NOWPAP MERRAC

Northwest Pacific Action Plan
Marine Environmental Emergency Preparedness and Response
Regional Activity Centre

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UNEP IMO

Guideline for Shoreline Clean-up

MERRAC Technical Report No. 2

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First published in 2005
by Marine Environmental Emergency Preparedness and Response
Regional Activity Centre
the Northwest Pacific Action Plan (NOWPAP MERRAC)
Established at KORDI/MOERI
P.O.Box 23, Yuseong, Daejeon 305-600 Republic of Korea

For bibliographical purposes this document may be cited as:
MERRAC Technical Report No. 2, Guideline for Shoreline Clean-up, NOWPAP MERRAC, 2005.

Foreword

MERRAC, the Marine Environmental Emergency Preparedness and Response Regional Activity Centre, is one of four Regional Activity Centres of the Northwest Pacific Action Plan (NOWPAP) which was adopted in 1994 as a Regional Seas Programme of the United Nations Environment Programme (UNEP) by the People's Republic of China, Japan, Republic of Korea, and Russian Federation. MERRAC is responsible for regional co-operation on marine pollution preparedness and response in the region.

With technical support from the International Maritime Organization (IMO), MERRAC is currently functioning as secretariat for the NOWPAP MERRAC Focal Points Meeting, Expert Meeting, Competent National Authorities Meeting for NOWPAP Regional Oil Spill Contingency Plan (CNA meeting). The Centre also carries out other special activities including the management of a regional information system, organization of training and exercise, capacity building, co-ordination of research and development on the technical aspects of oil spills.

As one of main outcomes of MERRAC activities, the NOWPAP Regional Oil Spill Contingency Plan (the Plan) and its relevant Memorandum of Understanding (MoU) have been developed and officially come into effect as being signed by all NOWPAP Members. The purpose of the Plan is to provide an operational mechanism for mutual assistance through which the Member States will co-operate during major marine oil pollution incidents in the region.

In order to provide practical and technical guidelines to promptly and effectively respond to major oil spill accidents within the framework of the Plan, the 5th MERRAC Focal Points Meeting (MERRAC, Daejeon, 20-24 May 2002) especially agreed to carry out the series of MERRAC specific projects related to oil spill prediction model, sensitivity mapping, oil dispersant, shoreline cleanup, etc.

The documents have been prepared by the Experts Groups, whose members have been officially nominated by the NOWPAP Members and has a profound professionalism in the relevant fields. The 8th NOWPAP MERRAC Focal Points Meeting (MERRAC, Daejeon, 24-27 May 2005) finally reviewed the drafts and then approved to publish them as MERRAC Technical Report series. This technical reports are described the current situation of the relevant subjects and future actions of MERRAC related to relevant subjects. A series of the MERRAC Special Reports to be published in 2005 are as follows:

. Sensitivity Mapping
. Guideline for Shoreline Clean-up
. Guideline for the Use of Dispersants

As Director of MERRAC, I would like to thank the MERRAC Focal Points and all experts of the Expert Groups for their support and contributions to finalizing the MERRAC Technical Reports.

Chang-Gu Kang
Director of MERRAC, November 2005

GUIDELINES ON SHORELINE CLEAN-UP

Table of Contents

Chapter 1

Introduction

In the event of an oil spill, there are a number of options that should be considered to minimize the environmental damages or effects. In summary, there are basically four options: control at source; control or recover oil on water; protection of shoreline; treatment of oiled shoreline. The first line of response, where possible, is to contain and recover the oil at the source or to prevent the oil from reaching the shore zone area using offshore or open-water containment and recovery techniques. Shoreline protection and treatment are the next line of response, next to source control and/or control on water. These guidelines focuses on the treatment or cleanup of shorelines, source control and open-water response are not considered in these guidelines.

Shoreline protection and treatment are not mutually exclusive and may be carried out at the same time. The Decision process for shoreline treatment include: Gather information, Define the objective(s), Develop strategy(ies), Select method(s), Evaluate the feasibility, Prepare a plan, Obtain approval and permits and Implement the plan.

In order to facilitate the cleanup of oiled shorelines, an overview of shoreline protection techniques was included in these guidelines.

These guidelines have been developed to provide practical suggestions for the treatment or cleanup of oiled shorelines by the expert group taking account of the reference materials and the methods has been used in the NOWPAP region. In applying the information presented in these guidelines, it should be recognized that each spill is different from one another and that a wide range of factors must be considered. Of which, the particular importance is the type of oil and volume spilled, as well as the character of the coastal environment and the shoreline type that might be oiled. A wide range of environmental factors taken into account include period of year, weather, and wave conditions, as well as the presence of sensitive resources such as wildlife, fish stocks, plant communities, and commercial or human-use activities. This group of factors should be considered on a case-by-case basis.

1.1 Purpose

These guidelines have been prepared to assist in the selection of appropriate shoreline cleanup or treatment strategies and techniques during an oil spill response. It is designed for use in the field by spill response operations and planning teams in North West Pacific Region.

Emphasis is given to the techniques that are normally available and appropriate for the shoreline types and coastal environmental settings that are typical of NOWPAP region.

1.2 Content

These guidelines includes sections that describe (a) the decision-making process for defining operational objectives and strategies for shoreline treatment or cleanup, (b) overview of shoreline protection strategies, (c) treatment options for nine shoreline types, (d) shoreline treatment and cleanup methods, and (e) response strategies for specific coastal environment, such as tidal inlets, remote areas, and coasts with a high tidal range.

It is rare that only one method or technique is used during a response operation, even on a short section of oiled shoreline. These guidelines recognize this fact and indicate, where appropriate, how a combination of techniques might be used in a given situation. In effect, often there is no single or correct answer to shoreline cleanup or treatment recommendations.

For ease of use, these guidelines have been subdivided into sections as follow:

Chapter 1, Introduction

Chapter 2, Shoreline Protection Overview

During an oil spill event, in order to protect the shoreline or shoreline resources at risk from being polluted, shoreline protection must be carried out. In order to give a necessary introduction, this guide gives a brief overview of shoreline protection methods, which are defined as those techniques that are used nearshore and onshore.

Chapter 3, Shoreline Treatment or Cleanup Strategies

Shoreline treatment involves the use of various physical, biological or chemical techniques to remove or to treat stranded oil, with the primary intention to remove the oil or accelerate the natural recovery of an oiled shoreline.

For selection and evaluation of shoreline treatment and cleanup techniques or methods, guidelines are presented for each of the nine major shoreline types that are typical within NOWPAP region. These guidelines are organized in the context of two general response categories: response options preferred and options to be avoided.

Chapter 4, Shoreline Treatment Methods

Each of 16 treatment or cleanup methods considered most applicable to the NOWPAP region shorelines are described in terms of how the technique would be normally used, and the limitations that should be considered. The methods are described in the context of the shoreline and oil types for which they are appropriate. These methods have been categorized by type of response options, including: removal, washing and in-situ.

Chapter 5, Strategies for Specific Environments

The response methods and strategies described in this guide relate to typical operating conditions. Significant variations may occur from typical conditions, therefore consideration of three specific environmental settings are given to indicate how the overall response strategies may be modified for specific conditions. A fourth situation involving nearshore submerged or sunken oil is discussed, as this often is part of shoreline response operations.

1.3 Shoreline clean-up or Treatment Decision-Making Process

Shoreline clean-up management involves a decision-making process that allows for operational activities to be developed within a set of specified goals. The decision-making process shall follows a sequence of steps including:

- **Gather information or data and assess the situation,**
  - Define regional distribution of oiled shorelines(e.g. aerial survey).
  - Extract data from sensitivity maps and resource databases.
  - Segment shorelines and assess oiling conditions(ground survey).
  - Estimate persistence of stranded oil.
  - Identify ecological/cultural constraints.

- **Define response objective(s),**
  - Set regional cleanup objectives.
  - Define regional treatment priorities,
  - Identify acceptable treatment level.
  - Establish segment treatment objectives and priorities.

- **Develop strategies to meet the objectives,**
  - Develop regional treatment strategy to meet the objectives and priorities.
  - Establish segment treatment strategy(ies) to meet the segment treatment objectives.

- **Select appropriate technique(s) or method(s) to implement the strategy,**
  - Define acceptable and available procedures and techniques that can meet treatment objectives and strategies.

- **Evaluate feasibility of the strategies and methods in view of the environmental conditions and the nature of a spill,**
  - Ientify environmental(physical), ecological, and logistical constraints that might affect the proposed operations.
  - Evaluate the Net Environmental Benefit of the proposed actions.
  - Evaluate the practicality and capacity of the proposed operations and procedures to achieve the segment treatment objectives/ strategies.

- Evaluate the need to redefine an objective or strategy if the original proposed actions cannot be conducted in a safe or effective manner.

- **Prepare an action or response plan,**
  - Develop a long-range regional shoreline treatment/cleanup plan.
  - Prepare individual segment(or group-of-segments) clean-up or treatment plans.

- **Obtain appropriate approvals, permission, or permits and**

- **Implement the field response operation plan.**

These decision-making process should be applied to each specific shoreline unit or segment response objectives, strategies and methods will change alongshore on a segment-by-segment basis depending on the variability of the resources at risk (sensitivity), the risk of oiling(vulnerability), and the shoreline type.

The ultimate goal of a response is to mitigate the effects of spilled oil, and this should be carried out within an organized approach that allows for an evaluation of the feasibility of a desired action plan.

The objectives of response actions for treatment of a shoreline may include: allow the oiled shore zone to recover naturally, restore the oiled shore zone to its pre-spill condition, accelerate the natural recovery of the oiled shoreline, restore the oiled shore with minimal material removal, minimize remobilization of stranded oil during treatment, minimize operational damage to the environment etc.

The treatment objectives can be achieved by the development of a number of specific operational strategies that include: monitor, act quickly to remove oil before it is reworked and/or buried, remove bulk oil - allow residue to degrade, minimize waste generation by in-situ techniques, manual treatment techniques preferred, wetland or marsh treatment strategy, backshore riprap treatment techniques.

The feasibility of a selected shoreline treatment strategy is to be considered in the context of environmental constraints which, both physically and ecologically, may affect the likely success of a proposed activity. Such as access to the shoreline, staging area, machinery using condition, shoreline types, ecological or cultural resources present etc.

The relationship between treatment objectives and strategies are outlined as follow:

Strategies \ Objectives	Allow to recover naturally	Restore to pre-spill condition	Accelerate natural recovery	Restore with minimal material removal	Minimize remobilization of stranded oil	Minimize operational damage
Monitor	√		√			
Remove oil before reworked/ buried		√		√	√	
Remove bulk oil-allow residue to degrade			√	√	√	√
Minimize waste by in-situ techniques preferred			√	√		√
Manual treatment techniques preferred			√	√		√
Wetland treatment strategy			√			√
Riprap treatment techniques			√	√		

1.4 Net Environmental Benefit Analysis (NEBA)

It is recommended to plot environmentally and economically valuable components on shoreline sensitivities maps. The maps constitute the basis for a NEBA of strategies and technique application, i.e. weighing the advantages and disadvantages of chosen strategies for the area depending on the time of year. An NEBA is performed in two phases, including a preliminary analysis at the time when oil spill contingency plans are prepared and a real analysis in the decision-making process during an actual oil spill.

In conducting a preliminary analysis for planning purposes, the following factors must be taken into consideration:

- The list of environmentally and economically valuable components that must be protected on the basis of their priority.
- Seasonal variations of environmentally valuable components.
- The effect of floating and emulsified oil on environmentally valuable components.
- The advantages and disadvantages of different oil spill response techniques.

The preliminary analysis should be used as the basis for plotting areas where cleanup or treatment techniques should not be used at any time of year (Zone 1), areas where they may be used under special conditions on the basis of a real net environmental benefit analysis (Zone 2), and areas where cleanup and treatment technique can be and should be applied at any time (Zone 3) on the environmental vulnerability maps appended to the oil spill response plan.

The NEBA shall be performed by a team consisting of:

- biologists with a good knowledge of the region or area in question;
- oil spill response specialists;
- ecologists;
- experts on the behavior of oil at sea.

The author of the oil spill response plan shall assemble these teams in the planning phase.

Chapter 2

Shoreline Protection Overview

2.1 Objectives

Shoreline protection is defined as those response activities that take p1ace at or near the shoreline, rather than on open water, to protect the shore zone from becoming oiled or to protect vulnerable shoreline resources that are at risk.

The objectives of shoreline protection aim to:

- Prevent oil from making contact with the shore zone or a resource at risk in the shore zone,
- Minimize the degree of oil contact with the shore zone or a resource at risk in the shore zone, direct the oil to sacrificial zones of shore,
- Prevent oil from moving alongshore into adjacent shore-zone areas or adjacent resource at risk,
- Contain oil that has already stranded on the shoreline to avoid remobilization,
- Prevent oil from moving into an inlet or channel,
- Avoid causing more damage in responding to the spill than the oil itself would do,
- Use available resources in a safe, efficient, and effective manner,
- Minimize generation and handling of waste materials.

2.2 Strategies

Shoreline protection objectives can be achieved by developing strategies as follow:

Contain/Recover Oil on Water
Divert a moving direction of spilled oil on water surface
Prevent Oil Movement in Channel
Trap or Contain & Collect Oil at Shoreline
Prevent Remobilization
Prevent Overwash into Backshore/Lagoon
Pre-impact Debris Removal

The decision process used to develop appropriate strategies that can be employed to achieve these objectives outlined in 2.1 is described in following table.

Objectives / Strategies	Prevent contact	Minimize degree of contact	Prevent alongshore movement of oil	Contain stranded oil at shoreline	Prevent oil transport into inlet, channel
Contain/recover oil on water	√	√	√		√
Divert a moving direction of spilled oil on water surface	√	√	√		√
Prevent oil movement in channel		√	√		√
Trap or contain & collect oil at shoreline			√	√	√
Prevent remobilization			√	√	√
Prevent overwash into backshore/ lagoon		√		√	
Pre-impact debris removal			√	√	

2.3 Shoreline Protection Methods

The common shoreline protection methods or response action to achieve shoreline protection objectives can be divided into two groups, i.e., nearshore protection and onshore protection.

2.3.1 Nearshore Protection Overview

The purpose of nearshore protection is to prevent oil from making contact with a shoreline or a sensitive area along a shoreline.

Nearshore protection is typically used when offshore oil containment and recovery activities are not available or sufficient enough to control the entire spill. Similar protection techniques can be implemented in the offshore and nearshore zones of the shoreline, but distinctions should be made between the three types of environment on the basis that :

(a) onshore protection involves work to be conducted on land for protection of the shore zone,
(b) nearshore protection has at least one component on the water, and
(c) offshore techniques are applied on open waters rather than in areas adjacent to the coast or in sheltered bays and estuaries.

Nearshore protection can involve passive techniques such as exclusion or deflection booming, or active techniques such as skimming, in situ burning, dispersants, and, to some extent, diversion booming.

The nearshore protection activities involves consideration of several factors that include:

- Net Environment Benefit Analyze and prioritization,
- Technique selection,
- Logistics analysis, and
- Timing with respect to oil movement.

The nearshore protection techniques applicable to NOWPAP region shorelines are briefly described in Table 2-1.while such techniques to scenarios of various wave heights and current speeds are further provided in Figure 2-1.

Table 2-1. SUMMARY OF NEARSHORE PROTECTION TECHNIQUE

Nearshore Protection Techniques	Primary Use	Technique Description	Potential Environment Effects
A. Containment Booming	Used in nearshore waters with wave height less than 2 m to surround and contain portions of an approaching oil slick.	Boom is deployed in a "U" shape in front of the oncoming slick. The ends of the boom are anchored by work boats or drogues. The oil is contained within the "U" and prevented from reaching the shore.	No significant effects.
B. Exclusion Booming	Used across small bays, harbor entrances, inlets, rivers, or creek mouths where currents are less than 0.5m/s and breaking waves are less than 50 cm in height.	Boom is deployed across or around sensitive areas and anchored in place. Approaching oil is deflected or contained by boom.	Minor disturbance to substrate at shoreline anchor points.
C. Deflection Booming	Used to deflect oil away from relatively small sensitive areas where alongshore currents exceed 0.5 m/s, breaking waves are less than 50 cm, or available boom is insufficient to exclude oil from the area.	Boom is deployed from the shoreline away from the approaching slick and anchored or held in place with a work boat. Oil is deflected away from shoreline.	Minor disturbance to substrate at shoreline anchor points.
D. Diversion Booming	Used across small bays, harbor entrances, inlets, river, or creek mouths where currents exceed 0.5m/s and breaking waves are less than 50 cm, and on straight coastline areas to protect specific sites, where breaking waves are less than50 cm.	Boom is deployed from the shoreline at an angle towards the approaching slick and anchored or held in place with a work boat. Oil is diverted towards the shoreline for recovery.	Minor disturbance to substrate at shoreline anchor points and can cause heavy shoreline contamination at downstream end of boom.

E. Skimming	Used in nearshore waters with wave height less than 2 m to recover all or portions of an approaching oil slick. Also used independently or in conjunction with containment booming.	Self-propelled skimmers work back and forth along the leading edge of a windrow to recover the oil. Booms may be deployed from the front of a skimmer in a "V" configuration to increase sweep width.	No significant effects.
F. In situ Burning	Used in nearshore waters with wave height less than 2 m to contain all or portions of an approaching slick and dispose of an approaching slick through burning.	Fire-proof boom is deployed in a "U" shape in front of oncoming slick. The contained oil is towed away from the slick and ignited while still within the boom.	Localized air quality degradation and possible adverse effects on near surface organisms from increased water temperature.

