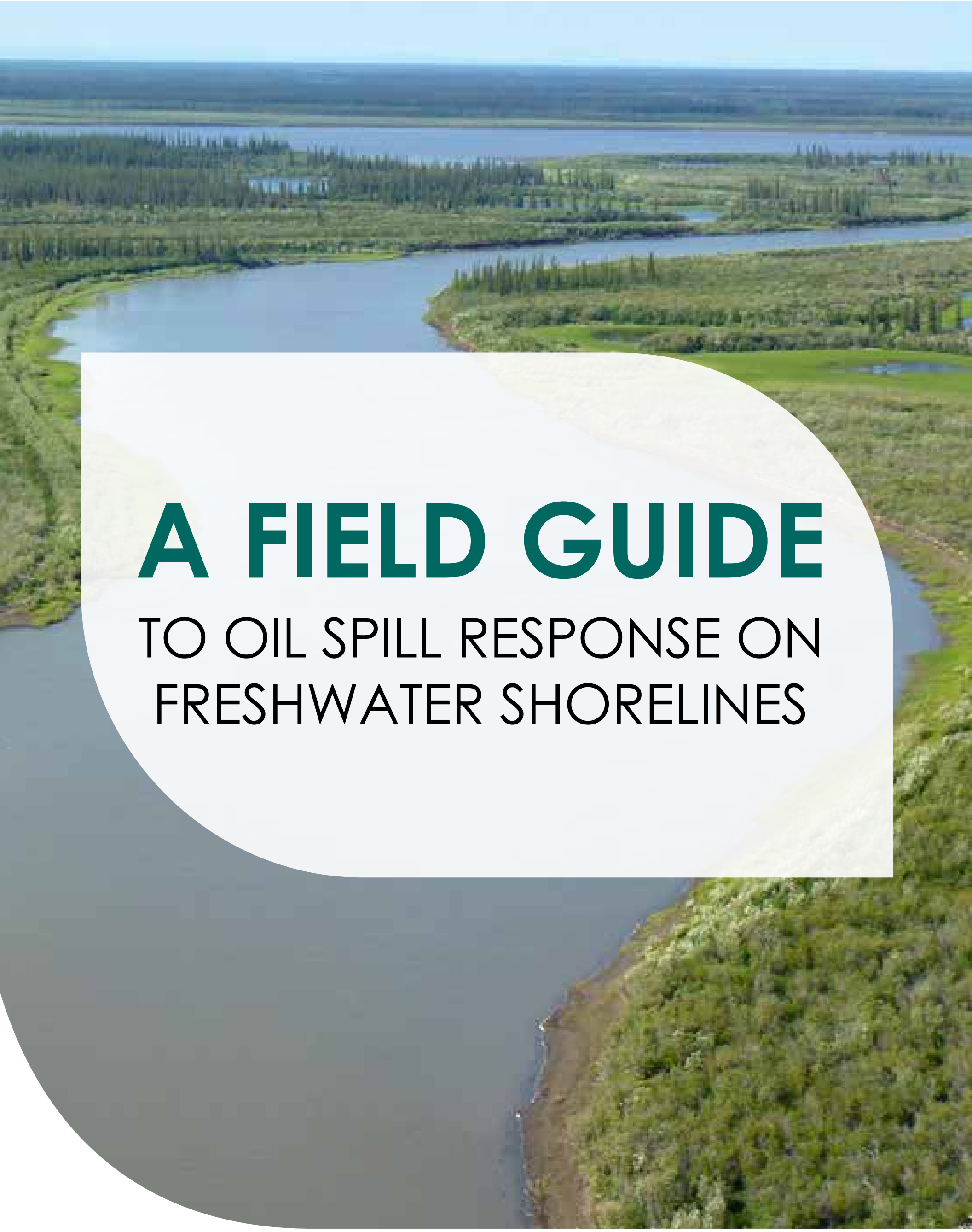
Environment and Climate Change Canada
Environnement et Changement climatique Canada



A FIELD GUIDE

TO OIL SPILL RESPONSE ON FRESHWATER SHORELINES

Canada

Citation:

Environment and Climate Change Canada (ECCC), A Field Guide to Oil Spill Response on Freshwater Shorelines, prepared and provided by Triox Environmental Emergencies Inc. and Owens Coastal Consultants, Ottawa, ON, 2021.

Cat. No: En4-412/2020E (Print)
ISBN: 978-0-660-37089-7

Cat. No.: En4-412/2020E-PDF (Online)
ISBN: 978-0-660-36098-0

EC7342

Environment and Climate Change Canada
Public Inquiries Centre
12th Floor, Fontaine Building
200 Sacré-Coeur Boulevard
Gatineau, QC K1A 0H3
Telephone: 819-938-3860
Toll Free: 1-800-668-6767 (in Canada only)
Email: enviroinfo@ec.gc.ca

Aussi disponible en français

A FIELD GUIDE

TO OIL SPILL RESPONSE ON FRESHWATER SHORELINES

Acknowledgements

The Management of Emergencies Science and Technology Section would like to acknowledge the team of shoreline experts whose contributions made a *Field Guide to Oil Spill Response on Freshwater Shorelines* possible. The Guide was written by Edward Owens (Owens Coastal Consultants), Leanne Zrum (Triox Environmental Emergencies Inc.) and by Doug Reimer (Environmental Mapping Ltd.), with technical input from Shannon MacDonald, and Stephane Grenon (Triox Environmental Emergencies Inc.), and Mark Brown (ECRC-SIMEC). From Environment and Climate Change Canada's Emergencies Science and Technology Section and the National Environmental Emergencies Centre were Sonia Laforest, Project Manager and Technical Authority; Natalie Jones; Patrick Lambert; Michael Goldthorp; Kevin Watson; Yuan Yao; Merlo Gauvreau and Ayumi Therrien, who provided detailed scientific reviews.

Executive Summary

Environment and Climate Change Canada (ECCC) has developed a series of field guides to provide technical support tools for decisions regarding the evaluation of freshwater and marine shorelines and treatment options during an oil spill response. The new freshwater shoreline response Guide is aligned with and complements the most recent editions of the ECCC Shoreline Cleanup Assessment Technique (SCAT) Manual (ECCC, 2018) and the ECCC Field Guide to Oil Spill Response on Marine Shorelines (ECCC, 2016). ECCC is engaged to provide science-based information to the spill response community and develop an expertise in spill response.

The purpose of the freshwater shoreline response Field Guide is to provide advice and guidance on the protection and treatment of freshwater shorelines threatened or affected by an oil spill. This Field Guide focuses on conventional tactics normally available to responders and appropriate for freshwater shoreline environments. The content of the Field Guide is organized to describe key elements of:

- Health and safety for field teams;
- Net Environmental Benefit Analysis (NEBA) / Spill Impact Mitigation Assessment (SIMA);
- Freshwater environments;
- Oil fate and behaviour in freshwater environments;
- Response – planning, treatment, special topics, and completion and monitoring.

This Field Guide includes stand-alone "Shoreline Information Technical Sheets" for shoreline protection tactics, different types of freshwater shoreline substrates, and shoreline treatment tactics. These information sheets have been developed as a quick reference for planners and field responders, and to provide a visual reference for the range of tactics that may be considered during an oil spill response.

Key learnings from inland oil spill responses that occurred in the last 25 years and the freshwater environment expertise of the project team were important sources of knowledge used to develop this Field Guide.

Quick Start Guide

The Quick Start User Guide provides immediate direction to sections of the Freshwater Shoreline Response Field Guide. If you need information on:

Table of Contents

Table of Contents — Continued

List of Figures

List of Figures — Continued

List of Figures — Continued

List of Figures — Continued

List of Tables

List of Tables — Continued

Acronyms

ALARP	As Low As Reasonably Practicable*
API	American Petroleum Institute
ATV	All-Terrain Vehicle
BMP	Best Management Practice
BTEX	Benzene, Toluene, Ethylbenzene and Xylenes
ECCC	Environment and Climate Change Canada
EU	Environmental Unit
EUL	Environmental Unit Leader
FOSC	Federal On-Scene Coordinator*
GIS	Geographical Information System
GPS	Global Positioning System
GRP	Geographic Response Plan
IAP	Incident Action Plan*
ICP	Incident Command Post
ICS	Incident Command System*
IMS	Incident Management System
IMT	Incident Management Team
JSA	Job Safety Analysis
K9-SCAT	Canine Shoreline Cleanup Assessment Technique
LC_{50}	Lethal Concentration that will kill 50% of the test species
NEB	Net Environmental Benefit
NEBA	Net Environmental Benefit Analysis
NFT	No Further Treatment
NOAA	National Oceanic and Atmospheric Administration
NOO	No Observed Oil
PAH	Polycyclic Aromatic Hydrocarbons
PPE	Personal Protective Equipment
PTA	Post Treatment Assessment

* Incident Command System terms: for further information on ICS terminology, see USCG (2014).

Acronyms — Continued

QA/QC Quality Assurance / Quality Control

RO Response Organization

SCA-TS Shoreline Cleanup Assessment – Technical Specialist

SCAT Shoreline Cleanup Assessment Technique

SIR Shoreline (or Segment) Inspection Report

SOS Shoreline Oiling Summary

SRP Shoreline Response Plan

SSC Scientific Support Coordinator

STR Shoreline Treatment Recommendation

TAG Technical Advisory Group

TL Team Lead

TPH Total Petroleum Hydrocarbons

TWG Technical Working Group

UAS Unmanned Aerial System

UAV Unmanned Aerial Vehicle

UTV Utility Task Vehicle

1 Introduction

This field guide provides responders with response strategies and tactics adapted for freshwater environments with an emphasis on the protection and treatment of oil spills on shorelines. It provides spill response teams with technical support tools for decisions regarding the evaluation of freshwater shorelines and treatment options and is principally based on the experiences and lessons learned during responses and shoreline-related projects, since 2005. This guide is one of a series produced by Environment and Climate Change Canada (ECCC) to provide the best available knowledge, guidance, and standards for responders and decision-makers dealing with oil spills in marine and freshwater shoreline environments.

The Freshwater Shoreline Response Field Guide is aligned with, and complements, the most recent editions of the ECCC SCAT Manual (ECCC 2018) and the ECCC Field Guide to Oil Spill Response on Marine Shorelines (ECCC 2016). These field guides combine existing scientific and technical knowledge with experience from recent responses, experts, and practitioners in order to assist and educate spill responders and enhance the spill response process.

