- Not effective on heavy or weathered oils
- For large spills, limited dilution of dispersed oil in rivers likely to raise toxicity concerns
- Impacts on water intakes downstream would have to be evaluated



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## *Most Adverse Habitat Impact*

### *Herding Agents*

- High currents make proper application difficult and carry product away
- Not applicable to heavy oils because oil must be fluid

### *Insufficient Information*

#### *Nutrient Enrichment and Natural Microbe Seeding*

- Not applicable to gasoline and diesel-like oil spills because they rapidly evaporate
- There is insufficient information on impact and effectiveness for other oil types, particularly for applications in rivers

### 3.4 SMALL LAKES AND PONDS

#### *Habitat Description*

Lakes and ponds are standing bodies of water of variable size and water depth. Waves and currents are generally very low, although the water surface can become choppy. Water levels can fluctuate widely over time, particularly on manmade lakes. Smaller ponds can completely freeze over in winter. The bottom sediments close to shore can be soft and muddy, and the surrounding land can include wet meadows and marshes. Floating vegetation can be common.

The rate of water exchange is highly variable within this group, ranging from days to years. These water bodies can include sections of a river with low flow rates (e.g., behind diversion dams) or that are somewhat isolated from regular flow (e.g., backwater lakes or oxbow lakes). Isolated water bodies, such as kettle lakes, are unique members of this category because they have no surface water outflow, and therefore have very low flushing rates. In shallow water, boat operations would be limited and most response operations would be conducted from shore.

#### *Sensitivity*

Small lakes and ponds have medium to high sensitivity to oil spill impact because of low physical removal rates, limited dilution and flushing of oil mixed into the water column, and high biological and human use. They provide valuable habitat for migrating and nesting birds and mammals, and support important fisheries. Small lakes can be the focus of local recreational activities. Associated wetlands have higher sensitivities and are discussed in Section 3.13.

Wind will control the distribution of slicks, holding the oil against a lee shore or spreading it along shore and into catchment areas. Wind shifts can completely change the location of slicks, contaminating previously clean areas. Thus, early protection of sensitive areas is important. The inlet and outlet are key areas for focusing protection efforts. Oil impacts on floating vegetation depend to a large degree on dose, with possible elimination of plants at high doses. Section 5 addresses sinking oils and response under ice conditions.