Figure 2-1. NEARSHORE PROTECTION TECHNIQUE APPLICABILITY MATRIX

Key ● Applicable ○ May Be Applicable ✕ Usually Not Applicable — Not Applicable	Water Depths > 20 M						Water Depths < 20 M					
	Wave Heights>2m	Wave Heights<2m	Breaking Height>1m	Breaking Height<1m	Current/Vessel Speed>0.5m/s	Current/Vessel Speed<0.5m/s	Wave Heights>2m	Wave Heights<2m	Breaking Height>1m	Breaking Height<1m	Current/Vessel Speed>0.5m/s	Current/Vessel Speed<0.5m/s
Containment Booming	✕	●	✕	●	✕	●	✕	●	○	●	✕	●
Exclusion Booming	—	○	—	○	—	○	—	●	✕	●	✕	●
Deflection Booming	—	○	—	○	✕	○	✕	●	✕	●	○	●
Diversion Booming	—	○	—	○	✕	○	✕	●	✕	●	○	●
Skimming	✕	●	✕	●	○	●	✕	●	○	●	○	●
Dispersants	●	○	●	○	○	○	—	—	—	—	—	—
Gelling Agents	○	○	✕	○	○	○	—	—	—	—	—	—
In Situ Burning	—	●	—	●	✕	●	—	●	✕	●	✕	●

2.3.2 Onshore Protection Overview

The purpose of onshore protection is to minimize the effect of oil that makes contact with a shoreline or a sensitive area along a shoreline.

Onshore protection involves techniques or methods that can be employed to minimize the degree or extent of oil that makes contact with a shoreline. The techniques are typically implemented along a shoreline or across narrow tidal inlets. Onshore protection is considered the last line of defense next to offshore protection and nearshore protection, and it is usually implemented only if one or both of the other options are not feasible or have not been completely successful.

Onshore protection involves passive techniques such as beach berms, dam, geotextiles, sorbents or sorbent barriers. While carrying out onshore protection, several factors have to be considered that include:

- Sensitivity analysis and prioritization,
- Technique selection,
- Logistics analysis, and
- Timing with respect to oil movement.

The onshore protection techniques that could apply to NOWPAP region shorelines were briefly described in Table 2-2. And the applicability of such protection techniques to various shoreline conditions including wave height at the shoreline, sediment type, the presence of logs and shore-zone slope, is provided in Figure 2-2.

Table 2-2. SUMMARY OF ONSHORE PROTECTION TECHNIQUES

Onshore Protection Techniques	Primary Use	Technique Description	Potential Environment Effects
Beach berms	Used on fine-grained sediment, low-energy beaches to prevent or minimize oil from reaching the upper intertidal zone.	A berm is constructed along the top of the mid-intertidal zone from sediments excavated along the downgradient side. The berm should be covered with plastic or geotextile sheeting to minimize wave erosion.	Disturbs upper 50-60 cm of mid-intertidal zone.
Inlet Dams	Used in relatively small tidal inlets, stream channels, or other narrow waterways.	A dam is constructed across the channel using local soil or beach sediments to exclude oil from entering channel.	Disturbs channel substrate and adds suspended sediments to water. Can be harmful to landward biota dependent on the periodic flushing.
Culvert Blocking	Used to block tidally influenced culverts to prevent oil from passing through and reaching back water areas.	Sandbags, wood sheeting, earth, or sediments are placed in front of the culvert opening to seal it off and prevent oil or water from entering.	Disturbs channel substrate and can be harmful to landward biota dependent on the periodic flushing.
Geotextiles	Used to high-energy shorelines to protect log piles or sediments in the supra-intertidal zone from oil splash	A roll of geotextile, plastic sheeting, or other impermeable material is spread along the bottom of the supra-tidal zone and fastened to the underlying logs or stakes placed in the ground.	No significant effects.
Sorbent Barriers	Used in relatively small tidal inlets, stream channels or other narrow waterways with low current velocities to exclude and recover oil.	A barrier is constructed by installing two parallel lines of stakes across a channel, with wire mesh fastened to the stakes and the in-between space filled with loose sorbents.	Minor disturbance of inlet or channel substrate.

Figure 2-2. Onshore Protection Technique Applicability Matrix

Key:

● Applicable

○ May Be Applicable

× Usually Not Applicable

— Not Applicable

	Steep or Inclined Shoreline							Low Angle or Flat Shoreline						
	Breaking Wave Heights>1m	Breaking Wave Heights>1m	Fine-Grained substrates (Mud, sand, Gravel)	Coarse-Grained substrates (Cobble, Boulder, Rock)	Tidal Inlet	Tidally Influenced Streams	Log Pile In Supra-Tidal Zone	Breaking Wave Heights>1m	Breaking Wave Heights>1m	Fine-Grained substrates (Mud, sand, Gravel)	Coarse-Grained substrates (Cobble, Boulder, Rock)	Tidal Inlet	Tidally Influenced Streams	Log Pile In Supra-Tidal Zone
Beach Berms	—	×	○	—	—	—	—	×	●	●	—	—	—	—
Dams	—	—	—	—	●	○	—	—	○	—	—	—	○	●
Culvert Blocking	●	●	●	●	●	○	—	●	●	●	●	●	●	●
Geotextiles	●	●	○	○	—	—	●	—	—	—	×	—	—	—
Sorbent Barriers	—	×	○	—	●	●	—	×	●	●	●	●	●	—

Chapter 3

Shoreline Treatment or Cleanup Strategies

In this section, attention is focused on appropriate strategies for different shoreline types. The northwest Pacific region has a wide variety of shoreline types. In order to present cleanup strategies for oiled shorelines, nine shoreline types have been defined; each of these is defined and described in the following sections.

- Impermeable or solid shorelines have no surface sediments are stable, and oil will not penetrate below the surface layer, whereas;
- Permeable or unconsolidated shorelines contain organic or inorganic sediments are mobile, and oil can penetrate into or be buried below the surface materials.

For permeable shorelines, the size of the materials and the primary coastal landform are used to further subdivide shoreline types.

At many locations, more than one shoreline type may be present, for example, pebble-cobble sediments on a bedrock platform, or an intertidal mud flat that gives way to a salt marsh. In terms of the fate and behavior of stranded oil and for treatment or cleanup decisions, these different components of the coast are treated separately.

3.1 Objectives

Shoreline treatment or cleanup involves the use of various physical, biological, or chemical techniques to remove or to treat stranded oil with the primary intention being either to remove the oil or to accelerate the natural recovery of an oiled shoreline.

The decision process for shoreline treatment or cleanup is described in section 1.3. The objectives of a response that involves the cleanup of oiled shorelines can include actions that:

- allow the oiled shore zone to recover naturally,
- restore the oiled shore zone to its pre-spill condition,
- accelerate the natural recovery of the oiled shoreline,
- restore with minimal material removal,
- minimize remobilization of stranded oil during cleanup,
- minimize operational damage to marsh systems,
- avoid causing more damage in responding to the spill than the oil alone would cause,
- use available resources in a safe, efficient, and effective manner,
- minimize the generation and handling of waste materials.

For each shoreline type, the shore-zone character and the likely oiling conditions are described briefly. This is followed by recommendations on:

(1) what to do that is practical to minimize damage (from the oil and from the response operations), and
(2) what to avoid for safety reasons and to minimize damage.

3.2 Shoreline Treatment or Cleanup Strategy by Shoreline Type

3.2.1 Bedrock

3.2.1.1 Oil on bedrock

- Bedrock is impermeable so that stranded oil remains on the surface.
- A zonation of plants and animals in the intertidal zone is common on sheltered bedrock outcrops. This is particularly true on exposed bedrock shorelines with steep slopes. Where present, biological communities usually are more prolific in the subtidal or lower intertidal zones and would be more affected by:
  a) Large amounts of oil rather than small oil concentrations, and;
  b) Light refined oil (diesel, No.2,etc.) rather than heavy oil products (bunker fuels) or weathered crudes.
- The lower half of the intertidal zone in bedrock areas usually stays wet, or even exposed, so that oil often would not adhere to the rock or plants.
- Oil is more likely to be deposited in the upper half of the intertidal zone:
  - Viscous or weathered oils would smother organisms in this zone and likely would have a lesser impact on biological communities present in the lower intertidal zone;
  - Light products or fresh crudes could easily flow downslope into the lower intertidal zone and could affect biological communities, often upon contact, due to the higher level of toxic components in these oil types.
- Mature plants and animals can only develop in cracks and crevices, the same locations where oil might deposit, and persist, because they are protected from wave action.

Exposed coasts

- On exposed coasts, oil often does not strand due to wave reflection. If stranded, the oil may be washed off rapidly (days to weeks) by wave action.
- Oil may be splashed above the limit of normal wave action.
- On platforms or ramps, oil may collect in hollows or tidal pools.

Sheltered coasts

- Where oil comes ashore in sheltered locations, it is likely to be deposited on the upper intertidal zone as a band near the last high water level.
- Because of the relatively low wave-energy conditions, heavy oils or weathered crudes may persist for some considerable time (years), as there is insufficient energy to naturally remove these types of oil.

- Light oils likely would be washed off the bedrock in a short time (days to weeks).

3.2.1.2 Preferred response options

- Natural recovery is the preferred option on exposed coasts, particularly early in the open-water season. This method is less appropriate for heavy oils, weathered crudes on a sheltered coast where the oil is likely to persist longer. It may not be appropriate immediately prior to freezeup as the oil would be encapsulated by ice and potentially remobilized during the next thaw.
  Shoreline treatment or cleanup would be carried out when factors other than ecology alone are considered in the decision-making process.
- For light, volatile oils, such as gasoline, no action is the safest option. If there is a need to remove this such oils, it can be done by one of the cold-water washing techniques, preferably from a safe distance (fumes, ignition, and flashback are factors to consider for safety).
- Flooding is appropriate for light oils, such as diesel, but is of little practical value for very viscous or semi-solid oils.
- Physical washing can be practical and efficient for oil on bedrock or ice surfaces provided that air temperatures are not so low that the water freezes.
- Low-pressure, cold water washing of light and some medium oils can minimize ecological impacts (see below for applications to avoid). If water depths allow, washing directly from a boat or barge can avoid damage to shore-zone organisms by foot traffic. Removed oil should be contained and collected by booms and sorbents or skimmers.
- High-pressure, cold water washing and low-pressure, warm/hot water washing may be useful for more viscous oils that cannot be removed by low-pressure, cold water washing.
- Manual removal of medium and heavy oils is recommended for small amounts of oil, but foot traffic should be minimized in areas where organisms could be crushed or trampled.
- It may be appropriate in some instances to cut oiled vegetation where there is extensive oiling of plants. Note: cut the oiled parts rather than pull up the whole oiled plants.
- Hand-deployed vacuum systems can be effective to remove light (e.g., diesel) or medium/heavy oils collected in tidal pools and hollows. Foot traffic should be avoid crushing or trampling organisms. This technique, for safety reasons, is not applicable to gasoline.
- Sorbents can be deployed to collect light and medium oils passively. Foot traffic should avoid crushing or trampling organisms. Sorbents are recommended for small amounts of oil.
- Dispersants can be used on a flooding tide on oil types for which the product is designed. Dispersants can be effective for small amounts of oil if applied correctly. Use of an approved product requires permission from the relevant

authorities.
- Shoreline cleaners can be used in conjunction with flooding or low-pressure washing to remove and collect the oil.

Typical Combinations of Response Methods

- Manual removal of oiled debris followed by manual removal using hand tools, vacuum, or sorbents in tidal pools (be careful not to trample organisms).
- Flooding and low-pressure washing combined with collection and recovery.
- Shoreline cleaners can be used in conjunction with flooding and/or low-pressure washing and oil collection and recovery.

3.2.1.3 What to Avoid

- On steep bedrock outcrops, great care should be exercised to avoid falls and slips, particularly on exposed shorelines (open coasts) where there is strong wave action or ice.
- In areas where there are plants (seaweeds) and animals (barnacles, mussels, etc.) in the shore zone, avoid washing oil from the upper to lower intertidal zones. Frequently the lower intertidal zones are not oiled and more damage can be caused by cleanup if oil is washed downslope or if foot traffic leads to trampling. This possible damage can be avoided by working only within the upper half of the tidal cycle (during the flooding tide from mid-tide to high-tide and during the ebb to mid-tide) so that the lower tidal zones are always under water.
- High-pressure, warm/hot water washing (including steam cleaning and sandblasting) should be avoided as this can also remove healthy organisms. Spot washing may be of value to remove oil if no organisms are present, or if the oil already had smothered or killed the biological community. Removal of the plants and animals, even if killed by the oil, may delay recolonization due to habitat modification.
- Avoid spraying freshwater on intertidal communities.
- Avoid vegetation cutting if at all possible, as it may kill the plants and remove the protective corer for smaller organisms and wildlife.

3.2.2 Man-Made Structures

3.2.2.1 Oil on Man-made Structures

- These shoreline types are very similar to bedrock shorelines in most respects, in particular, the substrate is impermeable so that stranded oil remains on the surface.
- Examples of solid man-made structures include retaining walls, harbor walls, and solid breakwaters. Permeable man-made structures, such as riprap breakwaters, are considered in the context of the size of the material used for construction.

- Special attention must be paid to historic structures that may be or have been oiled, and/or archeological or historic sites in backshore areas.
- Solid man-made structures can include a wide range of materials such as concrete, metal, and wood. Each of these materials has a different surface texture and roughness. It happens that one type of oil may not stick to a smooth, sloping metal surface, but may stick to a vertical, rough concrete surface.
- The lower half of the intertidal zone usually stays wet, particularly where weeds are present. Oil often would not adhere to the wet surface. Oil is more likely to be deposited in the upper half of the intertidal zone.
- The biological communities here generally are not so rich when compared to bedrock shorelines, for the surface area is usually steeper and smoother that there is less room for organisms to attach.

Exposed Coasts

- On exposed coasts, oil often does not strand due to wave reflection. If stranded, the oil may be washed off rapidly (days to weeks) by wave action.
- Oil may be splashed above the limit of normal wave action.
- On sloping surfaces or ramps, oil may collect in hollows.

Sheltered Coasts

- Where oil comes ashore in sheltered locations, it is likely to be deposited as a band near the last high-tide level.
- Because of the low wave-energy conditions, heavy oils or weathered crudes may persist for a considerable time (years), as there is insufficient energy for natural removal.
- Light oils likely would be washed off the surface of most man-made structure in a short time (days to weeks).

3.2.2.2 Preferred Response Options

- Natural recovery is the preferred option on exposed coasts. This method is less appropriate for heavy oils or weathered crudes on a sheltered coast where the oil is likely to persist longer. It may not be appropriate immediately prior to freeze up as the oil would be encapsulated by ice and potentially remobilized during the next thaw.
- Flooding is appropriate on sloping surfaces for light oils, such as diesel, but is of little practical value for heavy or semi-solid oils.
- Physical washing can be practical and efficient for oil on man-made solid shorelines and shore fast ice.
- The cleaning of historic structures, such as old wooden or stone work, must be treated on a case-by-case basis. Cleaning should only be conducted after appropriate consultation with authorized agencies.
- Low-pressure, cold water washing of light and some medium oils can

minimize ecological impacts (see below ***what to avoid***). Man-made surfaces often are steep so that washing from a boat or barge is preferred if water depths allow. Oil should be contained and collected by booms and sorbents or skimmers.

- High-pressure, warm/hot water washing and low-pressure, warm/hot water washing may be useful for more viscous oils that cannot be removed by low-pressure, cold water washing.
- High-pressure, warm/hot water washing techniques, with the spray nozzle held only 10 cm from the oiled surface, have been used successfully to remove viscous oils on historic stonework and plaster.
- On surfaces where no organisms are present, such as on ice-scoured man-made surfaces, high-pressure washing techniques, steam cleaning or sandblasting may be appropriate.
- Manual removal of medium and heavy oils is recommended for small amounts of oil, but foot traffic should be minimized in areas where organisms could be crushed or trampled.
- Sorbents can be deployed to collect light and medium viscosity oil passively. This is recommended for small amount of oil.
- Dispersants can be used on oil types for which the product is designed. Dispersants can be effective for small amounts of oil if properly applied. Use of an approved product requires permission from relative authorities.
- No action is the safest option for light, volatile oils, such as gasoline. If there is a need to remove this type of oil it can be done by one of the cold-water washing techniques, preferably from a safe distance (fumes, fire, and flashback are factors to consider for safety).

Typical Combinations of Response Methods

- Shoreline cleaners can be used in conjunction with flooding or low-pressure washing to remove and collect the oil.

3.2.2.3 What to Avoid

- On steep or shelving man-made solid structures, great care should be exercised to avoid falls and slips, particularly on open coasts where there is strong wave action.
- In areas where there are plants (seaweed) and animals (barnacles, mussels etc.) in the intertidal zone, avoid washing oil from upper to lower intertidal zones. Frequently the lower intertidal zones are not oiled and more damage can be avoided by working only within the upper half of the tidal cycle (during the flooding tide from mid-tide to high-tide and during the ebb to mid-tide) so that the lower tidal zones are always under water.
- High-pressure, warm/hot water washing (including steam cleaning and sandblasting) should be avoided where healthy organisms are present. On surfaces where organisms are present, these techniques may be of value for spot washing if the oil has already smothered or killed the biological

community. Removal of the plants and animals, even if killed by the oil, may delay recolonization due to substrate modification.
- High-pressure, warm/hot water washing techniques on historic stonework and plaster may be appropriate provided that abrasives and chemicals are avoided.