1.1 Contents of the Field Guide

Section 1 (Introduction) provides the objectives and purpose of this field guide and outlines the different aspects of oil spill response on freshwater shorelines, including response phases. For a more detailed overview of response phases, management activities, and the types of decisions that collectively make up the shoreline protection and treatment components of a spill response operation, refer to the Field Guide to Oil Spill Response on Marine Shorelines (ECCC 2016).

Section 2 (Health and Safety for Field Teams) provides an overview of safety requirements for field teams, including identification of risks, implementation of mitigation measures, effective communication through Safety Plans, Job Safety Analyses (JSAs), and briefings, and proper use and maintenance of appropriate Personal Protective Equipment (PPE).

Section 3 (Freshwater Environments) provides an overview of freshwater watercourse types and their shoreline types, geomorphology, and hydrodynamic features.

Section 4 (Oil Fate and Behaviour in Freshwater Environments) provides an overview of the physical and chemical processes that cause oil to change (weather) and migrate in freshwater environments. The natural attenuation of oil on shorelines and the main physical/chemical properties, behavioural characteristics, and adverse effects of various types of oil in freshwater are described. An introduction to ice and snow, and the effects of winter conditions on oil behaviour and weathering is provided. Important differences between marine and freshwater environments are identified when transferring knowledge and spill response experience from one environment to another.

Section 5 (Response – Planning) introduces Net Environmental Benefit Analysis (NEBA) that may be used to help select the most effective and feasible oil spill response option(s), shoreline response planning, lake and river segmentation and mapping, and contingency and tactical planning.

Section 6 (Response – Operations) provides useful tips for responders, such as estimating water velocity and listing typical response equipment for different environments. Response strategies and tactics for shoreline protection both at and near the shore zone are described in a package of eight (8) information sheets. Recognizing different substrate types and knowing how oil will likely behave on them and the potential effects of various treatment approaches are important elements in selecting appropriate shoreline treatment options. This knowledge along with best practices are provided in a package of seventeen (17) information sheets for the various freshwater substrate types. Sixteen (16) shoreline treatment tactics, categorized broadly as natural recovery or weathering, wash and recover, removal, in-situ treatment, and chemical or biological treatment, are described in a package of information sheets. An overview of waste generation, handling, and disposal for various shoreline treatment options is also provided.

Section 7 (Response – Special Topics) considers aspects of unique response operations in rivers (e.g. fast water, woody material), describes detection and delineation and response options for more challenging situations (e.g. submerged and sunken oil), and introduces newer response ‘tools’ (e.g. oil detection canines).

Section 8 (Response – Completion and Monitoring) describes the monitoring and completion phase, including the development of, and agreement to, shoreline treatment criteria (previously referred to as treatment endpoints).

Section 9 (Case Studies: Freshwater Spills) provides Canadian and international freshwater spill case studies to convey lessons learned and best management practices.

Most importantly, the field guide has been constructed so that main sections can be used as stand-alone documents.

1.2 Objectives and Purpose

The field guide provides advice and guidance on the protection and treatment of freshwater shorelines threatened or affected by an oil spill. The information is presented primarily with planners and field responders in mind but is equally applicable to decision-makers involved in both preparedness and response.

This guide focuses on conventional tactics normally available to responders that are applicable and appropriate to the freshwater shoreline environments of Canada. As similar physical types of shoreline are found around the world, the guide is also relevant to oil spills on freshwater shorelines in most other countries.

1.2.1 The Response Framework

The primary objective of an oil spill response operation is to ensure the safety of the public and responders in the immediate area and to minimize adverse effects on the environment, including essential infrastructure, such as municipal water intakes. Although this typically involves a range of decisions and actions, the components of the response operation can be broadly organized and addressed in a logical and sequential manner. Understanding the framework of this process, as well as being aware of state-of-the-art knowledge, tools, and best practices contribute to the decision-making process during a response.

When an oil spill occurs, the overall objectives after safety are to minimize its effects and then to assess recovery of shoreline and/or shoreline resources; these are outlined in Figure 1.1. If possible, the most immediate actions should focus on controlling the spill at its source to reduce the volume of oil released in the environment. At the same time, strategies for on-water containment and recovery should focus on 1) minimizing the spread of the oil and therefore the size of the affected area, and 2) reducing the volume of oil remaining in the environment.

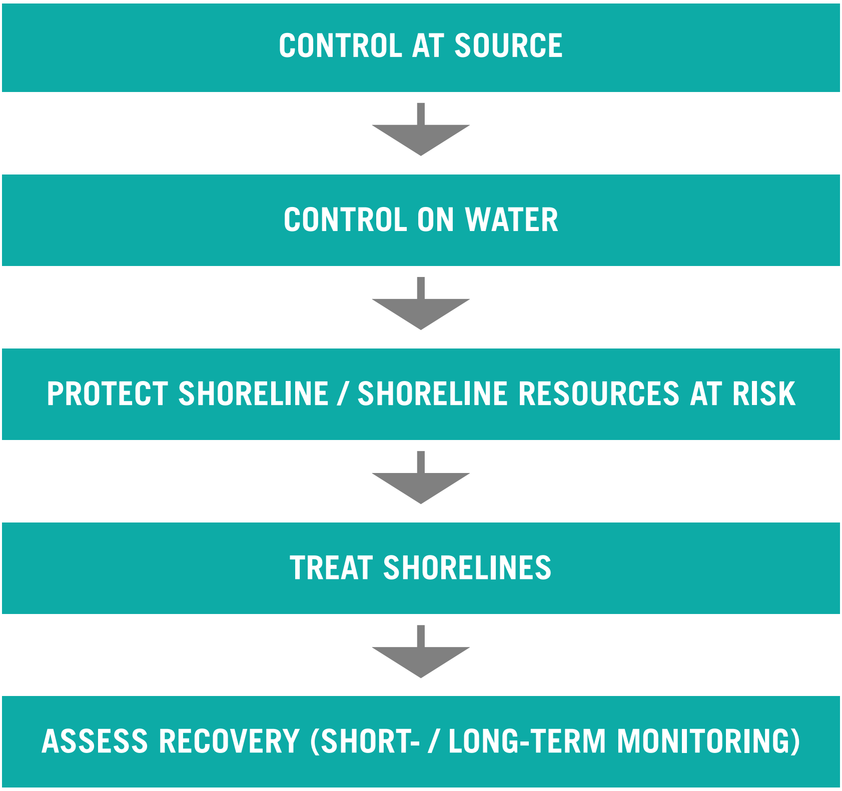


Figure 1.1 Spill control objectives

This field guide describes the protection and treatment of shorelines (Section 6), which typically follows the attempts to control oil at its source and/or on water.

1.2.2 Shoreline Response Phases

Shoreline response actions and decisions ideally follow four phases within a framework that allows for continuous learning and improved response effectiveness (Figure 1.2).

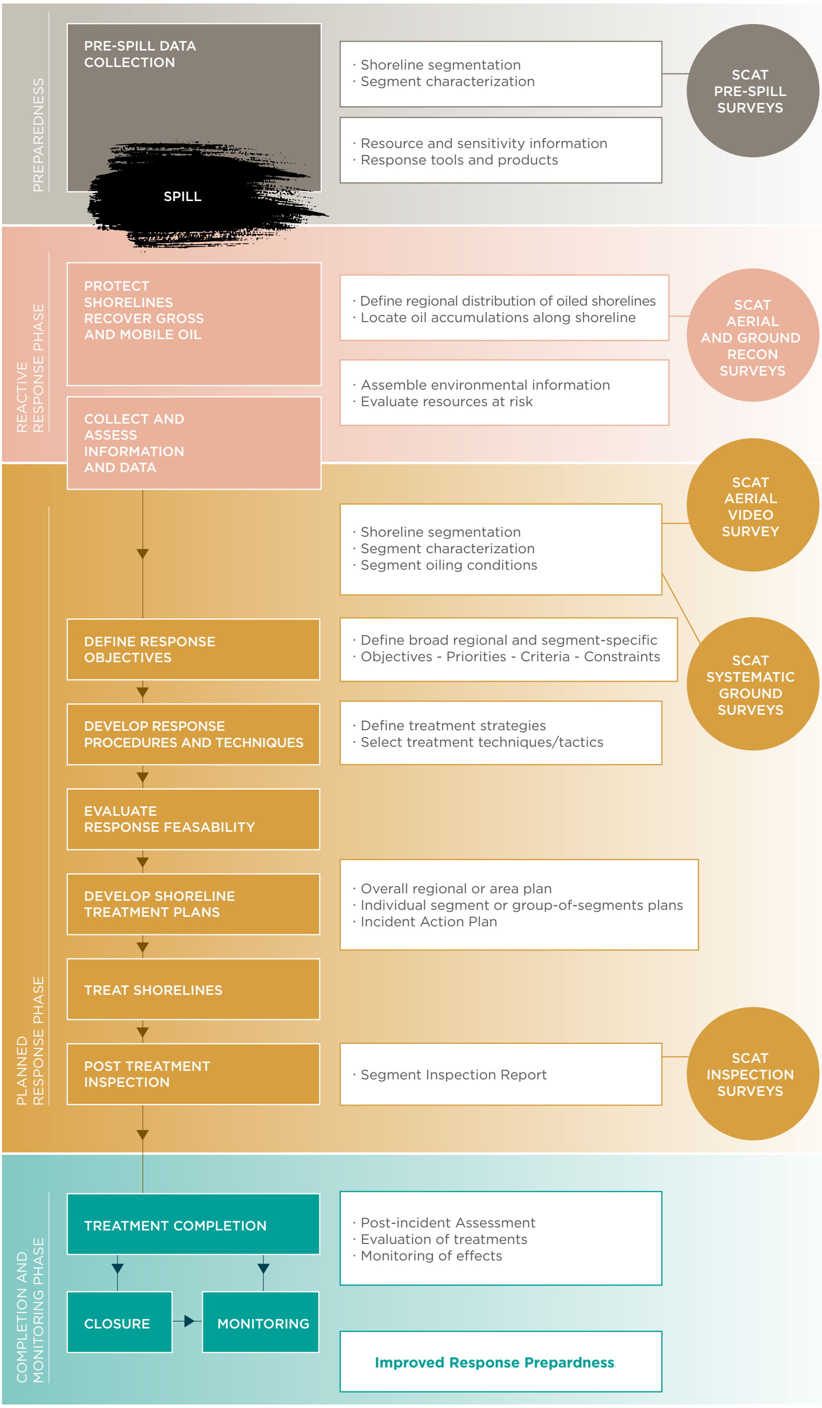


Figure 1.2 Shoreline response and decision framework (revised from ECCC 2016)

1. **The Preparation Phase** (pre-spill) is ideally contributed to by both government and potential responsible parties. Knowledge, tools, and expertise are developed and included in contingency or response plans to be called upon if a spill occurs.

2. **The Emergency Response Phase** (reactive) immediately follows an incident with the primary focus on source control and/or control on water. Shorelines are addressed in the context of protection priorities for sensitive areas, strategies, and tactics. The initial actions will make use of available contingency or response plans.

3. **The Planned Response Phase** is transitioned to under the direction of the spill management team. For shoreline treatment, management by objectives involves a series of planned activities based on an assessment of the situation and decisions about response priorities. Planned shoreline protection and treatment activities include determining the process by which treatment completion can be achieved.

4. **The Monitoring and Completion Phase** consists of an inspection process to ensure that shoreline treatment has been completed according to plans, which eventually leads to closure. Lessons learned are incorporated into an improved contingency or response plan.

2 | Health and Safety for Field Teams

The health and safety of personnel is the primary objective of spill response operations. All response personnel should apply these guiding principles:

- everyone within the work environment has the responsibility for health and safety;
- a safe and healthy work environment is always maintained; and
- there is a framework for participation, transfer of information and refusal of unsafe work.

Response operations must comply with all local regulations pertaining to the health and safety of workers.

Response personnel, particularly supervisors, must be familiar with any health or safety hazards that they may encounter and must be provided with (or provide) such information, instruction, training, supervision and facilities that are necessary to the health or safety of the workers. Response personnel within the field teams must be made familiar with the proper use of all devices, equipment and PPE required for their protection. Communications and site control are key components of health and safety. The transfer of information before, during and after work is completed is vital, and should include reporting procedures for accidents and near misses. The 'Buddy System' is used to ensure that no responder is isolated in the field, and that there are always at least two people working together – 'Buddies' will always look out for each other's well-being.

2.1 Identification of Risk Factors and Preventative Measures

The identification of risk factors for field workers is an ongoing process and must be continuously assessed as conditions change during short- and long-term time frames. It is important to keep in mind that each response will have unique risk factors. The hazards field teams are exposed to may include a variety of risk factors such as hydrocarbons, environmental conditions, the physical environment, transportation requirements, and the machinery and equipment being used.

Table 2.1 lists some examples of hazards and risk factors that may be encountered by field teams, as well as a range of potential preventative measures. It is important to keep in mind that each response will have unique factors.

Table 2.1 Potential hazards/risk factors and corresponding preventative measures

Potential Hazards* and Risk** Factors	Preventative measures
Petroleum Product: Inhalation, Absorption, Skin Contact, Aspiration	Safety Data Sheet review, PPE, first aid kits, eye wash stations, site control
Immersion	PPE (PFD, Personal Floatation Device), rescue stations, person overboard procedures
Slips/Trips/Falls	Proper footwear, situational awareness, workplace housekeeping, carefully step over logs/hoses, etc.
Boat Operations: Underwater Hazards, Dams, Weirs, Bridges	Navigation aids, trip plans, local knowledge, experienced boat operator
Ice Safety	Ice Safety Plan, ice thickness surveys, ice safety and rescue training, rescue stations, PPE (including thermal protection, PFD, safety lines and harnesses and proper footwear for ice), site control
Fast Water	Person overboard procedures for fast currents, rescue stations, experienced boat operator, local knowledge, PPE
Weather	Check forecast before work begins, monitor conditions for changes and updates to weather forecasts, procedures for lightning
Heat and Cold Stress	Wear proper layers of clothing to regulate temperature and prevent sweating in cold weather, cooling/warming breaks, proper hydration
Skin Exposure	Sunscreen, proper outerwear including hats, coveralls, gloves
Noise Exposure	Appropriate hearing protection

Potential Hazards* and Risk** Factors	Preventative measures
Wildlife/Insects/Poisonous Plants	Insect repellent, bear repellent, report allergies (e.g. bee stings and EpiPen use) to supervisor, check vegetation for poisonous plants, wear PPE to prevent skin contact, report wildlife sightings, do not feed or interact with wildlife, do not attempt to capture or aid injured or oiled wildlife
Biohazards	Do not touch hypodermic needles, avoid areas with large concentration of bird droppings (may be an inhalation hazard)

*** Hazard: any source of potential damage, harm or adverse health effects on something or someone (source: Canadian Centre for Occupational Health and Safety)**

**** Risk: the combination of the likelihood of the occurrence of a harm and the severity of that harm (source: Canadian Centre for Occupational Health and Safety)**

Cold water immersion is of concern for field teams working on/near fast-moving water or on/near ice. Field teams need to be trained in emergency procedures, understand the severity of cold-water immersion and know how to use the emergency equipment that is available. Rescue stations on shorelines may be set up using life rings/throw bags/rescue lines and ice thickness surveys must be conducted before working on ice. Additional safety issues include cold-related injuries due to exposure (e.g. hypothermia, frost bite, falling into icy water, slippery surfaces, operating vessels in ice-infested waters, bearing capacity of ice, and movement of broken ice by currents and wind).

2.2 Site Control and Communications

Site Control should be established to ensure the health and safety of all personnel proximal to the spill. Visual barriers and security personnel can be used to guide, control or prevent foot and vehicular access to a worksite (i.e. shorelines undergoing treatment, staging areas, decontamination areas, active wildlife hazing areas). The communication of the Safety Plan, risk factors and preventative measures to the field teams is key to their health and safety. Upon arrival to the worksite, field teams should be provided with a site orientation to ensure they understand the following:

- Name and contact information of supervisor;
- An overview of the work location and site control measures;
- Specific hazards of the site;
- Emergency procedures;
- Communication procedures;
- Location of first aid kit(s) and eye wash station(s);
- Location of designated smoking areas/rest areas;
- PPE requirements;
- Incident and near miss reporting procedures;
- Safety Plan.

2.3 Job Safety Analysis

A Job Safety Analysis (JSA) is a procedure that incorporates accepted safety and health principles and practices into a specific task or job operation. Before commencing work, a JSA Form should be reviewed with the field teams – it is important that any questions or concerns are raised at this time. The four basic steps in conducting a JSA include:

STEP 1 ➔ Identifying the job to be performed

STEP 2 ➔ Breaking the job down into a sequence of steps

STEP 3 ➔ Identifying potential hazards associated with each step

STEP 4 ➔ Listing the preventive measures in order to mitigate these hazards

The JSA template used is typically specific to the response contractor or other organization(s) (e.g. industry, regulatory agency) involved in spill response activities.

2.4 Personal Protective Equipment

Personal Protective Equipment (PPE) is used as a preventative measure and is designed to reduce exposure to a specific hazard. The PPE required is dependent on the hazards that are present in the work environment and on the task(s) that is to be performed. The proper wearing and use of PPE must be communicated to the field teams and any deficiencies reported. Some examples of PPE that may be required by field teams include:

Head Protection	➔ hard hats, sun hats, thermal headwear
Eye Protection	➔ safety glasses, tinted safety glasses, goggles, face shields
Foot Protection	➔ safety shoes, safety boots, hip or chest waders
Hearing Protection	➔ ear plugs, earmuffs
Skin Protection	➔ coveralls, protective suits, rain gear, gloves, sunscreen, insect repellent
Breathing Protection	➔ respirators
Other	➔ high visibility vests, PFDs, thermal PFDs, bear repellent, harness, safety lines

3 | Freshwater Environments

In freshwater environments, the shoreline zones are defined in relation to seasonal or annual water levels and swash zones (Table 3.1 and Figure 3.1).

Table 3.1 Comparative definitions of shoreline zones based on inundation times

TIME INUNDATED	MARINE	LAKE – POND	RIVER – STREAM
RARELY	**BACKSHORE*:** terrestrial vegetation zone above the limit of marine processes	**BACKSHORE*:** terrestrial vegetation zone above the limit of lake processes	**BACKSHORE*:** terrestrial vegetation zone above the **active floodplain**
PERIODICALLY	**SUPRATIDAL:** above Mean High Water (MHW): salt-tolerant species, inundated during spring tides and/or storms	**SUPRASWASH:** continuous terrestrial vegetation, inundated during seiche events and/or storms	**SUPRA-CHANNEL:** **active flood plain** between the bankfull **level** and the **backshore**, continuous terrestrial vegetation, inundated during high discharge events
REGULARLY	**INTERTIDAL ZONE:** between Mean Low Water (MLW) and MHW: alternately exposed and inundated during each tidal cycle	**SWASH ZONE:** inundated for extended periods of time	**ACTIVE CHANNEL ZONE:** between the **bankfull level and channel margin**** (waterline); alternately exposed and inundated as discharge varies
ALWAYS	**SUBTIDAL:** below MLW: almost always under underwater	**LITTORAL:** almost always underwater	**CHANNEL:** almost always underwater

*** In aquatic environments, the "Backshore" is above the limit of water (marine, lake or river) processes and is only subject to rare or catastrophic hydrological events. For riverine environments, backshore is defined as the terraces and uplands above the 'active floodplain'. Long-term operational staging should use the backshore zone. Short-term staging can utilize the floodplain/supra-swash zone bearing in mind that this zone may be inundated rapidly during a high-water level event.**

**** The channel margin is the land/water edge of the real time channel and can change with water flow variations.**

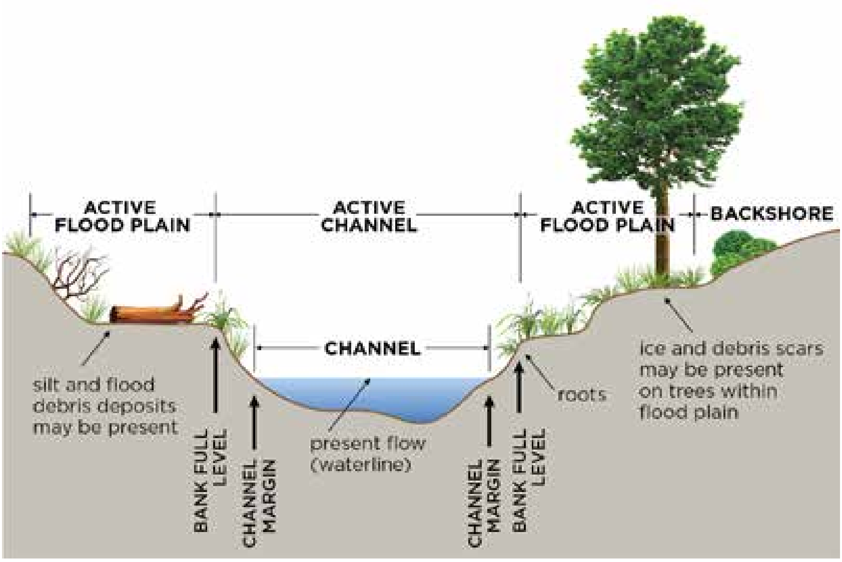


Figure 3.1 River-stream cross-section

3.1 Lakes

Lake type nomenclature varies depending on the basis for classification, which may include temporal variation in water levels and volume, geologic origin or biological conditions.