3.2.3 Sand Beaches

3.2.3.1 Oil on Sand Beaches

- Sand beaches are permeable for some medium and all light oils, and have a very dynamic, mobile, unstable surface layer.
- There is some distinction between fine- and coarse-grained sand beaches:
  - Coarse-sand beaches (sediment diameter 0.5 to 2 mm), usually have steeper slopes and poorer bearing capacity, whereas;
  - Fine-sand beaches (sediment diameter less than 0.5 mm), have flatter slopes and are harder with better traction for vehicles.
- Granules (sediment diameter 2 to 4 mm), are–usually considered “coarse sediments”.
- Even relatively little wave action (e.g., wave heights of 10 to 30 cm) can easily change the surface level on a sand beach by as much as 10 cm in one tidal cycle. Large waves, as would be expected during storms, can lower or raise a beach surface by as much as 1.0 m in a few hours. These processes can result in erosion, mixing or burying oil.stranded.
- Sediment supply to sand beaches is highly dependent on local resources and supply conditions.
- Pore spaces are small, which restricts oil penetration. Medium and heavy oils are unlikely to penetrate more than 25 cm. Sand can be very mobile on exposed coasts, and even in sheltered areas provided there is minor wave action. Burial and/or mixing can occur both easily and quickly.
- Light oils may readily penetrate a medium- or coarse-grained sand beach and mix with ground water. Light oils also can be refloated and transported by tidal change of water levels.
- Oil less likely stay stranded in the lower intertidal zones as these areas remain wet due to backwash and ground water flowing out of the beach. All but highly viscous or dense oils would be refloated and carried up to the beach by a raising tide and concentrated on the upper beach.
- Traction is usually good on sand beaches for most types of vehicles, but traction can be a problem in the lower intertidal zone, with water-saturated sediments, or above the normal intertidal zone, because of soft wind-blown sands. Reduction of tire pressure can partially compensate for low bearing capacity.
- Only a relatively few species of mobile (burrowing) animals can live in this unstable environment. Biological productivity is generally low, except in protected, low wave-energy environments.

3.2.3.2 Preferred Response Options

- Natural recovery is recommended for small spills, light oils, or on exposed coasts and/or in remote areas. It may not be appropriate immediately prior to freeze up as the oil would be encapsulated by ice and potentially remobilized during the next thaw. Release of oil may be acceptable in fall or winter months (the die-back phase of vegetation when there is strong storm-wave action) and less acceptable during spring and summer growth periods.
- Flooding and low-pressure cold-water washing can remove light and medium oils. This technique becomes ineffective as the oil viscosity, penetration, or burial increase.
- Manual removal is preferred for medium and heavy oils, as little non-oiled material is removed. Effectiveness decreases as the area of oiled sediments increases or where oil has become buried or reworked into the sediments. Straight-edge shovels are more effective than pointed shovels for removing or scraping surface oil on a sand beach.
- Mechanical removal often is appropriate for long sections of beach where the oil is present in high concentrations and is on the beach surface. The removal of oil that has been reworked or buried can involve large volumes of material with low concentrations of oil.
- Graders are the preferred heavy equipment as they can scrape only a thin layer of oiled sand. Front-end loaders have less accuracy in terms of the depth of cut and bulldozers should only be used as a last resort. Windrows made with graders can be removed by front-end loaders.
- Factors in the decision process to select manual and mechanical removal techniques include:
  - Size of the area to be cleaned,
  - Time available for cleanup, and
  - Amount of oiled sediment that requires handling, transfer, and disposal.
- Sorbents may be useful to collect oil as it washes ashore. Their effectiveness decreases with increasing oil volumes. Use of large amounts of sorbent material can generate a waste disposal problem.
- Tilling/aeration, sediment reworking, or surf washing can accelerate weathering of light oils. Surf washing, in particular, may be an important polishing step for stained sands that remain after other treatments such as removal of bulk oil have been completed.

Typical Combinations of Response Methods

- Flooding or floating oil into lined collection trenches or sumps dug by a backhoe, followed by recovery with vacuums or skimmers.
- Mechanical removal followed by surf washing.

3.2.3.3 What to Avoid

- Excessive removal of sediment is probably the greatest concern on this type of beach, as natural replacement rates can be slow in many areas. Excessive removal could lead to retreat of the beach (i.e., erosion).
- Treatment or cleanup activities should be designed to avoid mixing clean and oiled sediments. In particular, mixing oil into clean subsurface sediments should be avoided except as part of a planned tilling/aeration or surf washing strategy.
- Oil-in-sediment concentrations typically are low, which means that mechanical or manual sediment removal methods can generate a large volume of lightly oiled waste, which will then require transfer and disposal.
- The spillage from graders can increase when more than two passes are made to side cast oiled sediments. If more than one machine is used, these should generate separate windrows rather than try to move windrows successively up a beach.
- Avoid tracking oil into clean areas. Vehicles and personnel should always work from a clean towards an oiled area to avoid cross-contamination.
- During manual cleanup, avoid over-filling collection bags or containers to minimize spillage and to prevent bags or containers from breaking.

3.2.4 Mixed-Sediment Beaches

3.2.4.1 Oil On Mixed-Sediment Beaches

- Mixed-sediment beaches are composed of sands, granules, pebbles, and cobbles and also may be referred to as “gravel beaches”. The surface layer often has predominantly coarse sediments with increasing amounts of sand in the subsurface. Boulders may be scattered on the beach surface.
- The coarser fractions (pebbles and cobbles) are infilled with the finer sands and granules so that these beaches are permeable only for some medium oils and all light oils, and have a dynamic, mobile surface layer.
- From an oil fate and persistence perspective (for example, in terms of penetration of oils), this beach type is similar to a sand beach, but for response operations (in terms of bearing capacity and cleanup techniques), this beach type is more like a pebble-cobble beach.
- Depth of oil penetration is primarily a function of the oil type (viscosity). Depth of burial or reworking of oiled sediments is primarily a function of wave-related beach erosion and recovery processes.
- Light oils may readily penetrate a mixed-sediment beach with medium- or coarse- grained sand beach and mix with ground water and /or be transported by changing tide levels.
- Medium or heavy oils penetrate a mixed-sediment beach less readily than a coarse-sediment beach. However, oil that penetrates is more likely to be retained in the subsurface of a mixed-sediment beach.
- Usually only the surface layer of sediments is reworked by normal wave

action. Oil that penetrates below the surface may not be physically reworked except during infrequent, high-energy storms.

- Oil is less likely to stay stranded in the lower beach zones as these remain wet due to wave action and ground water flowing out of the beach. All but lightly viscous or dense oils would be refloated and carried up to the beach by a rising tide; as a result, oil is more likely to concentrate on the upper intertidal zone.
- Oil residence time or persistence is primarily a function of the oil type, depth of penetration or burial, and wave-energy levels on the beach.
- Asphalt pavements commonly form in upper-or supra-intertidal zones where weathered medium and heavy oils form a stable oil-sediment conglomerate.
- Few animals or plants can survive the continuous reworking of the coarse sediments, so that <u>exposed</u> beaches support little life, particularly in the upper intertidal zone. Sediments in the lower sections of the beach or in sheltered wave environments tend to be more stable and organisms are more likely to be present in this zone.
- This beach type typically has a steep section in the upper half of the intertidal zone and the coarse sediments provides poor traction for vehicles and sometimes for workers. Similarly, in river channels, the bank edges frequently are steep due to undercutting by stream flow.
- Supply of the coarse sediments to this type of beach is usually a very slow process. In most cases, oiled sediment that is removed may be replaced only at a very slow rate (decades), or not at all.

3.2.4.2 Preferred Response Options

- Natural recovery may be an acceptable option for small spills, light oils, or on exposed coasts and/or in remote areas. It may not be appropriate immediately prior to freeze up as the oil would be encapsulated by ice and potentially remobilized during the next thaw.
- Flooding is a non-intrusive technique that can wash mobile oil from surface sediments and light oil from surface and subsurface sediments for collection. Effectiveness decreases with increasing viscosity and stickiness of oil and usually is low for buried oil or oiled sediments
- Low-pressure, cold water washing can flush mobile oil from surface and surface sediments for collection. This is more effective for viscous oils than flooding, but effectiveness decreases with increasing viscosity and stickiness of oil and with burial.
- Manual removal can minimize the amount of oiled and un-oiled sediment that is recovered and can be appropriate for removal of surface oiled sediments. This technique is not very practical for deeply penetrated or buried oil. It is appropriate for removing asphalt pavement patches, tar patties, and small size oiled debris. Practicality decreases as the amount of oiled shoreline or sediment increases. Pointed shovels are more effective than straight-edge shoves for removing oiled sediments–on mixed sand,

pebble, cobble beaches.
- Mechanical removal can be effective if a large amount of semi-solid oil is to be recovered. Equipment that removes as little un-oiled sediment as possible is recommended. Because of the generally poor bearing capacity of this type of sediment, front-end loaders would be the equipment of choice, with a backhoe as an alternative. In most cases, it is appropriate to seek advice from a geologist on how much material can be removed safely from a mixed-sediment beach without sediment replacement.
- Sorbents may be useful for recovering small volumes of light and medium oils.
- Sediment reworking or surf washing would be appropriate on exposed coasts after any mobile oil has been removed or for small amounts of oiled sediment. This technique is dependent upon the availability of wave energy to abrade, redistribute, and replace the sediments or on the presence of fines (clays ,silts) to remove oil.

Typical Combinations of Response Methods

- Flooding with trenches or sumps to collect oil that is floated can be used in combination with vacuum systems to recover the oil.
- Mechanical tilling or aeration followed by surf washing and/or bioremediation.

3.2.4.3 What to Avoid

- Excessive removal of coarse sediment is probably the greatest concern on this type of beach, as natural replacement rates usually are very slow (decades). This can lead to retreat of the beach (i.e., erosion).
- Oil-in –sediment concentrations usually are very low, which means that mechanical or manual sediment removal methods generate a large volume of waste that contains a relatively small amount of oil.
- If attached animals or plants are present in the unoiled lower tidal zones, flushing or sediment reworking techniques should avoid spreading oil onto those areas.
- Avoid flushing techniques that only move the oil deeper into the sediments without flushing the oil out of the beach for recovery. Warm or hot water may temporarily mobilize viscous oil which could then move downslope or deeper into the beach. The loss of heat as the oil moves through the beach, or as it makes contact with cool or cold ground water, may cause the oil to be redeposited at a lower level in the beach.

3.2.5 Pebble-Cobble Beaches

3.2.5.1 Oil on Pebble-Cobble Beaches

- Pebble-cobble beaches (known also as “coarse-sediment beaches”) are permeable to all but the semi-solid oils, and have a dynamic, mobile, unstable surface layer. Boulders may be scattered on the beach surface.

- Pebbles have a grain-size diameter of 4-64mm; cobbles are in the 64-256mm range
- Pebble –cobble beaches include some permeable man-made structures, such as riprap or sand-bag walls, with material in the size range of 2 to 256 mm, the materials are defined as boulders.
- Granules (sediment diameter 2 to 4 mm) usually are included in the pebble category.
- Pebble–cobble beaches are distinguished from mixed-sediment (sand-gravel) beaches as the interstitial or pore spaces between the individual pebbles or cobbles are open, rather than being filled by sand. Stranded oil can more easily penetrate into the subsurface sediments on pebble-cobble beaches, but less easily on mixed-sediment (sand-gravel) beaches.
- Depth of oil penetration is a function of the oil type (viscosity) and the sediment size. The larger the particle size, the easier it is for oil to penetrate. However, retention also is relatively low so that the oil can be flushed naturally from these coarse sediments.
- Oil is less likely to stay stranded in the lower intertidal zone as this remains wet due to backwash and ground water flowing out of the beach. All but highly viscous or dense oils would be refloated and carried up to the beach by a rising tide. Oil, therefore, is more likely to concentrate on the upper beach.
- Oil-in-sediment amounts (by weight or by volume) are usually very low, often less than 1% unless the oil is pooled or very thick.
- Oil residence time or persistence is primarily a function of the oil type, depth of penetration, retention factors, and wave- or stream- energy levels on the beach.
- Light or non-sticky oils may be easily flushed out of the surface or subsurface sediments by tidal pumping.
- Usually, only the surface layer of sediments is reworked by normal wave action. Oil that penetrates below the surface may not be physically reworked except during infrequent, high-energy storms or run-off events.
- Few animals or plants can survive the continuous reworking of the sediments, so that exposed beaches support little life, particularly in the middle and upper intertidal zones. Sediments in the lower sections of the beach or in sheltered wave environments tend to be more stable and organisms are more likely to be present.
- This beach type typically is characterized by a steep section in the upper half of the intertidal zone that provides poor traction for vehicles and sometimes for cleanup workers. Similarly, In river channels, the bank edges frequently are steep due to undercutting by stream flow
- Sediment supply to this type beach usually is very slow. Oiled sediment that is removed may be replaced only at a very slow rate (decades), or not at all.

3.2.5.2 Preferred Response Options

- Natural recovery is preferred, particularly for small spills of light oils, or on exposed coasts and/or in remote areas. It may not be appropriate immediately prior to freeze up as the oil would be encapsulated by ice and potentially remobilized during the next thaw.
- Flooding is a non-intrusive technique than can flush mobile oil from surface and subsurface sediments for collection. Effectiveness decreases with increasing viscosity and stickiness.
- Low-pressure, cold water washing can flush mobile oil from surface and subsurface sediments for collection. This is more effective increasing viscosity, stickiness, and depth of penetration.
- Manual removal can minimize the amount of oiled and un-oiled sediment that is collected and can be appropriate for removal of surface oiled sediments. This method is not very practical for deeply penetrated or buried oil. It is appropriate for removing asphalt pavement patches, tar patties, and small-size oiled debris, but the practicality decreases as the amount of oiled shoreline or oiled sediment increases. Pointed shovels are more practical than straight-edge shovels for removing oiled pebbles and cobbles.
- Mechanical removal can be effective if a large amount of semi-solid oil is to be recovered. Equipment that removes as little un-oiled sediment as possible is recommended. Because of the generally poor bearing capacity of sediment, front-end loaders would be the equipment of choice, with a backhoe as an alternative. In most cases, it is appropriate to seek advice from a geologist on how much material can be removed safely from a pebble-cobble beach without sediment replacement.
- Sorbents may be useful for recovering small volumes of light and medium oils.
- Mechanical tilling or aeration would be appropriate for light oils in surface or subsurface sediments. This method can be used in combination with surf washing.
- Sediment reworking or surf washing would be appropriate on exposed coasts after any mobile oil has been removed. It is useful also for small amounts of oiled sediment. This approach minimizes the possibility of erosion. It may be appropriate for oil that has penetrated or become buried. Sediment reworking is dependent upon the availability of mechanical wave energy to abrade, redistribute, and replace the sediments. Surf washing in low wave-energy environments requires mechanical energy or the presence of fines (clays and silts) to remove oil.

Typical combinations of Response Methods

- Removal of oiled debris followed by manual removal, vacuums, or use of sorbents on surface oil patches.
- Flooding and low-pressure washing.
- Tilling or aeration followed by surf washing and/or bioremediation.

3.2.5.3 What to Avoid

- Excessive removal of sediment is probably the greatest concern on this type of beach, as natural replacement rates usually are very slow (decades). Excessive removal can lead to retreat of the beach (i. .e., erosion).
- Oil-in-sediment concentrations usually are very low, which means that mechanical or manual sediment removal methods generate a large volume of waste that contains a relatively small amount of oil.
- If attached animals or plants are present in unoiled lower intertidal zones, flushing or sediment reworking techniques should be avoided spreading oil onto those areas.
- Avoid flushing techniques that only move the oil deeper into the sediments without flushing the oil out of the beach for recovery. Warm or hot water may temporarily mobilize viscous oil that would then possibly migrate more deeply into the beach. The loss of heat as the oil moves through the beach, or as it makes contact with cool or cold ground water, may cause the oil to be redeposited at a lower level within the beach.

3.2.6 Cobble-Boulder Beaches

3.2.6.1 Oil on Boulder Beaches

- Boulder beaches are permeable, and have a stable surface layer.
- Boulders are, by definition, greater than 256 mm in diameter and are moved only by ice, man, and under extreme wave conditions.
- The shoreline type includes riprap structures, such as breakwaters or seawalls, which may be constructed of quarry materials, or pre-formed concrete, such as dolos.
- Boulder beaches frequently give way to mud or sand tidal flats in the lower intertidal zone.
- The large spaces between the individual boulders allow all types of the oil to be carried into the sediments.
- Oiled residence time or persistence is primarily a function of the oil type and wave-energy levels on the beach. Light or non-sticky oils may be flushed easily out of the surface or subsurface sediments by tidal pumping.
- This beach or shore type is stable, so that attached animals and plants may be common on or between boulders, except in areas where boulders may be abraded or be moved each winter by ice action.

3.2.6.2 Preferred Response Options

- In some respects, boulder beaches are similar to a bedrock outcrop so that surface areas may be cleaned in the same way as bedrock; however, oil can penetrate into the underlying sediment on a boulder beach.
- In most cases, all but surface oil would be difficult to recover and natural recovery is the preferred option, in particular for small amounts-of oil. There

is probably little that can be done practically to recover or treat heavy or semi-solid oils that penetrate into the large void spaces. It may not be appropriate immediately prior to freeze up as the oil would be encapsulated by ice and potentially remobilized during the next thaw.

- Flooding can wash mobile oil from surface and subsurface sediments for collection. The effectiveness of flooding decreases with heavier oils (increasing viscosity and stickiness).
- Low-pressure, cold water washing can flush mobile oil from surface and subsurface sediments for collection. This is more effective for heavy oils than flooding, but effectiveness decreases with increasing of oil viscosity, stickiness, and depth of penetration.
- Manual removal can be appropriate for removing asphalt patches, tar patties, and small-size oiled debris, but the practicality of this method decreases as the amount of oiled debris.
- If oil leaching is of concern, the boulders (or man-made riprap) could be lifted out mechanically (either from the land side or from a barge), and the subsurface oil could then be removed or treated after the boulders are replaced.
- Sorbents may be useful for recovering light and medium oils at or near the surface. This is recommended also for small amounts–of oil. On man-made riprap shorelines, sorbent materials (pads, pillows, etc.) can be stuffed in cracks to prevent oil from penetrating into the structure, which, again, can be fairly labor-intensive.

Typical Combinations of Response Methods

- Removal of oiled debris followed by manual removal of surface oil.
- Flooding and low-pressure washing.