Temporal (Permanent/Temporary)

Lake classifications may be based on seasonal variation in water levels and volume and include:

- **Perennial:** a lake that contains water throughout the year;
- **Ephemeral** or **Intermittent:** a short-lived lake or pond which fills with water and dries up (i.e. disappears) seasonally;
- **Dry:** an ephemeral lake that contains water only intermediately at irregular and infrequent intervals.

Origin (Geologic History)

Lake classification based on origin has traditionally included 11 major lake types: tectonic lakes, volcanic lakes, landslide lakes, glacial lakes, solution lakes, fluvial lakes, aeolian lakes, shoreline lakes, organic lakes, anthropomorphic lakes, and meteorite lakes (Hutchinson 1957). These can then be subdivided into more than 70 subtypes.

Trophic (Biological Productivity)

Lakes are commonly classified by their biological productivity or trophic level and range from oligotrophic (low productivity) to eutrophic (high productivity) with mesotrophic conditions in between (Figure 3.2). Oligotrophic lakes generally contain low nutrient levels and thus low plant productivity allowing for abundant oxygen in deeper parts while eutrophic lakes are rich in nutrients and thus support high plant productivity. This high productivity in turn leads to increased decomposition rates and thus decreased oxygen levels at depth.

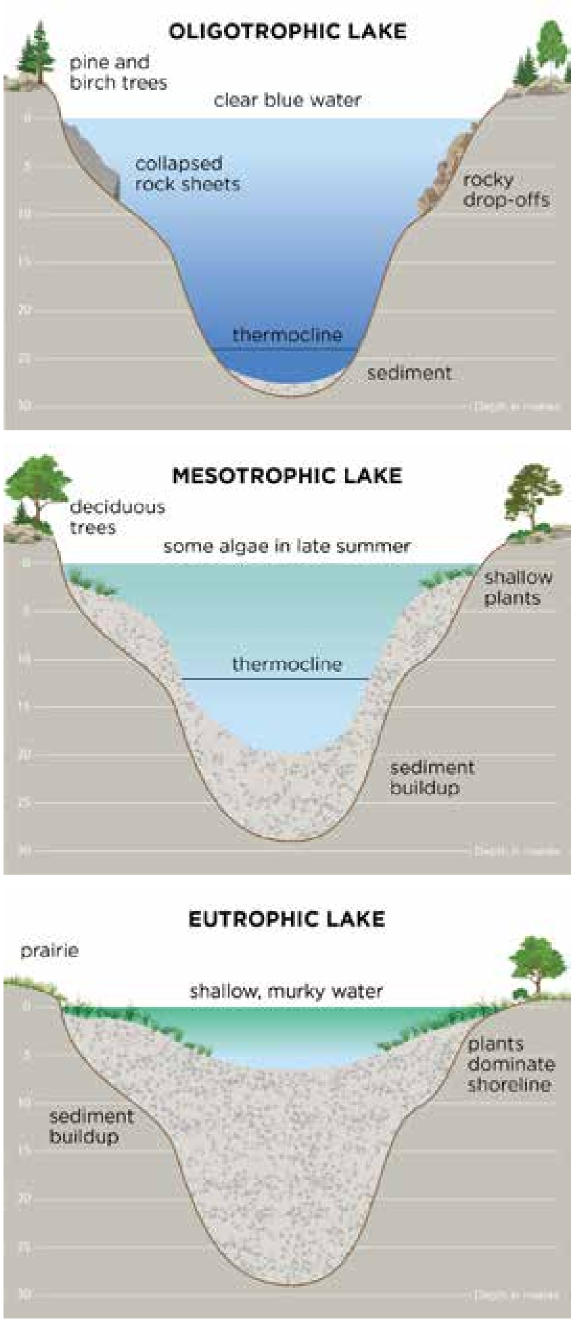


Figure 3.2 Lake trophic states

Considerations for the influence of different trophic levels on oiling include **visibility**, which decreases as productivity increases and **sediment load**, which increases as productivity increases. These in turn may have implications for detection and delineation and sediment loading of oil.

3.1.1 Swash Zone Shoreline Types

The swash zone is that zone on a lake shoreline where oil is most likely to be stranded and where treatment would be conducted (Table 3.1). The substrates of the swash zone types that have been defined for this field guide are listed in Table 3.2 and described in Section 6.3.

On the Shoreline Cleanup Assessment Technique (SCAT) Lake Temperate Shoreline Oiling Summary (SOS) form (Section Shoreline Forms) the swash zone type is identified in box “4a. SHORELINE TYPE”.

Table 3.2 Swash zone shoreline types

Swash Zone Shoreline Types	
Bedrock	Boulder Beach
Ice	Mud Flat
Solid Man-made	Sand Flat
Permeable Man-made	Mixed and Coarse Sediment Flat
Vegetated Shore	Wetland - Reed/Rush (deeper water, up to approx. 1.5-2 m)
Small and Large Woody Material	Wetland – Grassy (shallow, near shore)
Sediment Cliff or Bluff	Organic, Soil, Peat
Sand Beach	Tundra Cliff
Mixed Sediment Beach	Inundated Low-Lying Tundra
Pebble-Cobble Beach	Snow-Covered

Treatment approaches for different types of shoreline substrates are provided in Section 6.3.

3.1.2 Backshore Geomorphology

In lacustrine or pond environments, the "Backshore" is above the limit of normal lake shore processes and is subject to inundation only during rare or catastrophic hydrological events (Table 3.1). Medium- and long-term operational staging would be based in this backshore zone. Short-term staging can utilize the supra-swash zone bearing in mind that this zone may be rapidly inundated during an unpredictable high-water level event such as a storm surge or seiche (Section 3.1.3).

On the Lake Temperate SOS form the backshore character is identified in box "4b. BACKSHORE CHARACTER".

3.1.3 Hydrodynamics

Significant differences between freshwater and marine environments in terms of water density, fetch, water levels and flow are introduced in Section 4.5. The following provides examples of these and other hydrodynamic characteristics of lakes.

Waves

Wave energy at the shoreline is a function of the fetch (the area over which the wind blows to generate waves), wind speed and wind duration. This energy can be generated by local winds or on distant parts of a large lake in the same manner as waves propagated on marine waters travel as swell towards a shoreline.

Water Levels

Water levels on lakes vary in the long-term (annually or monthly and seasonal) and short-term (hours to weeks) depending on precipitation, seasonal snow and ice melting, and water storage in contributing rivers.

Long-Term and Seasonal Change Water Levels

An example of the long-term annual average water levels for Lake Superior is provided in Figure 3.3, which shows a range of approx. 1.2 m. Within these long-term variations there is a seasonal (summer-winter) cycle that is illustrated in Figure 3.4, showing an approx. range of 0.9 m.

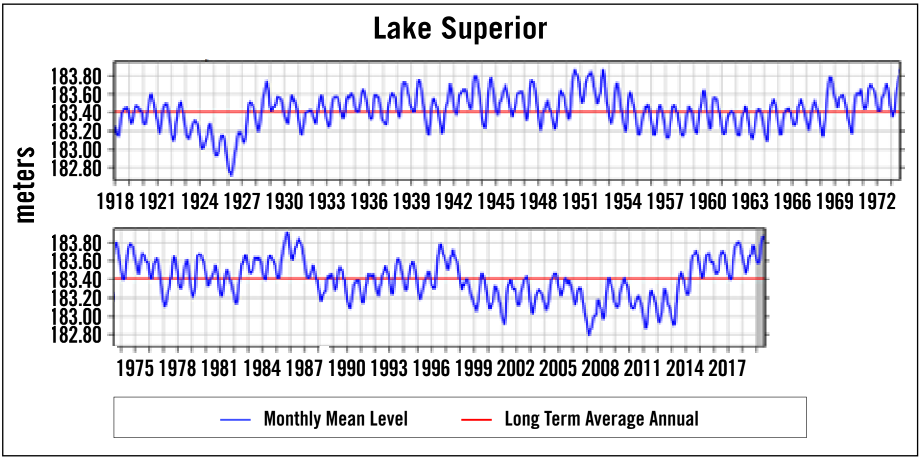


Figure 3.3 Long-term annual average water levels for Lake Superior, 1918-2018 (revised from US Army Corps of Engineers Detroit District)

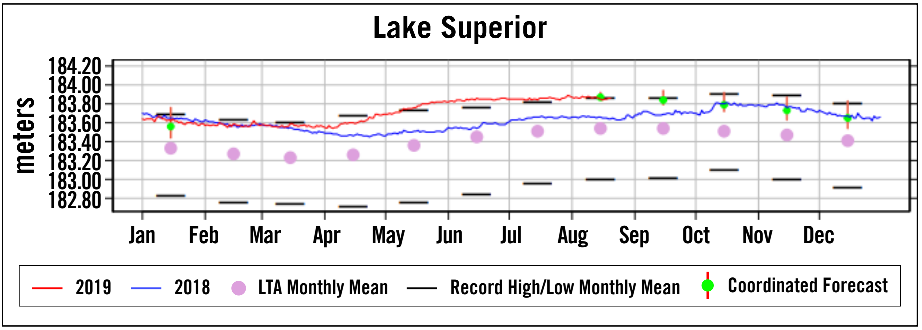


Figure 3.4 Daily average water level variations in Lake Superior with the seasonal high and low envelopes (revised from US Army Corps of Engineers Detroit District)

Tides, Seiches and Storm Surges

Tides occur on large lakes, such as the Great Lakes, but tidal water level changes are small (< 5 cm) and minor compared to other water-level fluctuations that result from winds and pressure changes.

Wind and weather conditions may create a seiche, which is an oscillating wave that can be a metre or greater in height. In many of the Great Lakes, the interval between the "high water" (i.e. set up) and "low water" (i.e. set down) of a seiche may be between four and seven hours. Figure 3.5 provides water level data for an approx. 3 m range seiche event measured on the north shore of Lake Erie with the primary oscillation in the early morning on 12 December 2000.