3.2.6.3 What to Avoid

- Removal of sediment is not practical or effective for this shore type in many cases. A significant concern would be that boulder-size sediments–form a strong armour layer and probably would not be replaced naturally. Removal without replacement, therefore, could lead to retreat of the beach (i. e., erosion).
- If attached animals or plants are present in unoiled lower tidal zones, avoid flushing or washing techniques that spread oil onto those areas.
- Flushing techniques that only move the oil deeper into the sediments without flushing the oil out of the beach for recovery, are not appropriate. Warm or hot water may temporarily mobilize viscous oil that would then penetrate more deeply into the beach. The loss of heat as the oil moves through the beach, or as it makes contact with cool or cold ground water, may cause the oil to be redeposited at a lower level within the beach.

3.2.7 Sand Tidal Flats

3.2.7.1 Oil on Sand Tidal Flats

- Sand tidal flats are usually:
  - Wide,
  - Flat or have low-angle slopes,
  - Permeable only for some medium-and all low-viscosity oils,
  - Containing large amounts of silt, and
  - Having a very dynamic, mobile, and unstable surface layer.
- Sand/silt flats commonly are found adjacent to low-lying areas, lagoons and estuaries (deltas).
- These shorelines are an important bird habitat in many areas, as migrant species feed on zooplankton, insects, larvae, and worms.
- Sand flats do not fully drain at low tide and many sections are water-saturated at or just below the surface of the sediments. Oil penetration potential is therefore limited, although low-viscosity oils can mix with the waters in the sediments.
- All but highly viscous or dense oils would be refloated and carried landward by a rising tide. Therefore, oil is more likely to concentrate in the upper tidal zones or on the crests of dry, sand ridges rather than on the lower, water-wet or water-saturated areas.
- Burial is possible, but is only possible for highly viscous or dense oils. Oil may penetrate the subsurface through the burrow~~s~~ and persist in the subsurface sediments for long periods (years).
- The trafficability of sand flats would be expected to be poor for both personnel and vehicles.
- The surface of ~~a~~ sand flat is dynamic. Migrating waves or ripples of sand are common. Sediment movement can result in surface changes of several centimeters during a single tidal cycle or following wind-generated wave action.
- The impact of non-persistent, light oils could be immediate (on contact with animals), and heavier oils could fill burrows and smother organisms inside.

3.2.7.2 Preferred Response Options

- Cleanup on sand flats usually is difficult from an operations standpoint, and response activities may cause more damage than the oil itself. Natural recovery is the preferred option where this choice exists, in particular for small amounts of oil. It may not be appropriate immediately prior to freeze up as the oil would be encapsulated by ice and potentially remobilized during the next thaw.
- Flooding and collection with sorbents may be effective for low-medium-viscosity oils.
- Manual removal or vacuums may be effective for smaller amounts of oil pooled or collected in natural depressions.

- Highly viscous oils may be removed mechanically where the bearing capacity and safe access allow.
- Methods of trapping or containing oil (trenches and ditches) for collection on a falling (ebb) tide may be effective.

3.2.7.3 What to Avoid

- Operations in the intertidal zone must be planned to factor the changing water levels. Although predicted tides are accurate at a particular site, the effects of winds and wave action can alter actual water levels so that actual, rather than predicted, conditions must be factored into schedules and work plans.
- The bearing capacity of a sand flat may vary from one place to another, and access of personnel or vehicles may not be possible in some areas.
- Barges or flat-bottomed boats may be used to support operations and personnel. These can then ground on falling tide or low water levels and be refloated by the flood tide, providing a form of transport in unforeseen conditions, such as an unexpected surge condition.
- Mixing of oil into sediments must be avoided. Subsurface oil could remain for a very long time (years). Sediment disturbance can have an impact even in the absence of oil, thus, all movement (personnel and vehicles) must be carefully controlled in oiled and unoiled areas.

3.2.8 Mud Tidal Flats

3.2.8.1 Oil on Mud Tidal Flats

- Mud tidal flats are usually:
  - Wide,
  - Flat with low-angle slopes,
  - Water-saturated and not permeable, and
  - Having a very mobile surface layer.
- Mud flats commonly are found adjacent to low-lying areas, lagoons and estuaries (deltas), and in many cases, they are relatively sheltered in terms of wave-energy levels.
- These shorelines are an important bird habitat in many areas, as migrant species feed on zooplankton, insects, larvae and worms.
- Steep-sided creeks or drainage channels may be present that could hinder access.
- Mud flats are frequently water-saturated at or just below the surface of the sediments. The potential for oil penetration is limited, although light oils can mix with the waters in the sediments.
- These sediments generally have a low bearing capacity for both personnel and vehicles.
- All but highly viscous or dense oils would be refloated and carried landward by a rising tide, resulting in oil being more likely to concentrate on the upper

tidal zones or on the crests of dry ridges rather than on the lower, water-wet or water-saturated areas.

- Burial is possible with heavy or dense oils. Oil may enter the subsurface through mud cracks or animals (e.g., clams and worms) burrows and may have a long persistence time (years).
- The surface of a mud flat is very dynamic and elevation changes of several centimetres may occur during a tidal cycle or following periods of wind-generated wave action.
- Mud flats usually are very productive biological habitats with many burrowing animal species (e.g., snails, worms, and clams). These organisms often are a food source for birds and man.
- The impact of non-persistent oils could be immediate (on contact with animals) and heavier oils could fill burrows and smother organisms.

3.2.8.2 Preferred Response Options

- Natural recovery is the preferred option where this choice exists. Cleanup usually is difficult from an operations standpoint and response activities may cause more ecological damage than the oil itself. It may not be appropriate immediately prior to freezeup as the oil would be encapsulated by ice and potentially remobilized during the next thaw.
- In practical terms, few techniques can be effective in this type of shoreline environment. Less intrusive strategies, such as herding by flooding or washing and collection using sorbents or vacuums, may have some applicability.
- Barges or flat-bottomed boats may be used to support operations and personnel. These can provide a form of transport in unforeseen conditions, such as an unexpected surge condition.

3.2.8.3 What to Avoid

- Operations in the shore zone must be planned to deal with the changing water levels. Although predicted tides are accurate at a particular site, the effects of winds and wave action can alter water levels significantly so that potential changes in water level conditions, rather than predicted, must be factored into schedules and work plans.
- The bearing capacity of a mud flat may vary from one place to another. Some areas may not support the weight of a person or vehicle.
- Mixing of oil into sediments must be avoided. Subsurface oil could remain for a very long time (years). Sediment disturbance can have an impact even in the absence of oil, thus, all movement (personnel and vehicles) must be carefully controlled in oiled and unoiled areas.

3.2.9 Salt Marshes

3.2.9.1 Oil on Salt Marshes

- Marshes usually:
  - Are permeable for light oils,
  - Support a stable surface vegetation cover and root system, and
  - May be fringed by muddy tidal creeks or mud tidal flats.
- Marshes are common and are an important habitat from a biological standpoint.
- Marsh types vary from narrow fringing marshes to wide salt marsh meadows. Usually the marsh meadows are above the normal high-tide water level and flooded only during spring tides or storm surges.
- Oil can impact the fringe of a marsh, during neap high tides or normal water levels, or can be deposited on higher interior meadow. Oiling may be washed by subsequent tides and weathered more rapidly, depending on energy levels. Oil on the meadow area, which experiences little or no current and wave action, may weather slowly.
- Light oils can penetrate into marsh sediments or fill animal burrows and cracks. Medium or heavy oils are more likely to remain on the surface and would have a potential smothering effect on plants and animals.
- Natural recovery rates vary depending on the oil type, total area affected, oil thickness, plant type, growth rates, and season during which the oiling occurred. Recovery may take as little as a few years following light oiling but can take decades in extreme circumstances (extensive, thick deposits of viscous oil).
- Marsh habitats are extremely productive in terms of plant and micro-animal life and are important to large migratory bird populations. Populations of birds, productivity, and sensitivity vary with the season.

3.2.9.2 Preferred Response Options

- Natural recovery should be considered as the preferred option, particularly for small amounts of spilled oil. Factors that influence the decision include:
  - The rate of natural recovery,
  - The possible benefits of a response to accelerate recovery, and
  - Any possible damage or delays to recovery that may be caused by response activities.

  Natural recovery may not be appropriate immediately prior to freezeup as the oil would be encapsulated by ice and potentially remobilized during the next thaw.
- The preferred strategy for cleanup involves flooding and washing techniques that herd oil into collection areas without extensive disturbance of the vegetation cover.
- Low-pressure, cold water washing can remove light-to-medium oils without incurring damage, particularly if the operation is carried out from a boat

and/or crane and does not involve foot or vehicle traffic on the marsh.

- Sorbents can be placed on the marsh fringe to collect oil and can be deployed and retrieved without accessing the marsh surface. This is recommended for small amounts of oil.
- It may be appropriate, in certain circumstances, to cut oiled vegetation where there is extensive oiling of plants.

3.2.9.3 What to Avoid

- Most activities that involve traffic on or through a marsh would delay natural recovery.
- Cutting of oiled plants will usually delay recovery and should only be considered if the risk of leaving the oil poses a threat to other resources (e.g., migratory or nesting birds). Cutting would usually involve traffic through the marsh, likely disrupting the plant root systems unless such operation is carried out from a boat. ***Note: cut the oiled parts and avoid pulling up an oiled plant.***
- Burning may be considered as an option; however, the damaging effects can be significant as most plants or animals could be killed. Burning should be avoided if the lower stems and roots of a plant are dry and therefore not insulated from the heat.
- Sediment removal or mixing or disruption of the root systems, such as compaction by machinery or trampling by workers, can significantly delay recovery.
- Removal techniques should be considered only if the recovery of the marsh is expected to take decades, as might be the case for thick deposits of heavy or viscous oils

3.3 Summary of Shoreline Cleanup Technique Applicability by Oil Types

The following table identifies those methods by oil type that are appropriate for various shoreline types and that would cause the least damage.

CLEANUP TECHNIQUE APPLICABILITY

Type A: Very Light Volatile Oil

Key:
- ● Applicable
- ○ May be applicable
- * applicable only for small amounts of surface oil
- — Not applicable

		Man-made Structure	BEDROCK		BEACH					INTERTIDAL FLATS					Estuarine Salt Marsh
					Gravel		Mixed			Gravel		Mixed			
			Bedrock Cliffs	Bedrock Ramp/Platform	Cobble/ Boulder	Pebble/ Cobble	Sand/ Pebble/ Cobble	Sand		Cobble/ Boulder	Pebble/ Cobble	Sand/ Pebble/ Cobble	Sand	Mud	
REMOVAL	Manual Oil/Sediment Removal	—	—	—	—	—	—	—		—	—	—	*	—	—
	Mechanical Sediment Removal	—	—	—	—	—	—	—		—	—	—	—	—	—
	Vacuum	—	—	—	—	—	—	—		*	*	*	*	*	—
	Vegetation Cutting	—	—	—	—	—	—	—		—	—	—	—	—	—
	Sand Blasting	—	—	—	—	—	—	—		—	—	—	—	—	—
WASHING	Flooding	●	●	●	●	●	●	●		●	●	●	●	●	●
	Flushing	●	●	●	*	*	*	*		*	*	*	—	—	—
	Spot Washing	—	—	—	—	—	—	—		—	—	—	—	—	—
	Sediment Washing	—	—	—	—	—	—	—		—	—	—	—	—	—
	Steam Cleaning	—	—	—	—	—	—	—		—	—	—	—	—	—
IN SITU	Passive Collection	*	*	*	—	—	—	—		*	*	*	*	—	—
	Relocation to Surf Zone	—	—	—	—	—	—	—		—	—	—	—	—	—
	Sediment Tilling	—	—	—	—	—	—	—		—	—	—	—	—	—
	Bioremediation	—	—	—	—	—	—	—		—	—	—	—	—	—
	Log/Debris Burning	○	○	○	○	○	○	○		○	○	○	○	○	—
	Chemical Treatment	—	—	—	—	—	—	—		—	—	—	—	—	—
	Natural Recovery	●	●	●	●	●	●	●		●	●	●	●	●	●

CLEANUP TECHNIQUE APPICABILITY

Type B: Light Fuel Oil (Low Viscosity)

Key:
- ● Applicable
- ○ May be applicable
- X Usually not applicable
- — Not applicable

		Man-made Structure	BEDROCK: Bedrock Cliffs	BEDROCK: Bedrock Ramp/Platform	BEACH: Gravel: Cobble/Boulder	BEACH: Gravel: Pebble/Cobble	BEACH: Mixed: Sand/Pebble/Cobble	BEACH: Sand	INTERTIDAL FLATS: Gravel: Cobble/Boulder	INTERTIDAL FLATS: Gravel: Pebble/Cobble	INTERTIDAL FLATS: Mixed: Sand/Pebble/Cobble	INTERTIDAL FLATS: Sand	INTERTIDAL FLATS: Mud	Estuarine Salt Marsh
REMOVAL	Manual Oil/Sediment Removal	○	X	○	○	○	○	○	○	○	○	○	○	○
	Mechanical Sediment Removal	—	—	—	X	●	●	●	X	●	●	●	○	X
	Vacuum	○	○	●	X	X	○	○	X	X	○	○	○	○
	Vegetation Cutting	X	○	○	○	X	—	—	○	X	—	—	X	●
	Sand Blasting	—	—	—	—	—	—	—	—	—	—	—	—	—
WASHING	Flooding	—	—	X	●	●	●	●	X	X	X	X	X	○
	Flushing	●	●	●	●	●	●	●	●	●	●	●	X	●
	Spot Washing	●	●	●	○	○	X	—	○	○	X	—	—	—
	Sediment Washing	—	—	—	—	○	X	X	—	○	X	X	—	—
	Steam Cleaning	○	○	○	○	X	—	—	○	X	—	—	—	—
IN SITU	Passive Collection	●	●	●	●	●	●	●	●	●	●	●	●	●
	Relocation to Surf Zone	—	—	—	X	●	●	X	—	—	—	—	—	—
	Sediment Tilling	—	—	—	—	●	●	●	—	●	●	●	X	—
	Bioremediation	○	○	○	●	●	●	●	●	●	●	●	●	●
	Log/Debris Burning	●	●	●	●	●	●	●	X	X	X	X	X	●
	Chemical Treatment	○	○	○	X	X	X	X	X	X	X	X	—	—
	Natural Recovery	●	●	●	●	●	●	●	●	●	●	●	●	●

CLEANUP TECHNIQUE APPLICABILITY

Type C: ANSC/Weathered Medium Fuel Oil (Medium Viscosity)

Key:
- ● Applicable
- ○ May be applicable
- X Usually not applicable
- — Not applicable

		Man-made Structure	BEDROCK: Bedrock Cliffs	BEDROCK: Bedrock Ramp/Platform	BEACH: Gravel: Cobble/ Boulder	BEACH: Gravel: Pebble/ Cobble	BEACH: Mixed: Sand/ Pebble/ cobble	BEACH: Sand	INTERTIDAL FLATS: Gravel: Cobble/ Boulder	INTERTIDAL FLATS: Gravel: Pebble/ Cobble	INTERTIDAL FLATS: Mixed: Sand/ Pebble/ Cobble	INTERTIDAL FLATS: Sand	INTERTIDAL FLATS: Mud	Estuarine Salt Marsh
REMOVAL	Manual Oil/Sediment Removal	●	●	●	●	●	●	●		●	●	●	○	○
	Mechanical Sediment Removal	—	—	—	○	●	●	●	○	●	●	●	○	—
	Vacuum	○	○	○	X	X	○	○	X	X	○	○	○	○
	Vegetation Cutting	X	○	○	○	X	—	—	○	X	—	—	X	●
	Sand Blasting	X	X	X	X	X	—	—	X	X	—	—	—	—
WASHING	Flooding	—	—	X	●	●	●	●	X	X	X	X	X	●
	Flushing	●	●	●	●	●	●	●	●	●	●	●	X	●
	Spot Washing	●	●	●	○	○	X	—	○	○	X	—	—	—
	Sediment Washing	—	—	—	—	○	○	○	—	○	○	○	—	—
	Steam Cleaning	○	○	○	○	X	—	—	○	X	—	—	—	—
IN SITU	Passive Collection	●	●	●	●	●	●	●		●	●	●	●	●
	Relocation to Surf Zone	—	—	—	X	●	●	—	—	—	—	—	—	—
	Sediment Tilling	—	—	—	—	●	●	○	—	●	●	○	X	—
	Bioremediation	○	○	○	●	●	●	●	●	●	●	●	●	●
	Log/Debris Burning	●	●	●	●	●	●	●	X	X	X	X	X	●
	Chemical Treatment	○	○	○	X	X	X	X	X	X	X	X	—	—
	Natural Recovery	●	●	●	●	●	●	●		●	●	●	●	●

CLEANUP TECHNIQUE APPICABILITY

Type D: Weathered and/or Heavy Crude and Fuel Oil (High Viscosity)

Key:
● Applicable
○ May be applicable
X Usually not applicable
— Not applicable

			BEDROCK		BEACH				INTERTIDAL FLATS					
					Gravel		Mixed		Gravel		Mixed			
		Man-made Structure	Bedrock Cliffs	Bedrock Ramp/Platform	Cobble/ Boulder	Pebble/ Cobble	Sand/ Pebble/ Cobble	Sand	Cobble/ Boulder	Pebble/ Cobble	Sand/ Pebble/ Cobble	Sand	Mud	Estuarine Salt Marsh
REMOVAL	Manual Oil/Sediment Removal	●	●	●	●	●	●	●	●	●	●	●	○	○
	Mechanical Sediment Removal	—	—	—	○	●	●	●	○	●	●	●	○	—
	Vacuum	○	○	○	X	X	○	○	X	X	○	○	○	○
	Vegetation Cutting	X	X	○	○	X	—	—	○	X	—	—	X	●
	Sand Blasting	○	○	○	X	X	—	—	X	X	—	—	—	—
WASHING	Flooding	—	—	X	○	○	X	X	X	X	X	X	X	X
	Flushing	○	○	○	○	○	X	X	○	○	X	X	X	○
	Spot Washing	●	●	●	●	○	X	—	●	○	X	—	—	—
	Sediment Washing	—	—	—	—	○	○	○	—	○	○	○	—	—
	Steam Cleaning	○	○	○	○	X	—	—	○	X	—	—	—	—
IN SITU	Passive Collection	○	○	○	○	○	○	○	○	○	○	○	○	○
	Relocation to Surf Zone	—	—	—	X	●	●	—	—	—	—	—	—	—
	Sediment Tilling	—	—	—	—	●	●	○	—	●	●	○	—	—
	Bioremediation	○	○	○	○	○	○	○	○	○	○	○	○	○
	Log/Debris Burning	●	●	●	●	●	●	●	X	X	X	X	X	●
	Chemical Treatment	○	○	○	○	○	X	X	○	○	X	X	—	—
	Natural Recovery	●	●	●	●	●	●	●		●	●	●	●	●

CLEANUP TECHNIQUE APPLICABILITY

Type E: Very Weathered Semi-Solid to Solid Oil

Key:
- ● Applicable
- ○ May be applicable
- X Usually not applicable
- — Not applicable

		Man-made Structure	BEDROCK		BEACH				INTERTIDAL FLATS					Estuarine Salt Marsh
			Bedrock Cliffs	Bedrock Ramp/Platform	Gravel		Mixed	Sand	Gravel		Mixed	Sand	Mud	
					Cobble/ Boulder	Pebble/ Cobble	Sand/ Pebble/ Cobble		Cobble/ Boulder	Pebble/ Cobble	Sand/ Pebble/ Cobble			
REMOVAL	Manual Oil/Sediment Removal	●	●	●	●	●	●	●	●	●	●	●	○	○
	Mechanical Sediment Removal	—	—	—	X	●	●	●	X	●	●	●	○	—
	Vacuum	—	—	—	—	—	—	—	—	—	—	—	—	—
	Vegetation Cutting	X	X	○	○	X	—	—		X	—	—	X	●
	Sand Blasting	○	○	○	X	X	—	—	X	X	—	—	—	—
WASHING	Flooding	—	—	—	—	—	—	—	—	—	—	—	—	—
	Flushing	X	X	X	—	—	—	—	—	—	—	—	—	—
	Spot Washing	●	●	●	●	○	X	—	●	○	X	—	—	—
	Sediment Washing	—	—	—	—	○	○	○	—	○	○	○	—	—
	Steam Cleaning	○	○	○	○	X	—	—	○	X	—	—	—	—
IN SITU	Passive Collection	—	—	—	—	—	—	—	—	—	—	—	—	—
	Relocation to Surf Zone	—	—	—	—	●	○	—	—	—	—	—	—	—
	Sediment Tilling	—	—	—	—	●	○	○	—	●	○	○	—	—
	Bioremediation	X	X	X	X	X	X	X	X	X	X	X	X	X
	Log/Debris Burning	●	●	●	●	●	●	●	X	X	X	X	X	●
	Chemical Treatment	○	○	○	○	○	X	X	○	○	X	X	—	—
	Natural Recovery	●	●	●	●	●	●	●	●	●	●	●	●	●

Chapter 4

Shoreline Treatment Methods

Shoreline treatment or cleanup techniques should be selected to be compatible with the character of the shore zone and with the oiling conditions (type and volume of oil).

In this section, each of the treatment options is described separately, although in practice, two or more usually are selected in combination to achieve the treatment objective.

A total of sixteen shoreline response techniques are described in table 4-1.

Table 4-1. Summary of Shoreline Treatment Methods

Shoreline Treatment Methods

- Removal — Section 4.1
  - 4.1.1 Manual Removal
  - 4.1.2 Mechanical Sediment Removal
  - 4.1.3 Vacuum/Skimmers
  - 4.1.4 Sand Blasting
- Washing — Section 4.2
  - 4.2.1 Flooding (Deluge)
  - 4.2.2 Flushing
  - 4.2.3 Spot Washing (High -Pressure)
  - 4.2.4 Steam cleaning
  - 4.2.5 Sediment Washing
- In situ — Section 4.3
  - 4.3.1 Passive Collection
  - 4.3.2 Relocation to Surf Zone
  - 4.3.3 Sediment Tilling
  - 4.3.4 Bioremediation
  - 4.3.5 Log/Debris Burning
  - 4.3.6 Chemical Treatment
  - 4.3.7 Natural Recovery

In the event that oil does contact a shoreline, the appropriate response actions should be implemented as soon as practicable to minimize environmental damage. In situations where oil continues to wash ashore, it may be preferable to wait until all or most of the oil has become stranded, as repeated cleanup of a shoreline may create more harm than the oil itself. Conversely if the oil has a high remobilization potential, it is often better to clean the shoreline as the oil arrives rather than to allow it to be refloated by the tides and possibly impact another previously unoiled area.

The appropriate cleanup technique to be used on a shoreline depends primarily on the sediment type, beach slope, level of oiling and potential impacts from the candidate cleanup technique(s).

Detailed procedures for the implementation of each technique are discussed below with information included on use, limitations, logistics, and use variations. On occasions, spill circumstances may involve simultaneous use of several techniques.

4.1 Removal

4.1.1 Manual Removal

Purpose

To remove limited amount of oil, oiled sediment, vegetation, or debris from a shoreline which cannot be left to natural degradation.

Description

Manual removal involves recovery of surface oil, oiled sediment or oily debris by manual methods (hands, rakes, shovels, pitchforks, sorbents) and placing these materials into containers (plastic bags, drums, etc.) for disposal from the shoreline. Generally, in this situation, mechanical equipment is not used, except for the possible use of all-terrain vehicles, wheel barrows, etc., to transport the contained material to a staging or disposal area.

Application

Manual removal can be used on most shoreline types with the possible exception of mud flats and salt marshes, where considerable foot traffic generally creates more impact than the oil itself. Manual removal is most applicable to lightly oiled or relatively inaccessible shorelines where the use of mechanical equipment is not warranted or feasible, or where the equipment would cause undue environmental damage. Manual removal is very useful for removal of oiled vegetation such as marsh grasses, kelp, and eelgrass to avoid leaching and re-oiling. It is also widely used in the final stages of cleanup where only minor amount~~s~~ of oil remains.

Limitations

Manual removal is labour-intensive and time-consuming. Removal of recovered wastes may be difficult in areas with limited access. Heavy foot traffic can cause environmental damage; and vegetation cutting and removal can cause damage to root systems, particularly in marsh areas with soft sediments. In most cases, the impact~~s~~ of leaving the oiled vegetation in place are less than the trampling associated with cutting and removal.

Implementation

Oil layers on hard surfaces (e.g. bedrock, boulders, man-made structures) can be removed by wiping with sorbents or, if very weathered, by scraping or wire brushing. Sorbents can also be used to remove thin films remaining during the cleanup phases and to prevent oiling of walkway and work areas during the cleanup operation. Manual cutting of vegetation requires moderate to large crew equipped with some special tools.

Small quantities of oil or oiled material can be placed in plastic bags and removed for disposal. Larger quantities can be placed in barrels, debris boxes, etc. for temporary storage and/or subsequent disposal. All materials should be stored above the high waterline to prevent loss or remobilization by high tides. Containers may be removed manually by vehicle, or loaded onto small boats or barges from shorelines or makeshift docks.

Considerations for conducting manual removal include:

- Wear protective clothing, gloves, boots, and hand barrier cream.
- Do not rake/cut healthy unoiled vegetation
- Cut algae above the holdfast and cut macrophytes above the ground: do not uproot.
- Cut and/or collect oiled material into small piles.
- Fill plastic bags or containers only to the point where they can be easily carried by one person (i.e. 18 - 23 kg)
- Double bag heavily-oiled materials

Logistics

The logistical requirements for manually cleaning a shoreline vary with the amount and distribution of the oil, and the length of shorelines.

4.1.2 Mechanical Sediment Removal

Purpose

To remove oiled sediments or surface oil by mechanical methods.

Description

Various types of heavy mechanical equipment are used individually or in conjunction with other types of equipment, to remove oiled sediments or weathered oil from the surface of a beach for processing and/or disposal at an approved facility. Earthmoving equipment such as motor graders, elevating scrapers, front-end loaders, or dump trucks are most commonly used in sediment removal, whereas beach cleaning machines are used for removing weathered surface oil. The sediments can be transported directly to a temporary storage or disposal site or loaded onto dump trucks for transfer to the storage or disposal site.

Application

Mechanical sediment removal is primarily used to remove oiled surface sediments or weathered surface oil on fine-grained sediment (sand) beaches where the oil is on or near the surface, and where trafficability permits the use of heavy equipment. Certain types of equipment may also be used to remove subsurface oil from shorelines with similar sediments. Mechanical removal should not be considered where beach erosion may result, unless only small amount of sediment are removed.

Limitations

Large-scale sediment removal is one of the least desirable techniques due to the level of potential physical and environmental impacts. Use of this technique may be restricted by disturbance to adjacent habitats such as bird rookeries, backshore wetlands or fish-spawing areas.

The equipment is generally heavy and large, and often support-intensive (maintenance, fuel, parts). Transportation of equipment to the site may involve aircraft, land vehicle, or barge movement. This method can result in shoreline erosion if excessive material is removed without replacement. Depletion of sediment-dwelling organisms is also associated with large-scale excavation although recruitment from nearby areas, if available, may be typically rapid.

Releases of oil and fine-grained oily sediments to the water during sediment removal activities are also common. Containment or sorbent booms placed in the water off shore of the work area can prevent the uncontrolled release of significant quantities of oil to the marine environment by flushing during the first several tidal cycles following removal activities.

Implementation

There are several methods that can be used to mechanically recover oiled sediments and surface oil depending on the circumstances and the type of available equipment. On large beaches with mixed sediment (e.g. sand, granule, pebble) and good trafficability, motor graders with elevating scrapers or front-end loaders are preferred, whereas bulldozers with front-end loaders are more applicable on pebble/cobble beaches with low trafficability.

Logistics

A range of mechanical devices can be used to remove oil and oiled surface and subsurface materials from shoreline, for example, front-end loader, backhoe, bulldozer, dump trucks etc. The logistical requirements for what kind and how many devices to be used vary with the size of the oiled area and the type of the shoreline. For selected equipment, enough operators, fuel and spare part are needed.

4.1.3 Vacuum/Skimmer

Purpose

To remove free oil from the shoreline surface or from the surface of nearshore or intertidal waters.

Description

Vacuum/skimmer may be used in combination with sumps excavated to collect oil.

Vacuum sources such as pumps, vacuum trucks, or portable vacuum units are used to recover free oil from the shoreline surface, where oil has accumulated in pools or in cracks and crevices and interstitial spaces within coarse sediments. The equipment can range from small, portable pumps, to vacuum units fitted to a 55-gallon drum, and to large, truck-mounted super-suckers that can even lift large cobbles.

This equipment is not only best suited to picking up oil which has collected in pools or sumps on the shoreline, but can also be used to skim relatively thick layers of oil off the water surface. The latter use is somewhat inefficient, as large quantities of water are usually collected along with the oil, but it often proves invaluable where limited water depths preclude the use of skimmers.

Where water depths permit, such as in the nearshore area, tidal inlets, or marshes, skimmers are used to recover oil from the water surface. Skimmers are typically used in conjunction with flushing, flooding, or spot-washing techniques where oil is driven back into the water and contained by booms.

Applications

Vacuum equipment such as pumps or vacuum trucks are typically used for recovering mobile oil which has accumulated in sufficient quantities in natural depressions along the shoreline such as cracks, crevices, or interstitial spaces. Portable skimmers are primarily applicable to removing oil from the surface of water adjacent to the shoreline and from large tidal pools, tidal inlets, marshes, sloughs, and other tidally-influenced waters.

Limitations

Skimmers should not be used in areas where foot traffic and equipment operation are restricted. Effectiveness may be reduced for picking up very thin oil accumulations or highly viscous or weathered oils. Access may also restrict the use of vacuum trucks and larger storage tanks. High surf or larger grained sediments would tend to considerably reduce the effectiveness of vacuum recovery on the shoreline.

Implementation

The vacuum equipment can be positioned adjacent to the area to be worked either onshore or on a shallow draft vessel. Reinforced suction hoses are attached to the vacuum sources, fitted with a coarse screen or wire mesh over the end of the hose or fitting to minimize the intake of rocks and debris. Hose diameters of 2 to 5 cm for 1ighter oils and 5 to 10 cm for heavier and weathered oils are often required to prevent clogging. The vacuum source is activated and the hose end placed directly in the oil accumulation. When used to recover oil from the surface of the water, the hose opening should be positioned at an angle to the water with the lower edge of the hose end just below the oil-water interface. This would minimize the amount of water recovered along with the oil. Pumps are also used in this manner.

Portable skimmers are typically deployed from vessels to recover oil contained within the boom. In order to recover as much oil as possible, skimmers should be placed in the heaviest concentrations of oil and be periodically repositioned. Shallow draft skimmers such as rope mops and disc types usually work well with most types of oil. If rope mops are used, outriggers should be fitted to the vessel to hold the tail pulleys in place instead of using anchors that must be repositioned as the tide rises and falls.

When using this technique, storage tanks are typically required, particularly when recovering oil from the water. If operating from the shoreline, the tanks should be placed in an easily accessible area for periodic transfer of the tank or contents to a disposal site. For vessel operations, the storage tanks can be placed directly on the vessel or a separate vessel nearby and connected by hose.

In case of a shoreline with alongshore current, a sump can be dug up in the intertidal zone with a berm built from the excavated material extending from the back of the sump into the surf on the down-current side of the sump. The alongshore current moves the oil down the beach where it is intercepted by the berm and channelled into the sump. A vacuum truck, trash pump, or skimmer can then be used to remove the oil from the sump.

Logistics

The logistical requirements for using the vacuum/skimmer technique vary considerably with the amount of oil to be collected as well as the percentage of water recovered along with the oil. If skimmers are used, the percentage of water recovered will likely be low thus requiring fewer containers or tucks. Conversely pumps and vacuum systems typically recover large amount of water along with the oil, practically, several storage containers or disposal vehicles may be needed. Therefore, the primary logistical concern is temporary storage and disposal of the oil and water. The more oil collected, then the greater number of storage tanks and/or vacuum or tank trucks will be needed to transport the liquids away.

4.1.4 Sand Blasting

Purpose

To remove thin accumulations of weathered oil residues from rock surface or man-made structures with relatively few or no living organisms attached.

Description

Sand is applied to the structure at high velocity using sandblasting equipment. The oil is removed from the substrate by the abrasive action of the sand. In most cases the sand used for blasting cannot be taken directly from a nearby shoreline as it must be screened to obtain the proper size and washed to prevent clogging of the machine.

Application

Sandblasting is primarily used to remove weathered (i.e. relatively hard) coating from man-made structures or other impermeable surfaces (bedrock, boulder) where other techniques are not applicable or feasible.

Limitations

Sandblasting can possibly remove any vegetation or animals inhabiting the surface and should not be used where repopulation may take considerable time, or where other techniques can also be used. Because it is very difficult to recover all of the spent sand, consideration should be given to the potential impacts of some oily sand left in the area. The availability of adequate supplies of clean sand is another possible limitation.

Implementation

Blasting should begin at the highest vertical level of oiling and work down to the base of the structure or rock. It should be conducted on an ebbing tide or near low tide so that the lowest point will be reached, while still allowing time to recover the spent sand prior to the working area becoming submerged by the rising tide.

Removal of spent sand, oil residues, and surface material is generally performed manually with shovels. Should the quantity become too large for manual removal, front-end loaders may then be used. The materials collected can be loaded directly onto dump trucks for disposal or placed in a temporary storage area for subsequent disposal.

Logistics

The cleaning rate of the sandblasting technique depends on the type and degree of oiling, the type of equipment and abrasion used, and the accessibility to the substrate being c1eaned. The rates can vary from 2.3 m^2 /hr to 28 m^2 /hr depending on the variables. Under normal circumstances, a medium size compressor and equipment can clean 14 m^2 /hr. To maintain a reasonable cleaning rate, several sandblasting units may be required at the same time.

4.2 Washing

4.2.1 Flooding (Deluge)

Purpose

Flooding is to float oil off and out of shoreline rocks and sediments, and to drive the oil back onto the water surface using large volumes of ambient seawater at low pressure. The remobilized oil is subsequently recovered using skimmers or sorbents.

Description

A large diameter perforated header hose or pipe is placed parallel to the shoreline above the oiled area. A hose is preferred as it will better conform to the actual shoreline profile. Ambient temperature sea water is pumped through the hose at high volumes (200 to 1000 liters per minute) under low pressure (<3.5 bars: 50 psi). The water now flows out of the perforations and deliver across the shore downslope carrying much of the free oil with it. On porous beaches, water also flows through the substrate driving the mobile oil out or floating it up to the surface, then transporting it downslope to the water.

Application

Flooding is primarily applicable to coarse and fine gravel substrates such as boulder, cobble, pebble, and some mixed sediments where the oil is fluid and presents in relatively large quantities. It may also be used on rock platforms where oil has pooled or collected in depressions or crevices.

However, flooding is generally not applicable to mud, sand, vegetated upland, or steep rocky shorelines, or where the oil is highly viscous or weathered. It is also relatively ineffective on thin coatings of oil that have adhered tightly to the sediments. In practice, flooding is frequently used in conjunction with flushing and occasionally spot washing techniques to enhance effectiveness and minimize penetration of additional oil into the sediments.

Limitations

What may limit the use of flooding is the accessibility to the shoreline and the disturbance caused by equipment and manpower to the environmentally sensitive area. Effectiveness is also constrained on weathered, sticky or viscous oils, especially if the oil occurs in films or coating form on the surface.