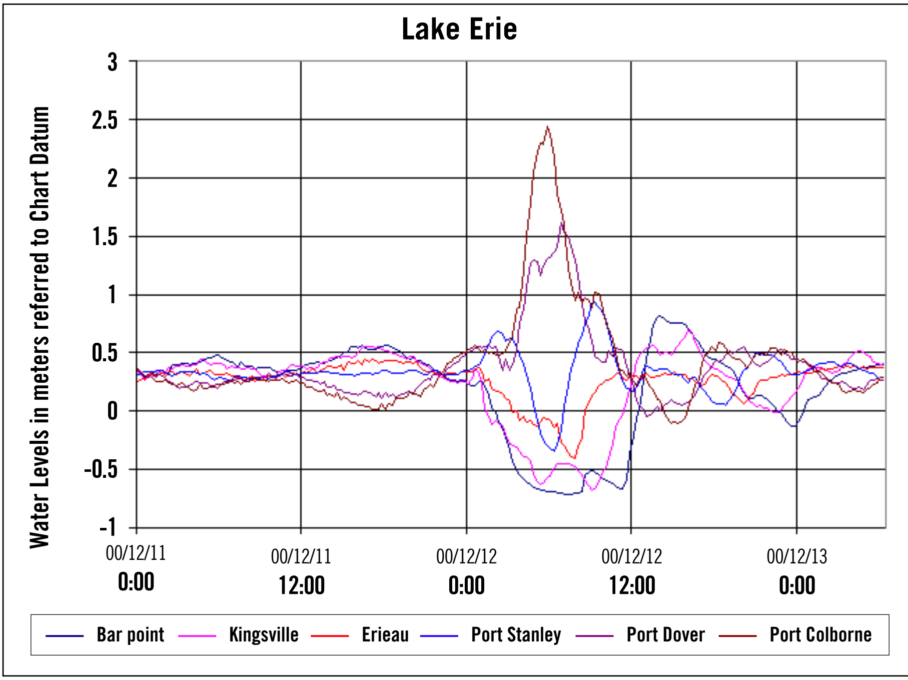


Figure 3.5 Water level data (in metres) measured at six gauging stations on the north shore of Lake Erie during a seiche event (Fisheries and Oceans Canada, Government of Canada)

Wind-driven or "storm" surges which do not involve an oscillation are common, to a greater or lesser degree, on all lakes and ponds.

Regulated Water Levels

Lake levels can be controlled by external (upstream) storage or release events on contributing rivers and streams or regulated by water control structures (e.g. dams, weirs). This ability to control water levels can buffer natural variations, but conversely can result in very large planned variations in the order of metres. On a larger geographic scale, water levels in the Great Lakes are regulated.

Ice

Ice may form on lake and pond waters anywhere in Canada as soon as air temperatures drop below freezing (Section 4.4.1). Ice can form in open waters, as shore fast ice, or as the growth of an ice foot, with the latter two forming earlier and persisting later in the season than on-water ice. These and other shoreline ice features (Section 4.4.2) may act to absorb or reflect waves. In winter months, the formation of these features may outweigh the role of waves as a factor in influencing oil movement and behaviour on lake shorelines.

An indication of the length of time each year that ice may form on a lake or lake shoreline can be gained from the average number of frost days (the number of days per year when the coldest temperature of the days is less than 0°C), which ranges from > 300 days in the Arctic to < 100 days near the Great Lakes, Atlantic and Pacific coasts. For example, long-term data (1976-2005; Prairie Climate Centre, Climate Atlas) for Great Slave Lake (NT) show an average on the order of 250 "frost days" each year, whereas Cochrane (ON) and Okanagan Lake (BC) are on the order of 200 to 210 days. Figure 3.6 shows the variability between years on a comparable date (early March) in terms of total ice concentration (minimum, 2016; maximum, 2019) for the Great Lakes. The ice season in northern Lake Superior can be from December through late April, whereas eastern Lake Ontario typically has ice from January through early/mid-March.

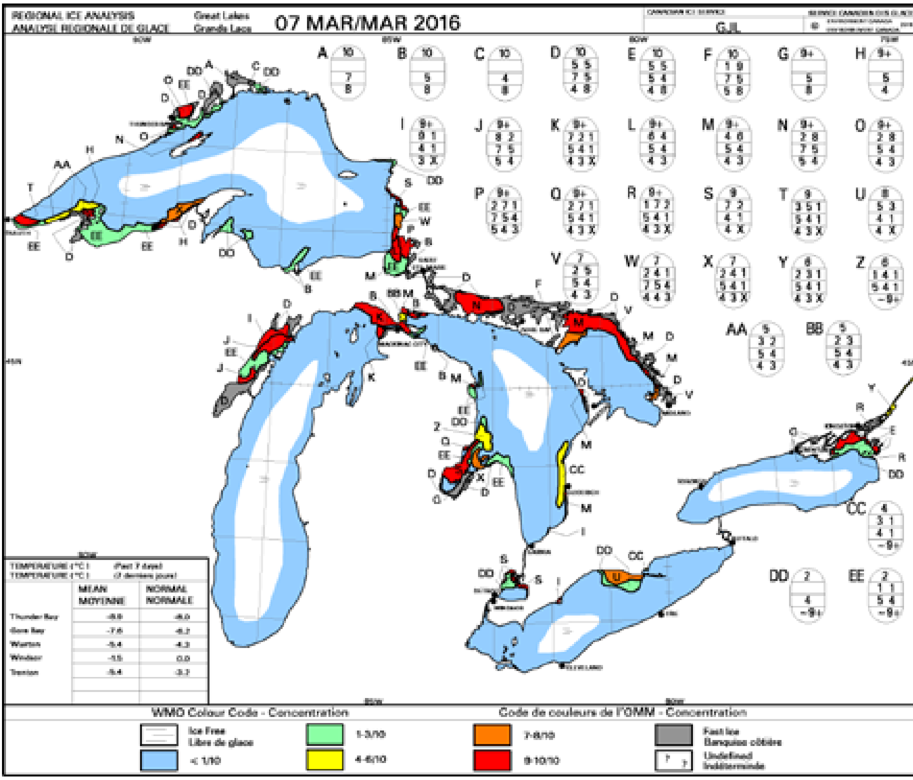


Figure 3.6 A Minimum total ice concentration, March 2016 for the Great Lakes (Meteorological Service of Canada, Environment and Climate Change Canada, Government of Canada)

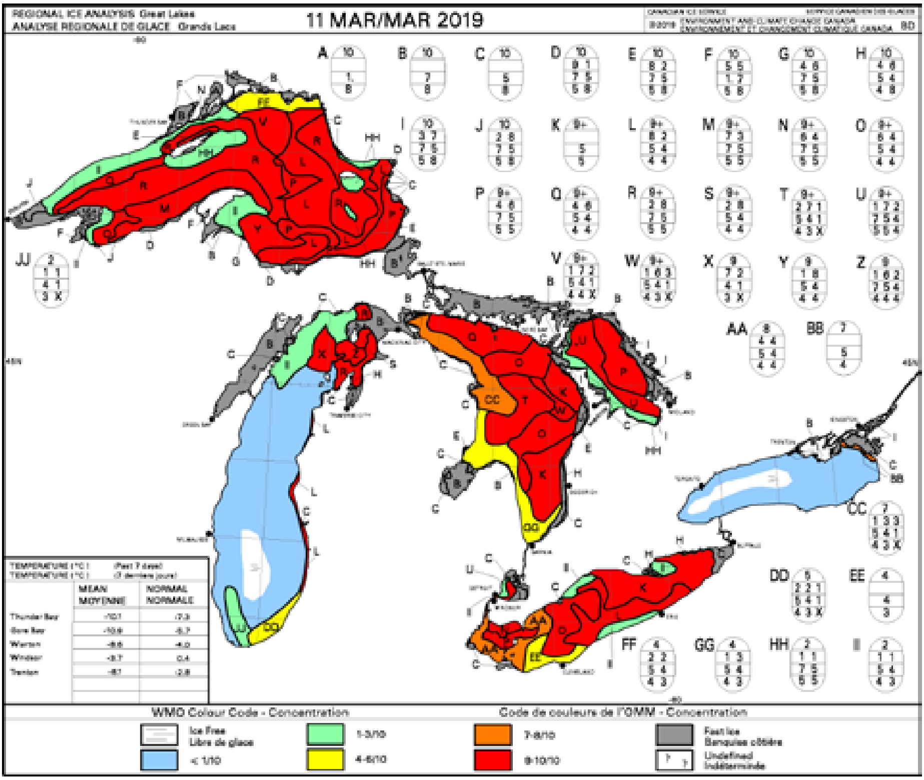


Figure 3.6 B Minimum total ice concentration, March 2016 (top panel) and maximum total ice concentration, March 2019 (bottom panel) for the Great Lakes (Meteorological Service of Canada, Environment and Climate Change Canada, Government of Canada)

3.2 Rivers and Streams

The three primary river channel types at the most generalized level are based on the dominant substrate type of the system:

- **bedrock**, which is composed almost entirely of exposed rock;
- **alluvial** or **unconsolidated**, which have a coating of sediment of varying thickness above existing bedrock;
- **man-made**, which can be comprised of either solid or permeable substrates.

3.2.1 Active Channel Margin Shoreline Types

The active channel margin type is the waterline, which varies within the active channel (Figure 3.1). The waterline varies through time (Section 3.2.4) and is the zone of river or stream bank where oil is most likely to be stranded and where treatment would be conducted (Table 3.1).

Within the generalized classification described above, there exist several more specific Active Channel Margin Types. The substrates of the Active Channel Margin Types that have been defined for this field guide are listed in Table 3.3 and described in Section 6.3. These can be found on the River (SOS) form and Stream (SOS) form in the box "4a. SHORE TYPE".

Table 3.3 Active channel margin shoreline types

Active Channel Margin Shoreline Types	
Bedrock	Boulder Bank/Bar
Ice	Mud Flat
Solid Man-made	Sand Flat
Permeable Man-made	Mixed and Coarse Sediment Flat
Sediment Cut Bank	Wetland – Reed/Rush (deeper water, up to approx. 1.5-2 m)
Small and Large Woody Material	Wetland – Grassy (shallow, near shore)
Vegetated Bank	Upland – Vegetated/Woody
Mud Bank/Bar	Organic, Soil, Peat
Sand Bank/Bar	Tundra Cliff
Mixed Sediment Bank/Bar	Inundated Low-Lying Tundra
Pebble-Cobble Bank/Bar	Snow-Covered

Treatment approaches for different types of shoreline substrates are provided in Section 6.3.

3.2.2 Character

River character can be classified in several ways and, depending on the system, some or all these approaches may be appropriate. The most applicable approach for spill response purposes is to document and describe the character of the valley which is occupied by the river channel(s), as this is important with respect to access and staging, and the character of the channel itself within which the river or stream flows. On the River (SOS) form and Stream (SOS) form (Section Shoreline Forms) these characteristics are captured in the "4c. RIVER CHARACTER" and "4c. STREAM CHARACTER" boxes by "VALLEY FORM, "RIVER/STREAM FORM", and "CHANNEL FORM". Documentation of physical features, such as width, water depth, the presence or absence of shoals or point bars and oxbows, and their substrates is important as these characteristics have direct implications for shoreline treatment response planning and operations. These features are defined in the first section of box "4c." on each form.

Valley Form

The character and shape of the valley form in which the channel(s) has developed is a primary feature in terms of response planning and operations. The Shoreline Forms classify "Valley Form" as either Canyon, Confined or Leveed Channel or Flood Plain Valley:

- **Canyon:** A deeply incised, steep-sided river valley typically dominated by bedrock.
- **Confined** or **Leveed Channel:** A narrow, constricted system with vegetated or unconsolidated banks either naturally occurring or man-made.
- **Flood Plain Valley:** A broad, flat-floored valley which may be subject to seasonal or periodic inundation.

Channel Form

Following the generalized river or stream and valley form characterizations, several more specific river channel forms/types are categorized as either **small or intermediate, high gradient (> 2% change in elevation) channels** or **large, low gradient (< 2% change in elevation) channels**. These classifications can be further subdivided and may result from variations in substrate type, sediment loads and/or riparian vegetation types and amounts. Within these landscape level channel types, specific local level channel patterns such as oxbows and point bars may form based on similar factors as those that influence channel type.

Small or Intermediate Channel/High Gradient
Small or intermediate, high gradient (> 2%) river and stream channels may display one or more channel types or forms including cascades, rapids, pools, riffles, glides or jams (Table 3.4, Figure 3.7). Development of these forms/types can depend on gradient and/or vegetation of the riparian zone and sediment or substrate.

Table 3.4 Small or intermediate (high gradient) channels (revised from Petts and Calow 1996; Goudie 2014)

Small or Intermediate (High Gradient) Channels	
Cascades	Steep reaches in which flow occurs over a sequence of steps dominated by boulders and cobbles and likely contain pools
Rapids	A stretch of rapidly flowing water associated with a steepening of the gradient along a stream course which will contain boulders and cobbles but lack pools
Pools	Areas of declining velocity and energy and increasing depth relative to the system
Riffles	Relatively shallow, rapid flow areas caused by a depositional bar on a river channel floor
Glides (Runs)	Reach with swifter, more uniform flow than a pool, similar to a riffle but without surface turbulence
(Log) Jams	An impediment to river flow because of the accumulation of woody debris across its course resulting in sediment filled back-water upstream and sediment starved riffle or rapid downstream

Figure 3.7 Select high gradient channel forms: clockwise from top left – pool, straight glide, riffle, rapids (from ECCC 2012)

Large Channel/Low Gradient

Large, low gradient (< 2%) river and stream channels can be divided into straight, meandering (single thread sinuous), anastomosing, braided and wandering forms or types (Table 3.5, Figure 3.8). Development of these forms/types can depend on gradient, vegetation of the riparian zone and sediment or substrate.

Table 3.5 Large (low gradient) channels (revised from Church 1992)

Large (Low Gradient) Channels	
Straight	A relatively stable, low width-depth ratio channel lacking curves and turns and occurring on a low-gradient valley slope
Meandering (Sinuous)	A channel with curves and turns occurring where there is a lower sediment supply for point bars
Anastomosed	A more stable, low-gradient, aggrading, multiple-channel and sinuous system dominated by channel sediments commonly having thick clay and silt banks
Braided	Channel type on steeper gradients where there is a large supply of sediment for braid bars
Wandering	A channel type falling between sinuous single thread and braided streams comprised of relatively stable multi-channel gravel beds

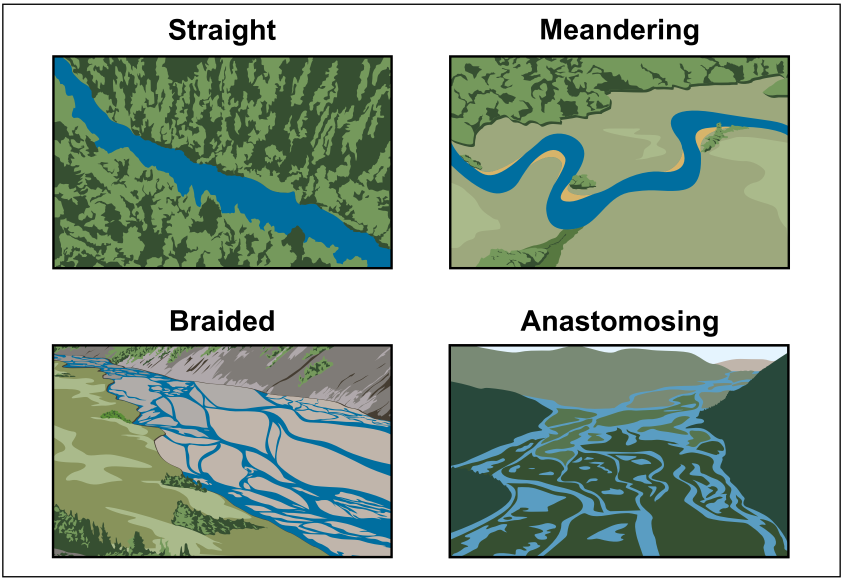


Figure 3.8 Large low gradient channel forms/types

3.2.3 Backshore Geomorphology

In riverine environments, the "Backshore" is above the limit of normal channel processes, is subject to inundation only during rare or catastrophic hydrological events and is defined as the terraces and uplands above the "active floodplain" (Table 3.1 and Figure 3.1). Medium- and long-term operational staging would be based in this backshore zone. Short-term staging can utilize the floodplain (i.e. suprachannel) bearing in mind that this zone may be inundated rapidly during high-water levels, such as an unforeseen precipitation or "flash flood" event in upstream regions.

The character of the backshore is described in terms of the valley and channel forms and types (Section 3.2.2). On the River and Stream SOS forms, the backshore type is identified in box "4b. OVERBANK/ BACKSHORE TYPE".

3.2.4 Hydrodynamics

Rivers are dynamic and highly variable environments with respect to currents and water levels. The most significant feature of rivers, streams and creeks is that, for the most part, the flow is one direction. Wave action is typically not a significant hydrodynamic factor but wakes from large vessels and small boat traffic can cause wave heights of 1 m or greater at the active channel margin. Winds may be important with respect to oil transport as they can drive a slick against one bank and keep a lee-shore oil free.

Currents and Flow

River, stream, and creek discharge vary constantly in response to changing inputs to the drainage system from precipitation, storm runoff, groundwater and snow/ice melt in the local and upstream areas. Flow direction and velocity typically vary locally, and back eddies or whirlpools are common as a river or steam channel varies in width and/ or depth and in the vicinity of shoals, bars, and islands (Figure 7.1.2).

The currents generated by river discharge are the dominant factor in oil dispersal and transport. Current speeds are lower at the banks and the bottom (due to friction) so that water moves faster at the surface in the centre of a channel. This causes oil to spread rapidly and there may be considerable mixing behind the leading edge of an oil plume. Flow, and therefore current speed, increase as the channel cross-sectional area decreases and decrease as a channel widens and/or deepens.

Importantly, turbulent mixing occurs throughout the water column, even in large rivers, so that floating oil is entrained throughout the water column. Two significant effects of this entrainment may be:

- contact of the oil with bottom sediments and a resulting increase in the density of the oil-sediment mixture (Section 7.3);
- to make detection of subsurface oil considerably more difficult and result in underestimates of oil distributions and volumes.

Figure 3.9 illustrates relatively little seasonal variability but three significant discharge events during which current velocities were observed to significantly and rapidly increase.

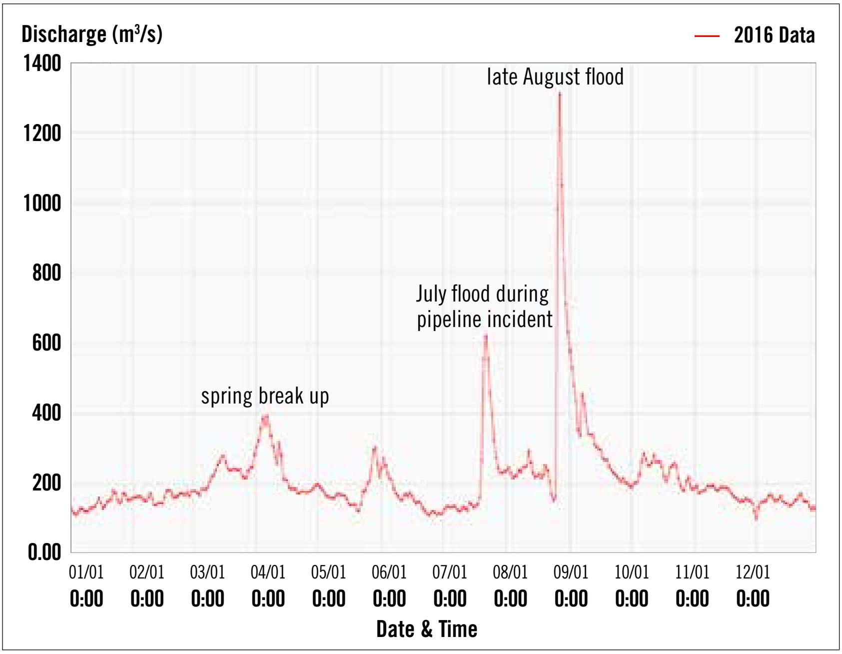


Figure 3.9 Observed discharge for the North Saskatchewan River near Deer Creek (AB), 2016 (Water Office, Government of Canada)

Water Levels
Water levels vary constantly in response to changing discharge volumes and can result from ice jams (Section Ice). Two critical effects of changing water levels are that the substrate character (Section 3.2.1) and the channel morphology (Section 3.2.2) typically change with rising or falling water levels. A channel that may be navigable at one water level may not be at a lower level. Similarly, a submerged sand shoal may be exposed as a sandy bar or island at low water levels and at higher water levels oil could be stranded on the suprachannel zone or floodplain vegetation (Section 7.1.1). For discharges in Figure 3.9, the corresponding water levels varied over a 3 m range.

Seasonal Change
Seasonal water level changes result from a combination of precipitation, storm runoff, groundwater and snow/ice melt in the local and upstream drainage basin. A typical feature of rivers in much of Canada is the increase in water levels during the spring high run-off period ("freshet") due to the thaw of snow and ice. Frequently the freshet inundates the active floodplain zone (Figure 3.1).