Intertidal habitat may be disrupted as the finer sand and gravel components of the substrate are translocated by the water flow. Smaller organisms may be flushed into lower tidal zones. Some sediment may be transported to shallow subtidal areas and bury benthic organisms.

Implementation

Multiple, large volume centrifugal pumps (l0 to 15 cm) are typically placed on shallow draft vessels anchored adjacent to the shoreline. The reinforced suction hoses are lowered over the side ~~and~~ into the water, fitted with screens to exclude large debris. PVC hoses, in larger diameter (5 to l5 cm) are used as header hoses with 0.25 to 0.5 cm holes drilled along the seaward side. The hose or hoses are laid along the top of the oiled area parallel to the water line. Similar hoses without the holes are used to supply water to the header hoses. A manifold can be fitted to the pump discharge to permit the connection of smaller hoses used to herd floating oil to the recovery equipment.

Containment and/or sorbent booms should be anchored in the water around the work area and just beyond the surf line, if present, to contain the oil being flushed back into the water. It is usually more effective if two lines of boom are used, with the primary (shoreward) boom being the standard containment type and the secondary boom being the sorbent type to recover any sheens that may escape from the primary boom. Prior to setting up the entire system, flooding test should be carried out in a small area to evaluate the effectiveness of such technique.

Logistics

The logistics required for conducting a flooding operation are dependent on several factors including:

- Length of shoreline to be cleaned
- Width of oiled area
- Porosity (size and sorting) of the beach sediments
- Depth to groundwater

In general, the flow rate required to produce the desired flooding effect is directly proportional to these factors. Insufficient flow rates typically result in the water percolating downward into the beach without producing the lateral component required to remove the oil and transport it to the water's edge.

4.2.2 Flushing

Purpose

Flushing is to remove oil that lightly adhered to surface materials or buried in shallow layers of sand/ gravel-sized sediments, and to flush the oil down slope and back onto the water surface for recovery.

Description

Flushing involves the use of relatively low-pressure water streams to remove mobile oil and lightly adhered surface oil coatings from surface and near surface sediments through direct contact with the water stream and agitation of the sediments. This is often used in conjunction with the flooding technique to minimize oil penetration into the substrate and assist in the transport of the oil back into the water. The water can be applied at ambient temperature or heated depending on the oil's viscosity and/or degree of weathering, and on ecological constrains.

Flushing is facilitated by pumping sea water through fire hoses equipped with fog type nozzles. This type of nozzle controls the flow and adjusts the spray from a narrow stream for sediment agitation and oil removal to a coarse spray for flushing the oil downslope. Industrial heat exchangers or boilers can be used to heat the sea water prior to delivery to the hoses, if necessary.

Application

Flushing, though primarily applicable to coarse and fine gravel and mixed sediment beaches, can also be used on rocky shorelines to get floating or loose oil out of tide pools, depressions, crevices, etc., or off attached organisms e.g., mussels.

Generally, flushing is not applicable to fine sediments (sand and mud), marshes and wetlands, or vegetated upland shorelines. Effectiveness is decreased with an increase in oil weathering and/or viscosity. Flushing with hot water should also be avoided in biologically sensitive areas with light to moderate oiling conditions.

Limitations

Mobilized oil may percolate or be driven down to greater depths by the water streams, especially if heated, unless an effective flooding system is also used. Other potential adverse effects are:

- Removal or mortality of surface organisms
- Surface and near-surface habitat disruption
- Transport of oil to lower intertidal or previously clean areas
- Burial of subtidal organisms by downslope sediment transport

This technique is generally not appropriate for use in fish spawning areas, including stream channels and estuaries.

Implementation

Containment and/or sorbent booms should be anchored in the water around the work area and just past the surf zone, if present, to contain the remobilized oil. During operations, flushing equipment is typically placed on a shallow draft vessel anchored to the shore. Diesel-driven centrifugal pumps are used to supply the flush water. The intake hoses can be lowered over the side of the vessel directly into the water. Hot water is provided by direct fired industrial heaters using either electricity, diesel or propane as the source of heat. A manifold is fitted to the discharge of each heater. Several fire hoses are then attached to the manifold and fitted with adjustable fog nozzles to produce the water streams or coarse sprays for flushing.

Flushing should begin at the top of the oiled area and proceed downslope. To minimize impacts to the lower intertidal areas, flushing should be conducted on an ebbing tide and timed such that the waterline is always just below the area being worked at. Oil that flows back into the water is then recovered by skimmers, pumps or sorbents. The water streams can also be used to direct the floating oil towards the recovery equipment. If authorized, dispersants or other surfactants (low toxicity beach cleaning agents) may be mixed in low concentrations with the flushing water to aid oil removal and prevent re-oiling by the removed oil.

Whereas elevated water pressures and temperatures remove weathered, viscous or sticky oils, it can also agitate the larger sized substrates to greater depths, and can typically impact the intertidal community to a higher degree than lower pressures and temperatures. Low pressure water streams can be used to flush out oil stranded in backwater areas or under docks and herd it into containment or recovery devices. Very low pressure water streams can also be used to remove oil from vegetation. When operating from a small skiff and using smaller pumps, low pressure water streams have been used effectively to flush out oil stranded within marsh vegetation into open water where the oil could be recovered. Additionally, low pressure water streams can be applied to remove oil from the surface of fine-grained sediments (sand and mud) by 'bathing' the surface with the water and floating the oil down gradient and back into the water for recovery.

Logistics

The logistical requirements for flushing vary with the degree and type of oil, sediment type, and size of oiled area. In general, the number of pumps, hoses and ancillary equipment is directly related to the size of the area and degree of oiling. The pressure used is also directly proportional to the size of the sediments and oil viscosity and weathering. The temperature selected is similarly dependent on the viscosity and weathering of the oil.

4.2.3 Spot Washing (High-Pressure)

Purpose

Spot washing is to remove oil coating from hard surfaces such as boulders, rock, and solid manmade structures.

Description

Spot washing uses a high pressure water jet that removes oil from almost any surface. The water is often heated close to boiling for increased effectiveness. The water jet should be used only by trained personnel. Too strong a jet will remove all plant and animal life and may also damage man-made surfaces. Most pressure washing units are relatively small, portable and self-contained with a pump, water heater, electric generator, hoses and spray wands. The units are typically placed on the shore with a suction line and screen attached to a float in the water.

Applications

This method is primarily applicable to relatively small areas, and to oil that is sticky weathered, or viscous and/or cannot be removed by flushing. Spot washing can be used on bedrock, boulders, logs or trees, and manmade structures such as piers, seawalls, or boat hulls. This method is not applicable to fine-grained sediment beaches or vegetated shorelines.

Limitations

This method is not appropriate where wholesale removal of attached organisms from the surface is unacceptable. It is difficult to recover all of the removed oil due to the size of the area with deflected water received and oil sprayed. The high pressures can cause damage to very hard or man-made surfaces.

Implementation

When spot washing conducted in small areas, the surrounding surfaces should be covered with plastic sheeting or sorbents, since the removed oil and water tend to spread over a large area. Collection of the oil and water can be accomplished by allowing it to pool in natural depressions, and channel it to a collection sump, or let it drain back into the water.

Flushing should begin at the highest point, and proceed downslope. For larger areas, it should be conducted during an ebbing tide and timed so that the water line is always just below the area being cleaned. Booms can be used to further concentrate the oil and recovery must be completed before the tide rises and re-oils the area.

Logistics

The logistics required to clean a shoreline using spot washing are dependent on the size of the area and the rate of cleaning. The rate at which a shoreline can be cleaned with this technique is affected primarily by the type and state of oil, the type of substrate, and the water pressure and/or temperature used. In general, the cleaning rate is inversely related to the weathering or viscosity of the oil, the convoluted nature of the surface and directly proportional to the pressure and temperature used.

4.2.4 Steam Cleaning

Purpose

Steam cleaning is to remove weathered or sticky oil coating from boulders, rock, and man-made structures.

Description

Steam cleaning equipment uses a moderate-pressure jet of steam that will remove oil from almost any surface. In addition to the physical forces of the steam jet, it also raises the temperature of the adhered oil, thereby lowering its viscosity and allowing it to flow off a surface. This method generally requires that precautions be taken to avoid impacting areas nearby and previously unaffected. It also requires special safety precautions due to the hazardous nature of working with pressurized steam.

Application

Steam cleaning is primarily used on oiled boulders, bedrock, and man-made structures (boat hulls, sea walls, piers) where the oil is not amenable to removal by other means such as flushing, spot washing, sand blasting or manual methods. This method should be used only where few living organisms are present.

Limitations

Living plants or animals attached to a surface would be unlikely to survive the high temperatures of steam cleaning. This process is not usually recommended for surfaces that support an abundance of living plants or animals.

Implementation

Cleaning should begin at the highest point of oiling, working downward, and be conducted on an ebbing tide so the lowest point is cleaned at or before low tide. The oil should be recovered before the tide rises and causes secondary pollution to the area. Oil is typically directed back onto the water where it is concentrated within containment booms positioned just offshore and recovered by skimmers, sorbents or vacuum equipment.

Plastic sheets should be placed over adjacent surfaces to prevent further oiling and flow of removed oil be directed to a collection point or back to the water. Berms or ditches can also be constructed to further channel guide the oil into collecting pools or back to the water.

Logistics

The logistical requirements for using the steam cleaning technique vary with the size of the oiled area and the capacity of the cleaning. In general, the larger the steam cleaner, the faster it can clean an area; thus, fewer units are needed. The size of the oiled area is directly related to the number of units required in order to maintain a reasonable cleaning rate. The logistics for such operation requires a steam-cleaning unit, adequate supply of fresh water, plastic sheeting, containment or sorbent booms, and means to recover freed oil.

4.2.5 Sediment Washing

Purpose

Sediment washing is to remove oiled surface material, cleanse it and replace it onto the shoreline.

Description

The oiled substrate is removed using heavy equipment or hand tools and placed into a washing unit. Washing units may be purpose-built drum types or adapted commercially available equipment, such as portable or truck-mounted cement mixers. Washing solutions may include cold or hot water, or a dispersant /beach cleaning agent solution. Consideration must be given to disposal of the washing solutions which could be regulated if surfactants are used.

Application

Primarily applicable to fine-to-medium-grained gravel (granule, pebble, cobble) shorelines where removal of sediment is undesired and other cleanup techniques are likely to be ineffective. Due to the highly intrusive nature of this technique, the associated physical and ecological impacts can be significant and the technique, therefore, is typically used for relatively small areas.

Limitations

Generally, sediment washing is unacceptable for highly productive shorelines or beaches, such as salmon and herring spawning areas that are sensitive to substrate disturbance. Although the shorelines amenable to sediment washing are typically low in productivity, the organisms that do inhabit the sediments will likely perish. Some erosion may occur during natural resorting of the sediments and some fine-grained materials will be lost during the washing process. Significant erosion can also occur if excessive shoreline is removed without replacement.

Implementation

Purpose-built sediment washers are not commonly available. They are designed as pass- through systems where the oily sediments are placed in one end of the unit and the clean sediments come out the other end for replacement onto the beach. The sediment washing system should be situated at a centralized location in the backshore of the area to be cleaned, or on a barge or vessel anchored to the shoreline. Cleaning should begin at the top of the oiled area and work should proceed parallel to the water line The oiled sediments are excavated using heavy equipment such as front-end loaders, for smaller areas, manual labour and hand tools. The sediment can be loaded directly into the washing unit or onto a conveyor that feeds the unit.

Depending upon the local regulations, wash water can be processed through an oil/water separator. The water is then discharged directly back into the sea.

Although the use of dispersants or other surfactants will enhance oil removal, they cause the oil to be dispersed into the water making separation difficult. Low toxicity beach cleaning agents will accelerate oil removal while having less of an adverse affection on oil/water separation.

Logistics

The logistics required for sediment washing will vary considerably depending on the quantity and type of material required for washing, shoreline access, the type of equipment used, and the method of wash water disposal. For larger quantities of oiled sediment, multiple washing units would be required to maintain an acceptable cleaning rate.

Larger sediments generally require larger units and may increase washing time. Shoreline access influences the type of equipment required to transport the washing units to the shoreline and may also limit the size of the unit that could be used. If the spent wash water can be separated and discharged back into the sea, only a small amount of tankage would be necessary to contain the recovered oil.

4.3 In Situ

4.3.1 Passive Collection

Purpose

To recover oil by sorption onto synthetic or natural oleophilic materials placed in the intertidal zone.

Description

Sorbent materials are anchored or otherwise installed on the surface of the shoreline substrate downslope of the oiled area. As the oil is remobilized or released from the sediments, typically on an ebbing tide, it contacts the sorbent materials and becomes immobilized. Oil migrating onto the shoreline is also recovered by the sorbent materials. Recovery effectiveness is dependent upon the capacity of the particular sorbent material. Snare booms are generally the most effective sorbent material for this technique when relatively light to heavy oils are involved. Sorbent booms are typically more effective on very light oils.

Application

Primarily used on low to moderate energy shorelines where oil conditions are light and the oil is leaching from the shoreline at a relatively low rate. This method can also be used where oil is mobile and transport of large quantities of oil is expected on or off the site. The oil must be of such a viscosity and thickness to be released by the substrate and absorbed by the sorbent material. This technique is also applicable to shorelines that are very sensitive to foot traffic and mechanical equipment.

Limitations

Passive collection can be slow thus allowing oil to remain in critical habitats during sensitive periods of time. Because it is a passive technique in nature, significant amounts of oil may remain on the shoreline after natural leaching and tidal pumping are no longer effective in removing stranded oil. This is typically due to the oil weathering to the point where it is no longer mobile. The method is also very labour-intensive and time-consuming.

Implementation

The snare or sorbent booms are installed on the shoreline using anchors and rope. In many cases the booms can be tied to large boulders or bedrock protrusions, thereby eliminating the need for anchors. If insufficient boulders or bedrock protrusions are available, anchors should be used to fix the booms in place. Danforth or mushroom are the preferred anchor types for this purpose. The number and size of the anchors should increase with the exposure of the shoreline. Sorbents are not recommended on high-energy shorelines, and should be regularly inspected, since they will be lost during periods of strong wave action.

Because the booms are situated in the intertidal zone just below the oiled area, allowances must be made for the rise and fall of the tide. Booms should be attached to the anchor points with sections of poly or nylon rope. Each rope section should be long enough to prevent the boom from submerging at high tide, but not so long to allow the boom to be pushed up into the oiled area by an incoming tide. Sorbent booms are often susceptible to breakage at their connecting points, even in light wave conditions, and should be strengthened by running poly rope along the entire length of the sorbent booms and attaching it to the booms with cable ties. This, however, is not necessary for snare booms as the snares are already attached to a length of poly rope. The booms should be checked periodically at various tidal stages to assess their performance and make adjustments to the anchor points and line lengths as necessary. Booms should also be checked periodically for oil saturation and replaced as needed. Sorbent booms also must be rotated periodical1y to maximize oil sorption capacity if wave action does not rotate them naturally.

Loglstics

The logistical requirements for passive sorbent use vary with the degree of shoreline oil conditions and the size of the oiled area. Specific manpower and equipment requirements depend on the length of boom used and the nature of the area in which it is deployed.

4.3.2 Relocation to Surf Zone

Purpose

To permit the natural cleansing action of waves to remove oil which has penetrated into beach sediments, and which is not removed by normal wave action from the subsurface.

Description

Heavy equipment, such as front-end loaders or bulldozers, are used to transfer the oiled sediments into the middle portion of the intertidal area where wave action and increased sediment movement will enhance natural abrasion and washing action. For small areas with limited access, sediments can be relocated manually using shovels or buckets. The sediments are returned to the upper portions of the beach within a relatively short period of time through natural wave and tidal action.

Application

Typically used on moderate to high energy shorelines with lightly to moderately oiled sediments which are located in the higher portion of the upper intertidal or supratidal zones. The method is also used on heavily oiled beaches where sediment removal may cause backshore erosion.

Relocation to the surf zone can be used on gravel and cobble beaches which are not heavily oiled and where flushing techniques have not been successful in removing oil which has penetrated into the upper beach surface. There must be sufficiently large waves on the beach to provide the energy for agitation of the sediments.

Limitations

This technique should not be used on shorelines with a high sensitivity to sediment disturbance, for example, during fish spawning, or on those parts of the shore with highly productive attached organisms, such as mussel beds and seaweed. This technique also is inappropriate for shorelines c1ose to sensitive areas, such as bird rookeries, as the oil that is released is rarely fully contained and could impact adjacent areas. It should not be used on fine-grained sediment beaches due to the potential for sediment loss resulting from alongshore suspension and movement of sediment in the water.

Implementation

Ideally, relocation should be conducted during neap tides with the deposition area situated just below the neap high tide line. This would maximize the time during which waves are directly acting on the material relocated. As the tide height increases, at least some of the sediments will be pushed up to the beach while maintaining maximum exposure to wave action.

Logistics

The logistical requirements for sediment relocation depend upon the equipment used, the relocation distance and the amount of material requiring relocation. If the size of the area or quantity of material is large, or the relocation distance significant, several pieces of equipment may be needed to maintain a reasonable cleaning rate.

4.3.3 Sediment Tilling

Purpose

Sediment till is to turn the oiled sediments over or break up oiled layers, enhancing the natural degradation rate of the oil by exposure to weathering and to abrasion by wave action. Oil is mixed throughout the upper sediment profile, thereby increasing the surface area exposed to weathering.

Description

Oiled areas are tilled to break up thin asphalt layers or light to moderately oiled sediments, as a means of maximizing their exposure to physical, microbial and photochemical degradation processes. The surface and near-surface beach sediments are mechanically or in some cases manually tilled or dried using a tractor equipped with cultivating tines or other apparatus. For small areas, hand tools such as shovels, etc. can be used to till the surface sediments. This process is often repeated over time to further speed the rate of degradation. Although this technique is rapid and efficient, the oil is not removed but broken up and mixed into the top layer of sediments and left to degrade naturally.

Application

Sediment tilling is primarily applicable to finer gravel and sand or mixed sediment beaches with moderate to high exposure and relatively good trafficability. Generally this method is used on non-recreational shorelines with light oil conditions existing either as a thin pavement on the surface or coatings on surface and near surface sediments. On heavily oiled beaches, there is the potential for mixing amounts of oil into the substrate which may prolong oil residence time.

Limitations

Sediment tilling should not be used on beaches near shellfish-harvest or fish-spawning areas because of the potential release of oil for a period of time. In some cases oil can be mixed deeper into the sediments and prolong its persistence. On beaches with a coarse sediment armouring over finer grained materials, tilling can result in the loss of some of the finer materials due to the erosional effects of the waves and alongshore transport.

Implementation

The tilling equipment discussed above is the same as that used for agricultural operations. The tilling procedures should begin along the backshore edge of the oiled area and continue parallel to the surf to the end of the oiled area The new path is started adjacent to, and slightly overlapping, the previous one. Tilling should be conducted at low tide to avoid operating the equipment in the water. If wave conditions permit, containment or sorbent type booms should be positioned off shore just beyond the surf line for the first several tidal cycles to contain and recover oil that is released by the tilling. Typically a large percentage of the oil is released from a tilling operation during the first few tidal cycles.

Logistics

The logistical requirements for sediment tilling are primarily dependent upon the size of the oiled area. Under normal circumstances, unless the area is very large, one tractor and tilling device can usually maintain a sufficient cleaning rate. The shoreline area that can be cleaned within a specified time by tilling is governed by the speed of the tractor and the width of the tilling equipment.

4.3.4 In Situ Bioremediation

Purpose

In situ bioremediation is to accelerate the oil degradation processes by stimulating the growth of existing natural microbial communities.

Description

Species of oil-metabolizing microbes exist to varying degrees on most shorelines, and begin to reproduce rapidly in the presence of a carbon source such as an oil spill. As the microbes metabolize the carbon in the oil, they also utilize various nutrients including nitrogen and phosphorus. Once the supply of nutrients is depleted, the microbes rapidly die off and the natural degradation rate of the oil similarly decreases. Bioremediation involves the application of a nitrogen and phosphorus fertilizer to the beach to enhance the microbial population and maintain a high rate of hydrocarbon metabolization or degradation.

Although bioremediation has been applied in some countries in the world, and some enterprises are devoted to the development of bioremediation techniques, this method has not been used actually during shoreline treatment in NOWPAP region till now. And the information on actual use of bioremediation in this region has not been collected.

4.3.5 Log/Debris Burning

Purpose

The purpose of burning oiled logs and debris is to minimize material handling and disposal requirements.

Description

Moderately to heavily oiled logs and other oiled organic debris including driftwood, cut vegetation, dried kelp and seaweed, and spruce needles, are placed in a pile on the beach at least 20 m from any combustible materials (clean logs and debris, local vegetation, trees) and burned. Larger logs and debris can be cut into smaller pieces for easier handling. Small, hand-held weed burners can be used to burn oil off moderately to heavily oiled logs. The intention is to selectively remove the heavy oil without having to dispose of the entire log. In some situations, oiled vegetation may be burned in place if the proper precautions are taken to prevent the fire from spreading beyond the oiled area. Fans or blowers can be used to sustain or increase combustion.

Application

Log/debris burning is primarily applicable to situations where driftwood is heavily oiled and presents either a potential source of oil release, an aesthetic problem, or the possibility of ingestion by animals using the beach. Burning is also used where removal of the logs is not desirable or feasible, or for aesthetic reasons in areas which receive high recreational use. Burning can be used on any beach type with safe access, a sufficient quantity of oiled logs, organic debris, and/or vegetation, and where local air quality regulations permit. (Burning can also be used in marshes or estuarine environments where large areas of grasses or other vegetation have been oiled and cutting would create too great an impact.)

Limitations

Non-organic or wet debris, such as oiled plastics, sorbents, and wet seaweed or kelp are *NOT* burned on-site. Open burning of materials in a manner which produces large amounts of black smoke should be avoided. In some cases, burning permits from the local air quality agency and/or landowner may be required. The heat generated by burning may impact any near-surface organisms in close proximity to the burning area. Burning should not be conducted during high wind conditions unless the wind is blowing seaward.

Implementation

Prior to burning, a plan that provides for safe, controlled burning should be prepared. Larger logs and debris should be cut into smaller pieces with chain saws to facilitate handling and minimize the size of the pile for burning. The pile itself should not be greater than 5 to 7 m in diameter to ensure that it can be easily controlled. In conducting burning operation, fire extinguishers, water hoses, or other fire control equipment should be at hand in case that the fire does begin to get out of control. Kerosene or diesel fuel can be used to aid in starting the fire, particularly if the material is wet or if it is raining. Once the fire is ignited, blowers (gasoline powered fans) can be placed around the perimeter of the fire and directed towards the fire to promote combustion and to increase temperatures which, in turn, reduces smoke. If vegetation is to be burned in place, the fire should be started at the upwind end and allowed to burn downwind. It may be necessary to section off the burn area with fire breaks to ensure controlled burning. Blowers generally have little effect on fires covering large areas and therefore are not recommended in this application. Once all of the oiled material has been burned, water should be applied to any smoldering areas to ensure that the fire is completely out and that re-ignition is not possible.

Logistics

The logistical requirements for burning logs and debris differ somewhat from burning vegetation in situ, but are concerned primarily with maintaining combustion and controlling the fire. The amount of heat required is dependent upon the ambient temperature and flammability of the oil, as well as the presence of precipitation. In general, once the fire is burning, combustion is self-sustaining unless the material is wet. Combustion promoters such as kerosene or diesel fuel can be used if necessary. The amount of fire control equipment required depends on the size of the pile or area to be burned and proximity to other sources of combustion. Table B-18 provides the logistical requirements for both burning piles of logs and debris and burning vegetation in place.

4.3.6 Chemical Treatment

Purpose

Chemical treatment is to increase the efficiency of oil removal from oiled shorelines, primarily during washing operations. Environment protection authorities of appropriate NOWPAP members shall approve their usage.

Description

The two common types of treatment agents are dispersants and surface-washing agents. Dispersants break down oil into small droplets, whereas washing agents lift oil from surfaces by detergency. These two mechanisms are entirely different. Dispersion makes recovery of the oil difficult whereas oil remobilized by a washing agent can be recovered.

Application

Chemical treatment is primarily applicable to gravel, bedrock, or manmade substrates; and to sticky weathered, or viscous oils. This technique may be most applicable when flushing becomes more difficult as the oil continues to weather. It is also useful in removing oil from near-surface sediments.

Limitations

Dispersant use is not recommended for ecologically sensitive shorelines or where adjacent nearshore areas are sensitive to increased oil concentrations in the water column, such as during fish spawning or emigration periods. In many cases, use of chemical treatment will require at least some biological toxicity tests and water-quality sampling prior to approval for the operation. Short-term toxic effects to organisms on the substrate and in the nearshore water column are possible because of the likelihood that oil will be dispersed into the water column and not recovered by booms, skimmers, or sorbents. The toxicity of chemical agents approved is unlikely to be significant on its own; rather, there is an increased toxicity of the oil plus chemical agent.

Implementation

Chemical agents are generally applied neat (undiluted) by spraying them onto the oiled sediment and allowing them to soak for a designated period of time. In doing this, a garden sprayers are acceptable for applying agents to small areas whereas backpack type garden sprayers, or even airless paint sprayers, are more suitable for larger areas. Containment or sorbent booms are often positioned in the water offshore just beyond the surf line, if present, to contain and concentrate the removed oil for recovery. The shoreline is then washed with warm water, typically using the flood and flush method to let the oil float back into the water for recovery. Water streams from hoses can be used to direct the re-floated oil to the recovery devices. In some cases, water soluble cleaning agents can be mixed into the water used for flushing to aid in removing oil from the sediments. This can be done either in addition to, or in place of, the presoak, although it is usually less effective if used without the presoak. Mixing of the cleaning agents with the wash water is best accomplished using an eductor with an adjustable suction orifice. Eductors are commonly used to introduce foam into water streams during fire fighting operations. Water passing through the eductor creates a vacuum which draws the chemical agent into the water stream which is then mixed by turbulent flow.

Logistics

The logistical requirements for chemical treatment vary considerably depending on whether the chemical agent is to be applied neat or in solution. They are also dependent on the size of the area to be treated and the concentration at which they are applied. In general, the larger the area and the heavier the oil conditions, the greater the number of application units required to maintain a sufficient cleaning rate. The quantity of chemical beach cleaning agents is also directly proportional to the size of the oiled area and the amount and type of oil.

4.3.7 Natural Recovery

Purpose

Natural recovery is to minimize environmental impact allowing natural degradation to remove oil from the shoreline.

Description

No cleanup activities are conducted on the shoreline. Removal of the oil is left to natural processes such as evaporation, erosion, biodegradation, photo-oxidation, dissolution and dispersion.

Application

Natural recovery is primarily preferred on highly exposed shorelines with light to moderate oil conditions and coarser grained sediments (primarily cobble, boulder, and rock) where wave action and other natural processes will remove most of the oil in a relatively short period of time. It is also frequently preferred on shorelines with little or no access, where cleanup operations would cause significant ecological impacts, or where safety factors constrain cleanup operations.

Limitations

Natural recovery is typically not suitable for low energy shorelines or heavy oil conditions where the oil would be expected to persist for substantial periods of time, particularly if the oil is fresh and relatively toxic. It is also not recommended for situations where the oil is very mobile and could impact down-current or nearby sensitive areas.

Implementation

No action is taken, except that the shoreline should be monitored periodically to determine if natural cleaning is sufficient and the oil is not remobilizing and impacting other areas. The natural cleaning rate varies with the level of exposure and amount of wave energy on the shoreline.

Logistics

Logistic requirements are not applicable to natural recovery.

Chapter 5

Strategies for Specific Environment

The response strategies and guidelines introduced in Sections 3, and 4 relate to typical operating conditions, which may vary from one location to another. With this in mind, this section considers specific environmental settings in which the overall strategies would need to be modified to adapt to the operating conditions.

Response Strategies:

Section 5.1. Tidal Inlets
Section 5.2. Remote Areas
Section 5.3. High Tidal Ranges
Section 5.4. Nearshore Shallow Waters with Submerged Oil

5.1 Response Considerations and Options for Tidal Inlets

Tidal inlets occur where the exchange of water between a backshore lagoon or bay must pass through a relatively narrow opening to the open sea. If the entrance to the lagoon or bay is wide, as in the case of most estuaries, the ebb and flow of the tide is physically unrestricted. Where a spit or barrier beach has grown across the embayment or estuary, this creates a narrow opening through which the tidal waters must pass as they rise and fall.

5.1.1 Physical Character of a Tidal Inlet

Inlets usually form on coasts where there is an available source of sediments to alter the configuration of the shoreline by the build up of a spit or barrier beach across a bay or estuary. Sediments also are redistributed in the areas adjacent to the inlet to form shoals and shallow areas that usually have a distinctive and recognizable pattern.

The constricting effect of the inlet on the tide causes current speeds to be greatest in the narrowest part of the inlet throat. The sediments that are carried through the inlet throat by the ebbing or flooding tides are deposited as the current slows down once it has passed through the throat. This results in the formation of shoals or underwater deltas on either side of the inlet throat.

The ebb-tidal delta that is created on the ocean side of the inlet usually is entirely underwater, even at low tide, as these sediments also are reworked by wave action. This reworking by waves gives a rounded character to the outer part of the ebb delta.

The flood-tidal delta that is created on the lagoon or bay side of the inlet usually is completely underwater at high tide, but largely exposed at low tide.

Not all inlets appear exactly as described above. On coasts where there is a dominant longshore drift of sediment in one direction, the inlet may have barrier beaches that overlap, creating a tidal inlet channel parallel to the coast. The same features of the tidal inlet are recognizable, although the deltas likely would be strongly skewed in the direction of the drift.

5.1.2 Tidal Currents

The pattern of the tidal currents is controlled in part by the shape and character of the channels and shoals of the ebb and flood deltas. These effects are more important during the lower half of the tidal cycle when parts of the deltas are exposed or very shallow.

In addition to varying water depths, the second factor that controls current patterns relates to the outflow from the bay or lagoon. At the low-water slack, as the tide is turning from ebb to flood, the water in the lagoon or back bay often continues to drain out. This drainage continues after the tide has turned if there is a large volume of water entering the bay from rivers or if the narrowness of the inlet throat does not allow all of the water to empty out of the bay in the available time. If the bay cannot drain within the ebb time period, then a situation occurs in which the water level on the bay side of the inlet is still higher than the water level on the ocean side during the early flood-tide stage.

The length of time that the ebb drainage encroaches into the flood tidal cycle is controlled by the amount of water that must drain through the inlet combined with the narrowness of the inlet throat. The volume of water that must drain out is a function of (a) the area and depth of the bay or lagoon, (b) the tidal range, and (c) the amount of river input. If the drainage volume is small or the inlet wide, the drainage may not significantly affect the incoming flood tide. If the bay has not drained fully by the end of the low-tide slack period, the flood tide is pushed into the inlet by the rising water level on the ocean side. The result is that the ebb continues to run through the center of the throat and the main ebb channel, draining the bay for 1 to 2 hours, while the flood attempts to enter the throat by one or both marginal flood channels. This current pattern continues until the bay and ocean water levels are equal, at which point the ebb drainage ceases and the flood tide is able to enter the inlet unimpeded.

The pattern of the currents through the tidal cycle can be summarized as a sequence of stages in which there is a distinct change in either location, direction, or water movement.

- ***Stage 1: Low Tide - Early Flood Tide***

  Normally, in the absence of an outflow from the bay through the inlet, the currents would be slack during the turn from the ebb to the flood. In reality, during this period of ebb drainage, after the turn of the tide, there is a strong seaward flow (often referred to as a "tidal jet") in the central inlet throat and in the main ebb channel. At the same time, there is a landward flow toward and into the inlet throat in one or both of the marginal flood channels.

  At this tide stage, when the water level is still relatively low, the main body of the flood delta is exposed, so that both the ebb drainage and the flooding currents must use channels on either side of the delta.

- ***Stage 2: Mid-flood Tide-High Tide***

  After the ebb drainage is finished, when the water levels are the same on both sides of the inlet, there are only flood currents in the inlet system. The currents are initially confined to the channels on the margins of the flood-tidal delta and the maximum flood current speeds usually occur after mid-tide when the flow is still restricted by the flood tidal delta. As the water level rises, the flood tidal delta is progressively submerged until water can flow completely across the entire delta, at which time the current is less restricted and the speed is slower.

- ***Stage 3: Early - Mid-Ebb Tide***

  As the tide turns, the tidal currents are initially slack for a period of several hours, then they reverse direction. If there is river drainage into the bay or lagoon, the currents flow seaward as these waters drain through the bay. The flood-tidal delta is submerged at this stage. The currents are strongest in the inlet throat (the "tidal jet").

- ***Stage 4: Mid-Ebb-Low Tide***

  As the water level falls, the flood tidal delta is progressively exposed until water only can flow around the margins of the flood tidal delta during the late ebb stage. The ebb current speeds usually increase as the tide falls and reach a maximum just before low tide as the out-flowing waters become more and more restricted in the channels.

5.1.3 Response Strategies for Tidal Inlets

If the objective of a response is to prevent oil from entering or exiting a lagoon or bay through a tidal inlet, the feasibility of a protection strategy is affected by current speed, current direction, and water depth. Inlets are very dynamic environments in which all three of these variables are changing continuously.
Some key points to bear in mind when developing a practical strategy include:
- Currents are faster in the inlet throat at all times, so that this is a location where response actions are likely to be least successful;
- Current conditions and water depths continuously change and generally will change significantly within a matter of hours.

- ***Oil in the bay:***
  - During an ebbing tide, redirection and/or recovery of oil is more likely to be successful on the bay side of an inlet, as a confused sea often develops on the ocean side where waves and tidal currents interact;
  - Ebb currents are likely to be strongest during the last hours before low tide.

- ***Oil on the ocean side:***
  - during the initial stage of a flooding tide, oil only would be transported into the inlet near the shore in one or both of the flood marginal channels;
  - during a flood tide, after the ebb drainage ceases, redirection and/or recovery of oil is more likely to be successful on the bay side of an inlet where the waters are sheltered from wave action;
  - after the ebb drainage ceases, the flood tide would carry oil in the channels around the flood tidal delta; and
  - flood currents are likely to be strongest during the 2-hour period after mid tide.

Based on this knowledge, some possible strategies for redirection and recovery are presented, using nearshore (on-water) and shoreline booming techniques.

- During ***Stage 1***, oil could be redirected (a) in the marginal flood channels towards the shore for recovery, or (b) away from the shore towards open water to bypass the inlet. In this illustration, the longshore drift is from the right and so the strategy shown would be for oil being transported towards the inlet from this direction.
- By ***Stage 2,*** the focus would likely shift to a strategy of redirection towards the sheltered beaches on the backside of the barrier by cascading booms in the channels in the lagoon.
- With the onset of the ebb (***Stage 3***), oil could be redirected away from the inlet throat, in the area of the shallow but submerged ebb shield, and towards the back-barrier beaches.
- As the water level lowers with the tide, booming would be only in the channels (***Stage 4***).

5.2 Response in Remote Areas

Remote areas are defined as locations where little or no local infrastructure exists to support spill response operations. The effect is that shoreline cleanup would have to be conducted from temporary onshore or floating offshore/ nearshore staging areas that could accommodate personnel and equipment overnight. Many coastal regions away from built-up areas would be considered remote and response activities and would require logistical support to stage a shoreline treatment programme.

The need for logistical support in a remote area places focus on activities that:

- Limit the need for extensive equipment and personnel resources, and
- Minimize waste generation.