Event-Related Changes
The late July high discharge/water level event illustrated in Figure 3.9 occurred during an incidental oil release from the land into the river and resulted in oil stranding on the river banks during a period of a falling water levels (Figure 7.1, bottom panel). The late August high discharge/water level event resulted in oil burial (Section 7.2) in river sections and a redistribution of stranded oil and oiled woody material (Section 7.1.3) farther downstream. Other examples of oiling during periods of high water-level events are provided in Section 7.1.1.

Tidal Influence
Tidal influence may occur on coastal rivers [e.g. Fraser River (BC), St. Lawrence River (QC), and Saint John River (NB)] for some distance upstream from their confluence with the marine environment. These rivers experience tidal-related water level changes and water flow direction reversals with corresponding water velocity fluctuations daily. For example, daily tidal-related water level changes on the Pitt River (BC) may be over 1 m depending on the time of year (Figure 3.10).

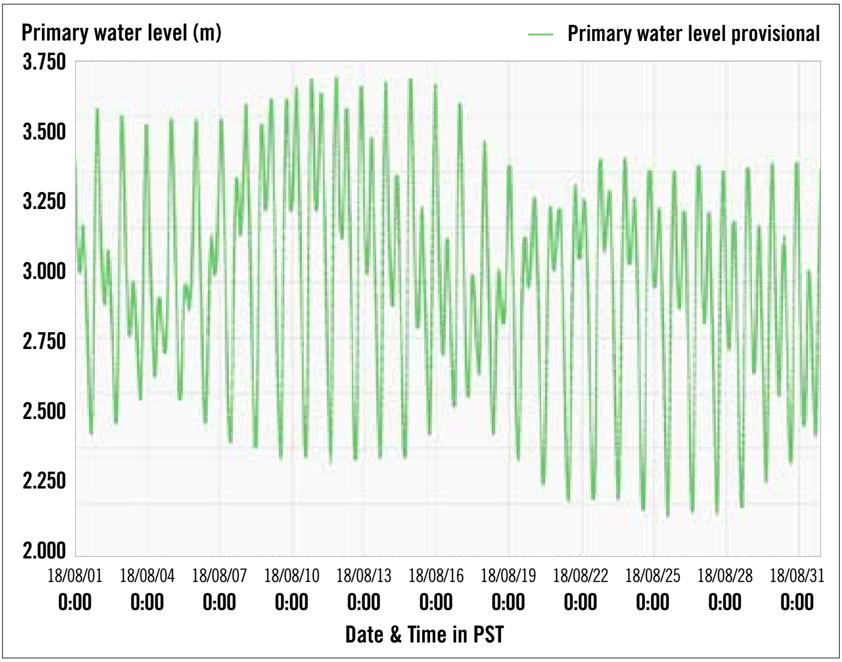


Figure 3.10 August 2018 record for the Pitt River near Port Coquitlam (BC) illustrating diurnal changes in water level due to tidal influence (Water Office, Government of Canada)

Regulated Water Levels

Many rivers are regulated by dams and weirs to adjust downstream discharge and water levels. For example, the 146,300 km^2 of drainage basin and 1,130 km of river length in the Ottawa River Basin have 13 control structures primarily to store water in reservoirs for release to augment low flow conditions and for flood control during the spring freshet. Figure 3.11 illustrates daily changes in river water level (green line) on the order of 25 cm due to regulation at a hydroelectric generating station (i.e. dam) on the North Saskatchewan River.

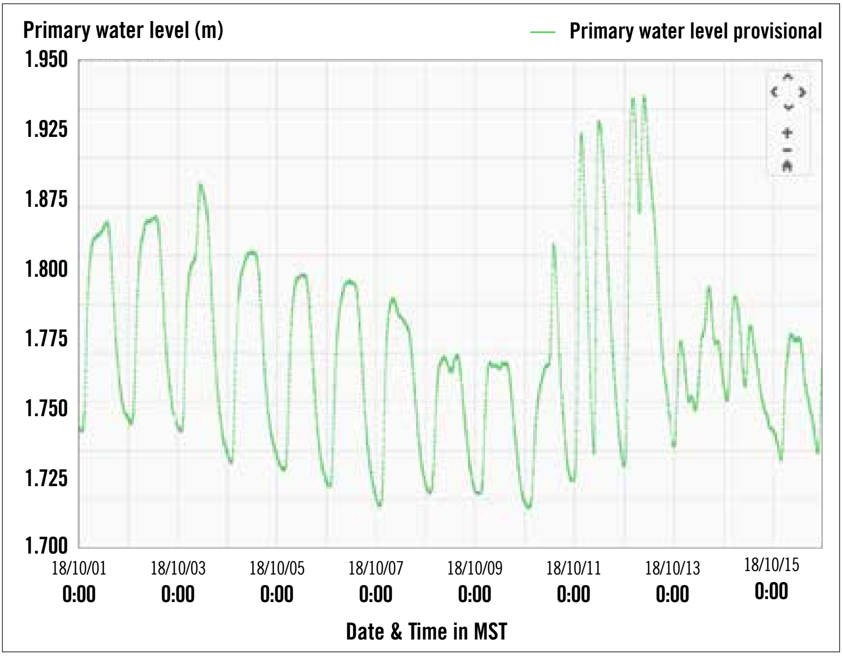


Figure 3.11 Two-week record for the North Saskatchewan River near Rocky Mountain House (AB) illustrating diurnal changes in water levels due to water releases from the Big Horn Dam, October 2018 (Water Office, Government of Canada)

Ice

Ice formation and shoreline ice features in rivers and streams are similar to those for lake and pond waters (Section 3.1.3). Ice jams that form during break-up are a common feature of rivers in Canada (Figure 3.12) and frequently lead to ice jam floods.

Figure 3.12 Ice jam under bridge at Acadie River (Environment and Climate Change Canada, 2021)

Ice may form on rivers, creeks, and streams anywhere in Canada. An indication of the length of time each year that ice may form on a river, creek or stream can be gained from the average number of frost days (the number of days per year when the coldest temperature of the days is less than 0˚C), which ranges from > 300 days in the Arctic to < 100 days near the Great Lakes, Atlantic and Pacific coasts. For example, long-term data (1976-2005) for Inuvik (NT) on the Mackenzie River show an average on the order of 260 "frost days" each year, whereas Fort Simpson (NT) at the confluence of the Mackenzie and Laird Rivers in the southern portion of the drainage basin has 220, the North Saskatchewan River near Saskatoon (SK) has 200, and the lower Ottawa River (ON) has on the order of 165 days (Prairie Climate Centre, Climate Atlas). On large rivers, freeze-up and break-up vary with location. As an example, on the Mackenzie River:

- ice begins to break up in early to mid-May in the southern sections of the river, after break-up on the Liard River (tributary rivers typically are free of ice before the Mackenzie itself);
- high water levels and flooding are common during the break-up period, particularly when ice dams form;
- break-up across the lower Mackenzie River typically occurs late May and the channels in the delta are usually free of floating river ice by the end of May or early June.

4 | Oil Fate and Behaviour in Freshwater Environments

Oil released into the environment changes due to a variety of biological, physical and chemical processes collectively referred to as "weathering". These processes alter the behaviour and control the fate of oil in the environment and can affect the selection of appropriate strategies and treatment methods during a response. The following sections describe:

- the transport and weathering processes when oil is released in a freshwater environment or is stranded on shorelines;
- natural attenuation of oil on shorelines;
- the range of oil types;
- ice and snow and the effects of winter conditions on oil behaviour and weathering;
- key factors that differ between spills in freshwater and marine environments.

4.1 Transport and Weathering Processes

Several physical and chemical processes are set in motion when oil is released into the environment that result in changes to the character and behaviour of the oil. Understanding how weathering can change oil characteristics and oil behaviour is key for the selection of response strategies and treatment. The weathering processes are the same for marine or freshwater environments but the effect on oil behaviour can be somewhat different due to the hydrodynamic and geographic conditions encountered in freshwater environments. The rate and extent of oil weathering are highly dependent on meteorological and hydrological conditions at the time of the incident and on the oil type. Some of the weathering processes help the response as they remove oil from the environment whereas other processes can make the oil more persistent or more difficult to recover. The individual processes described in the following sections act together to weather oil, but the relative importance of each process varies in time (from hours to years) and space. Most of the weathering processes are pathways that move oil within and between environments and locations, as only photo-oxidation or biodegradation break down the hydrocarbons into other compounds. Figure 4.1 depicts the main weathering processes that affect the fate and behaviour of oil on water and these are described in the following sections.

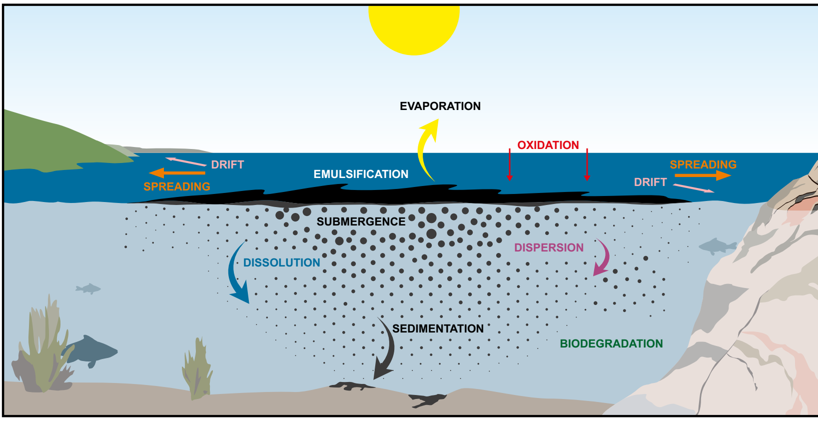


Figure 4.1 Main weathering processes affecting the fate and behaviour of oil on water

4.1.1 Spreading

Spreading begins immediately when oil is released onto a water surface. The thickness of the oil layer decreases rapidly for all except highly viscous oils and can be reduced to a few millimetres or less within minutes to hours. The rate at which spreading occurs depends on the quantity of oil spilled and the initial viscosity. Low viscosity oil spreads more than highly viscous oils. As it spreads, a slick fragments into smaller patches or long bands under the influence of winds, currents, and waves. In rivers, fragmentation can be significantly increased by the presence of rapids, eddies or falls. Oil slicks are rarely uniform, and thickness can vary greatly from one location to another. Oil appearance provides key information to estimate oil thickness and potential volume (Table A1.6, ECCC 2018). Spreading can greatly affect response operations as thin oil layers are difficult to recover while fragmentation and the larger surface area occupied by the oil affects oil recovery rates (Figure 4.2). In small bodies of freshwater (small lakes and ponds) a release may occupy the entire surface area.