With these two constraints in mind, the preferred response is to prevent the oil from reaching the shoreline if and when possible. If this is not feasible or practical, the preferred onshore option is to treat the oil in situ so that environmental recovery is accelerated without the requirements for a labour-intensive effort or waste management of large volumes of solid or liquid materials.

If natural recovery is not an acceptable option, the basic methods of in-situ treatment are:

- Tilling (with bioremediation),
- Surf washing,
- Burning (particularly logs and debris),
- Dispersants, and
- Bioremediation.

The decision-making process for remote areas initially identifies where a protection or treatment response is required (Section 1.3). Once it has been established that a response is required, the recommended strategy is to:

a) Contain and collect the oil on the water surface, if and when possible.

b) If the shoreline is oiled, then determine if the objective is to allow natural recovery, restore the shore to its pre-spill condition, or to remove bulk oil and accelerate recovery. To select a treatment method, or combination of methods:
   - Identify the substrate type that has been oiled and refer to Section 3.0;
   - From the "Summary by Oil Type" section for that substrate, see the appropriate oil type in the table;
   - Identify any in situ methods that may apply; and
   - Assess if the available in situ option (s) would apply to the situation in this remote location.

c) If an in situ option is not applicable, then:
   - Evaluate the feasibility of one of the other alternatives in terms of logistics and waste management/disposal requirements.

5.3 Response on Coasts with High Tidal Range

5.3.1 Tidal Environments of Mid-Latitude Regions

A high tidal range (> 4 m) usually means that the nearshore environment has:

- Strong tidal currents, and
- A wide intertidal zone that is exposed at low tide.

These coastal characteristics can have significant implications in terms of response operations to protect shorelines in areas of strong currents or dealing with stranded oil. In the case of a wide intertidal zone, tidal range is not the only factor as low slopes combined with tidal ranges greater than 2 m can produce a similar effect. This section, therefore, is intended to focus on coasts that have either:

- A high tidal range (>4 m), or
- Low slopes with tidal ranges between 2 and 4 m.

5.3.2 Response Considerations in Areas with a High Tidal Range

The exposure of a wide intertidal zone to oil as it washes ashore leads to the possibility that a large surface area may become oiled.

The speed with which the rising (flood) tide covers the intertidal zone can be very rapid, particularly where slopes are low or flat, so that for operations in the intertidal zone that are solely land based, great caution must be exercised to:

- Time the intertidal activities with the changing water levels.

Although predicted tides are accurate at a particular site, the effects of winds and wave action can alter actual water levels. Surges (higher water levels) or set-downs (lower water levels) are common in all coastal environments so that actual rather than predicted conditions must be factored into schedules and work plans.

Where appropriate, barges or flat-bottomed boats may be used to support operations and personnel. These can then ground on the falling tide and be refloated by the flood tide. They have the added advantage of providing a form of transport in unforeseen conditions, such as an unexpected surge condition.

Tidal flats frequently do not fully drain by low tide so that the presence of surface water may act to prevent persistent, medium or high viscosity oils from adhering to the sediments. These oils may then be remobilized by the rising (flood) tide. Non-persistent or low-viscosity oils may mix with the water. In both cases, the tendency would be for the oil to be carried landward, except where strong offshore or alongshore winds would counteract the effect of the onshore (flood) current. Heavy weathered oils, because of their viscosity and density, may not be remobilized and could be submerged by the rising (flood) tide.

Shoreline booms or nearshore booms are not likely to be very effective in areas with high tidal ranges, strong tidal currents and rapid water level changes. Nearshore protection tactics are less likely to be effective so that on-water protection is the preferred strategy.

5.3.3 Response Options in Areas with a High Tidal Range

The decision process for areas with a high tidal range initially identifies where a protection or treatment response is required (Section 1.3). Once it has been established that a response is required, the recommended strategy is to:

a) If possible, contain and collect the oil on the water surface.
b) If the shoreline is oiled, then determine if the objective is to restore the shore toils pre-spill condition or remove bulk oil and accelerate recovery. To select a treatment method, or combination of methods:
   - Identify the substrate type that has been oiled (Section 3);
   - In the "Summary by Oil Type" section for that substrate, see the appropriate oil type;
   - Identify any methods that may apply; and
   - Evaluate the feasibility of one of the alternatives in terms of logistics, efficiency, effectiveness, and effects.

5.4 Nearshore Shallow Waters with Submerged Oil

5.4.1 Factors that Cause Oil to Submerge

Although most oils float on the water surface, spilled oil can submerge if it is denser than the water. Submerged oil is defined as oil that floats in the water or sinks to the sea or river bed. There are four conditions under which this can occur:

a) Heavy crudes or products that initially have a density greater than that of sea water, or, other oils that originally were less denser than sea water but that have weathered to become denser.
b) Oils that mix with suspended sediments in the surf zone can sink as the density increases with the incorporation of the sediments. Some products are close to the density of sea water (e.g., No. 6 fuel, Bunker C) so that only a relatively small increase in density is necessary to effect this change.
c) Stranded oils often are mixed with sediment in the intertidal zone under wave action. The incorporation of beach sediment increases the density and if that oil-sediment mixture is then refloated, for example, by a rising tide, it can be carried into the nearshore waters and submerge or sink.
d) Certain products are a blend of refined oils. If the blend separates after spilling, the heavier component may have a density greater than that of sea water and submerge or sink.
e) Heavy crude or products that weathered offshore could submerge when they drift to brackish water nearshore. Because the density of weathered crude or products is coming close to that of sea water while the density of brackish water is almost 1.0.

A fifth condition in freshwater environments relates to the formation of an heavier-than-freshwater emulsion by physical mixing, such as by the turbulence associated with river rapids.

Oil can rise in the water column or from the sea bed under a variety of conditions. The sand may separate from the oil by gravity, provided that oil has not weathered to the point where the viscosity changes prevent this process, e.g., in the case of tar balls. Seasonal temperature changes could modify the viscosity and/or temperature of the oil, but a short-term temperature change is not considered to be one of the factors. A change in water density, for example, where cold and warmer water meet or where surface ice melts on sea water, could cause oil to rise or submerge.

5.4.2 Detection of Submerged Oil

The character of the submerged oil closely affects the ability to accurately assess the location and scale of the problem. Detection is more difficult if the oil is in the water column, particularly in the form of submerged droplets, than if there is a large patch of oil resting on a sandy bottom in shallow water.

In clear water conditions, visual observations from an aircraft or a boat, or by a diver, can identify oil patches in depths up to 30 m. However, there are pitfalls

associated with observations from the air or water surface that include:
- Changes in the colour of bottom sediments,
- Coarse-sediment patches or bedrock outcrops, and
- Bottom vegetation.

Diver observations are preferred and are limited only by depth, range (area), and safety considerations.

Where the water is not clear, is deeper, or where there are changes in bottom features, then
- Remote sensing techniques (geophysical, sonar, or acoustic),
- Bottom sampling devices (grab or core samplers), or
- Remote operated vehicles with a video system,

can provide information on the location and extent of oil.

5.4.3 Recovery of Submerged or Sunken Oil

Recovery of sunken oil is more difficult than recovery of surface oil because:
- It is more difficult to locate the oil during the recovery activity,
- The oil is mobile or floating, and
- Recovery methods may involve collection of large volumes of water with the oil.

- Techniques that may be appropriate include:
  - Manual recovery,
  - Pumps and vacuums,
  - Nets, or
  - Dredging.
- Manual recovery with nets or rakes may be practical for viscous or semi-solid oil in shallow (<2m) water depths. Similarly, divers can manually recover small amounts of viscous or semi-solid oil. Snares may be useful where they can recover oil.
- Hand-held (water depths up to 2m) or diver-held (water depths up to 30 m) vacuum systems can be used for oil that will pump.
- Towed nets may be appropriate for floating submerged or near-bottom oil, depending on the oil viscosity and the net mesh size.

Limitations

The manual techniques are limited in the area that can be efficiently covered and by the large volumes of oil-water that must be transferred, stored, and separated. As water depths or as the scale of the oiling increase, the effectiveness of these manual recovery methods decreases rapidly.

Large amounts of oil on a sea or river bed, combined with deeper water conditions (>2 m), largely preclude the manual, vacuum/ pumping, or net recovery techniques. Under these circumstances, the use of commercially available dredge or pump systems may be the only practical solution for recovery. These recovery techniques generate large volumes of sediment and water that require appropriate storage and separation facilities.

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Annex B

Sediment Size

Artificial Fill

Material placed by man at the shoreline to raise the land surface or extend land into the water, for example, in the construction of roads across shallow bays. The material usually contains a range of sediment sizes and would be equivalent to natural mixed sediment, but generally is more hard-packed and poorly sorted.

Bedrock

Solid bedrock or rock that occurs at the coast or in the shore zone. Synonymous with rocky shores that are steep (> 45º) includes platform (bedrock) and shelving bedrock shore types, both of which have low-angle or near-horizontal slopes.

Boulder

A class of sediments with a grain size diameter greater than 256 mm (10 inches).

Clay

A class of sediments with a grain size diameter less than 0.004 mm.

Coarse Sediment

A descriptive term that is synonymous with shingle and is almost synonymous with the term gravel; that includes all sediments larger than sand (i.e., granule, pebble, cobble, and boulder sediments). From an oil spill perspective, there is a distinct difference between fine sediment and coarse sediment in terms of penetration, retention, and operations.

- Penetration and retention of oil in a beach: as only light oils (gasoline or diesel-like products and light crudes) can penetrate fine sediment, whereas all except the very viscous oils can penetrate into coarser sediments.
- Operations: as the bearing capacity and traction for vehicles decreases significantly as the sediment size becomes coarser than sand.

Cobble

A class of sediments with a grain size diameter greater than 64 mm (2.5 inches) and less than 256 mm (10 inches).

Fine Sediment

A descriptive term that includes all sediment smaller than granules (i.e., sand, silt, and clay). From an oil spill perspective, there is a distinct difference between fine sediment and coarse sediment in terms of:

- penetration and retention of oil in a beach: as only light oils (gasoline or diesel-like products and light crudes) can penetrate fine sediment, whereas all except the very viscous oils can penetrate into coarser sediments, and
- operations: as the bearing capacity and traction for vehicles decreases significantly as the sediment size becomes coarser than sand.

Granule

A class of sediments with a grain size diameter greater than 2 mm (0.08 inches) and less than 4 mm (0.16 inches).

Gravel

The term gravel includes all sediments in the pebble, cobble and boulder size ranges, i.e., all sediments with a grain size diameter greater than 4 mm (0.16 inches). The term gravel is almost synonymous with coarse sediment, except that gravel does not include the granule fraction.

Mixed Sediment

The term includes all sediments in the sand, granule, pebble and cobble size ranges, i.e., with a grain size diameter greater than 0.0625 mm (0.002 inches) and less than 256 mm (10 inches). This sediment type is distinctly different from sand or fine sediment types, and gravel or coarse sediment types as the coarser fractions pebbles and cobbles) are infilled with sands and granules. From an oil fate and persistence perspective, in terms of oil penetration and retention, this sediment type is similar to a sand beach, whereas from an operational perspective, in terms of bearing capacity and traction, the sediment is more similar to pebble and cobble sediments.

Mud

A general term for sediments composed of silt and clay.

Pebble

A class of sediments with a grain size diameter greater than 4 mm (0-16 inches) and less than 64 mm (25 inches). Sometimes referred to as pea gravel.

Riprap

Material placed by man as a shoreline control structure to prevent erosion or to provide protection from wave action, for example, as a breakwater. The material may be quarried rock, concrete forms (e.g., dolos), or construction debris. The material has a grain size diameter greater than 256 mm (10 inches) and is therefore analogous to natural boulder sediments. The structure usually is built so that the material is not moved by wave action and therefore is immobile.

Sand

A class of sediments with a grain size diameter greater than 0.0625 mm (0.002 inches) and less than 2 mm (0.08 inches).

Silt

A class of sediments with a grain size diameter greater than 0.004 mm and less than 0.0625 mm (0.002 inches).

Annex C

Shoreline Types and Environments

Shoreline protection and cleanup decisions depend to a large degree on the physical character of the shore-zone.

The acquisition of information on the physical character and the coastal processes that operate on a shoreline, at the time of a spill event, is an important element in making decisions concerning the type of protection and cleanup countermeasures ~~t~~hat may be implemented during a response.

Shoreline types

The shoreline types in NOWPAP Region can be categorized as in the following table in which, form, texture, slop, permeability and trafficability are summarized.

SHORE-ZONE CLASSIFICATION GUIDE

Form	Texture	Shore Zone Type	Permeability	Comments
BEDROCK SUBSTRATE				
Cliff	——	Bedrock Cliff	Impermeable; oil on surface only	• oil may not adhere to wet middle and lower tidal zones • thickness of stranded oil cover decreases as slope increases • access and trafficability often difficult; wet, vegetated or oiled surfaces very slippery • surface character dependent on rock type and, where applicable, strike and dip of rock layers
Platform	——	Bedrock Platform	Impermeable; oil on surface only	
SEDIMENT SUBSTRATE				
Beach	Boulder-cobble	Boulder-cobble beach	Highly permeable for all classes of oil; class A and B may be flushed by tidal action	• oil penetration likely; possibly greater than 1.0m • traction very poor for most equipment, especially on sloping surfaces • sediment replenishment rates usually very slow so that sediment removal should be avoided • surface form often irregular; cobble beaches may have storm ridge above tidal zone
	Pebble-cobble	Pebble-cobble beach	Highly permeable for Class S and B oils; surface penetration only<25 cm for Class C and D in most cases	• penetration dependant on oil type and sediment size • untreated oils (except Class A) may form an asphalt pavement • traction poor for most equipment, especially on sloping surfaces • sediment replenishment rates usually very slow so that sediment removal should be avoided • beach backed usually by ridge/berm system

SEDIMENT SUBSTRATE(continued)				
Beach (continued)	Sand–gravel	Sand-gravel beach	Low permeability to all but Class A oils, interstitial pore spaces filled by sand	• penetration dependant on oil types; usually only surface oiling • untreated oils (except Class A) are likely to form an asphalt pavement • traction poor for most equipment • sediment replenishment rates usually very slow so that sediment removal should be avoided • intertidal zone gives way landward often to ridge/berm landforms
	Sand	Sand beach	Low permeability to all but Class A oils	• only surface oiling; except for Class A oils • traction good but dependent upon slope • beach surface changes frequently due to wave and tide action so that burial or erosion of surface oil may occur rapidly
Flat	Boulder-cobble	Boulder-cobble flat	Highly permeable for all classes of oil	• penetration inhibited by interstitial water in lower tidal zones; oil may pool in depressions • traction very poor for most equipment • sediment replenishment rates usually very slow so that sediment removal should be avoided
	Pebble-cobble	Pebble-cobble flat	Highly permeable for Class A and B oils; surface penetration only (<25cm) for Class C and D in most cases	• penetration inhibited by interstitial water in lower tidal zones; oil may pool in depressions • untreated oils (except Class A) may form an asphalt pavement • traction poor for most equipment • sediment replenishment rates usually very slow so that sediment removal should be avoided
	Sand–gravel	Sand-gravel flat	Low permeability to all but Class A oils	• usually only surface oiling; penetration inhibited by sand in interstitial pore spaces and by water in lower tidal zones • untreated oils (except Class A) are likely to form an asphalt pavement • traction poor for most equipment • sediment replenishment rates usually very slow so that sediment removal should be avoided • sands may be easily redistributed by wave and tide action causing rapid burial or erosion of surface oil

SEDIMENT SUBSTRATE(continued)				
Flat (continued)	Sand	Sand flat	Lower permeability to all but Class A oils	• only surface oiling; except for Class A oils • traction good on dry areas only • sands are easily redistributed by wave and tide action causing rapid burial or erosion of surface oils • sand waves (or ridges) are a common feature
	Mud	Mud flat	Very low permeability to all classes of oil	• surface oil only unless penetration into burrows, worm holes, etc. • traction good in dry areas only • most mud is very easily transported by wave and tide action so that surface oil may be eroded or buried rapidly
MANMADE SUBSTRATE				
	Variable	Variable	Variable	• most man-made structures can be compared to natural shore-zone types (e.g. concrete walls = bedrock cliff; concrete cast forms = boulder/cobble beach; etc.) • pilings may be considered as "bedrock" as they are impermeable
VEGETATION SUBSTRATE				
Flat	Mud, sand	Marsh, estuary lagoon	Low permeability to all but Class A oils	• oil usually remains on the surface of marshes with little penetration (<25cm) except for light oils • access and trafficability often difficult; movement of personnel and equipment across marsh surfaces can cause more damage than oil alone • flat marsh areas usually give way to mud creeks or flats on seaward margins • reed beds not usually considered a shore environment; in nearshore zone

Remark:

Class A: Low Viscosity oils
Class B: Medium Viscosity oils
Class C: High Viscosity oils
Class D: Semi-Solid/Solid oil

Environments

In order to successfully implement the strategies during an oil spill event, shoreline environments is another important factor which should be considered.

For a very exposed shoreline, the wave energy can strongly impinged on it, and the oiled shoreline could be washed naturally. On the other hand, for a sheltered oiled shorezone, the oil could stay for a longer time.

Coastal processes can influence logistics and operations, implementation of protection options and crew safety.

Shoreline exposure can be estimated by calculating the fetch distance and fetch window.

Fetch is defined as the continuous area of water over which wind blow in essentially a constant direction.

Fetch Distance: Fetch Distance is the linear distance from the shoreline to the nearest landfall occupying a substantial portion of the fetch window.

Fetch window: Fetch window is the maximum angular window of fetches that affect a shore unit; it is commonly measured from the mid-point of the unit.

Other shorezone environment factor such as wave height, tides, and currents as coastal processes to the shoreline should be considered at the same time during an oil spill response.

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Guideline for Shoreline Clean-up