Figure 4.2 Fragmented oil on lake water surface, Lake Wabamun, AB (2005)

4.1.2 Drifting

Most oils initially float on the water surface and are transported under the action of surface water currents and winds. The trajectory of oil on the water surface of a large water body (lakes) can be estimated from knowing the friction parameters; movement will be influenced by water current and wind speed. In the case of streams or rivers, oil is typically transported downstream by currents with the wind pushing the oil towards one shore or the other (Figure 4.3). The configuration of the water body may have a significant effect on oil movement along shorelines as oil can accumulate in curves, bays and other areas. Drifting poses a significant challenge for oil spill response as oil is always moving on the water surface making timely and efficient equipment deployment difficult. In addition, the drift rate of oil at the surface may be affected by vegetation, as the oil tends to move more slowly through the vegetation than the water.

Figure 4.3 Oil drifting and spreading on river water surface, Chaudière River, QC (2013)

4.1.3 Evaporation

Evaporation is the transfer of the light volatile components of oil into the atmosphere as vapours and is the same process that occurs in a marine or terrestrial setting. The evaporation rate is controlled by oil composition, ambient temperature, winds, turbulence (waves, rapids) and the surface area of the slick. All oil types undergo evaporation to one degree or another. Generally, lighter oils (or products such as gasoline or diesel), warmer temperatures, greater sunlight exposure, higher winds and turbulence promote evaporation. With high intensity sunlight, the temperature of the oil can greatly exceed ambient temperature and will be the predominant factor affecting evaporation. Spreading and evaporation are closely related; as oil spreads the surface area of the oil increases so that a greater volume is exposed to evaporative processes. Evaporation can have a positive effect on the response as a significant volume of oil may be lost to the atmosphere, decreasing the oil volume that remains on the water or on shorelines. However, the remaining oil may have a higher viscosity and density due to the loss of the light fractions. Although airborne dispersion rates typically are high, vapours may be a health and safety risk for responders and the public as these may be toxic and flammable; for example, following a release into a narrow, steep-sided stream valley. Air monitoring should be implemented at the beginning of a spill to evaluate these hazards. Typically, evaporation takes place in the initial hours/ days of a release unless there is a continuous source of new oil.

4.1.4 Dispersion

Natural dispersion occurs when an oil slick is broken down by breaking waves and turbulence at the water surface to form oil droplets of various sizes in the upper layer of the water column. Oil droplets smaller than 70 µm may be held in suspension and remain in the water column, whereas larger droplets may re-surface forming slicks. Oil droplets that remain in the water column may eventually be diluted and biodegraded (depending on local microbial communities) where water depth is adequate for under-water dilution to take place. Oil dilution may be limited if the water depth is not sufficient relative to the volume of oil to enable the mixing process to take place, potentially resulting in adverse effects on the freshwater environment or water quality. Oil type and water energy levels are the two main factors influencing this process; low viscosity oils typically are dispersed more rapidly than higher viscosity oils. Natural dispersion can be beneficial for response operations as the water surface oil volume may decrease significantly. However, in a freshwater environment limited water depth may be an important factor influencing the extent of this process.

4.1.5 Emulsification

Emulsification occurs when either water droplets are incorporated into the oil to form a water-in-oil emulsion or oil becomes entrained within water droplets to form an oil-in-water emulsion. These processes can increase the volume of oil up to five times due to the addition of water in the oil matrix. This process is likely to occur when oil with a nickel/vanadium concentration greater than 15 ppm or an asphaltene content above 0.5% is exposed to energy in the form of waves or turbulence (e.g. rapids, falls). Emulsification significantly increases the oil viscosity and density. Stable water-in-oil emulsions can be highly persistent whereas non-stable emulsions may separate into oil and water in calm conditions, when heated by sunlight, or when stranded on the shoreline. Emulsification has an important effect on response techniques as viscous oils are generally more difficult to recover and the increased volume generates greater quantities of liquid waste.

4.1.6 Sedimentation

Sedimentation of spilled oil occurs when oil droplets interact with and attach to suspended organic material or large sediment particulates (>1 mm in size) present in the water column. This change in oil character can increase the density and cause the oil to either sink or to remain suspended under water (i.e. submerged). This process is more common in freshwater environments as water density is lower than in sea water. Sediment may be mixed with oil that flows overland to a freshwater lake or river or has stranded on a shoreline or river bank (or bar) and is agitated by waves or currents. There are three distinctly different Oil Particle Aggregate (OPA) mechanisms and types of aggregates, which are important for the understanding of sedimentation processes (refer to text box).

OcPAs (Oil colloidal Particle Aggregates)	➔	form by oil interaction with inorganic fine particles typically < 5 µm in size
OgPAs (Oil granular Particle Aggregates or Agglomerates)	➔	formed by oil interaction with inorganic particles typically > 1 mm in size
MOS (Marine Oil Snow)	➔	form by oil interaction with suspended microscopic particulate organic material (including plankton and bacteria)

The aggregate interactions depend on the:

- state of oil (dissolved, emulsified, floating);
- size and type of particles [colloidal (a mixture of microscopic dispersed insoluble particles suspended in another substance), granular, organic, inorganic];
- oil-particle interaction mechanisms;
- settling/suspension characteristics.

Section 7.3 provides a discussion on submerged and sunken oil in the freshwater environment.

4.1.7 Dissolution

A small fraction of the lightest components of the oil may dissolve in the water column. Components of interest are aromatic hydrocarbons such as benzene, toluene, ethylbenzene and xylene (BTEX) as they can be harmful to biota and water quality. However, as these compounds are also highly volatile, they tend to evaporate in a much larger proportion than they dissolve. As such, dissolution is considered a minor oil weathering process. The rate at which dissolution occurs is affected by oil type, spreading, droplet formation, weather conditions and water turbulence. In a freshwater environment, dissolution can be a significant concern as municipal drinking water intakes may be potentially exposed to dissolved hydrocarbons.

4.1.8 Biodegradation

All aqueous environments (freshwater and marine) contain populations of microorganisms that use oil as a source of carbon and energy leading to its ultimate attenuation into carbon dioxide and water. Microorganisms are very opportunistic and oil degrading organisms multiply rapidly once in contact with exposed oil surfaces. Biodegradation is the mechanism by which hydrocarbons are naturally removed from the environment. Typically, biodegradation occurs following emulsification or dispersion into small oil droplets. Heavier oils with high wax or asphaltene contents biodegrade more slowly than crude oils or products which primarily have a higher content of light and medium hydrocarbon compounds. Different microorganisms degrade different oil compounds and multiple communities interact in this suite of processes. Biodegradation occurs mainly at the oil-water interface and any increase of the oil surface area, such as the formation of small droplets through dispersion or OPA mechanisms (refer to text box), increases the rate of biodegradation. Oil type (generally lighter oil is easier to biodegrade), the presence of oxygen and nutrients (phosphorus and/or nitrogen) and temperature control the rate of biodegradation.

4.1.9 Photo-oxidation

Photo-oxidation is a chemical reaction promoted by sunlight to form oxidized compounds. Light products degrade slowly, whereas heavier products can form a protective surface layer (crust-like) making the oil more persistent (i.e. resistant to other weathering processes). Photo-oxidation contributes to the breakdown of hydrocarbon molecules.

4.2 Natural Attenuation of Oil on Shorelines

The natural attenuation or removal of oil stranded on shorelines may occur by one or a combination of six processes, including physical, photochemical and microbial degradation mechanisms.

The **four physical mechanisms** include:

1. **Evaporation**: physical volatilization of light hydrocarbon fractions into an atmospheric (air) environment.

    - Primarily a function of the available exposed surface area, the oil composition, wind velocity, sunlight intensity and ambient temperature.
    - A pathway to photo-oxidation in the atmosphere or to deposition on land or water surfaces where the hydrocarbon molecules are subject to biodegradation.

2. **Buoyancy partitioning** by a rising water level, with or without wave energy: physical dispersion into an aquatic environment.

   › Primarily a function of location and exposure to changing water levels, the internal cohesion of the oil and the adhesive properties of the oil.
   › A pathway to OcPA and biodegradation.

3. **Physical action** by waves: physical partitioning and dispersion into an aquatic environment.

   › Primarily a function of location on a shoreline with respect to wave action, the level of wave energy, the internal cohesion of the oil and the adhesive properties of the oil.
   › A pathway to OcPA and biodegradation.

4. **Aggregation by fines** (OcPA): emulsification and physical dispersion into an aquatic environment with or without wave energy.

   › Primarily a function of the available exposed surface area and the properties of the available fine sediments.
   › Concurrent with biodegradation and physical dispersion into an aquatic environment.

The **fifth process**, **photochemical degradation** by oxidation, occurs on exposed oil surfaces. The aromatic hydrocarbons are sensitive to photo-oxidation, whereas saturates are more resistant. Photo-oxidized products are found in resins and polar fractions, compounds that are more resistant to biodegradation.

The **sixth process** by which oil is removed from shorelines is the same microbial activity that attenuates oil in an aquatic environment and involves direct in situ **biodegradation** of stranded oil and natural attenuation by microbial activity:

– Typically requires aerobic conditions and water. Anaerobic degradation is a much slower process than the aerobic process and involves sulfates and carbon dioxide that reduce the hydrocarbons to sulphide and methane.
– Primarily a function of the available exposed surface area, the oil composition, and ambient temperature.
– Concurrent with partitioning and natural dispersion into an aquatic environment.

4.3 Oil Types

This section provides an overview of main physical/chemical properties, behavioural characteristics, and potential adverse effects of various types of oil in freshwater. The oil spill response community uses simple classification systems to cluster different oil types. The United States Environmental Protection Agency (US EPA) and United States Coast Guard (USCG) use a Group 1 to 5 based on density. ECCC (2016) used a 5-tier descriptive scheme (volatile, light, medium, heavy, solid). The latter schema is defined for this guide:

- volatile (gasoline products);
- light (diesel and light crudes);
- medium (intermediate products, medium crudes, fresh diluted bitumen or 'dilbit');
- heavy (residual products, heavy fuel oils, Bunker C, and heavy crudes, weathered diluted bitumen);
- solid (do not pour; bitumen, weathered Bunker C, tar, and asphalt).

Table 4.1 compares the physical properties of each oil category to freshwater.

Table 4.1 Typical physical properties of oil types and freshwater (from Emergencies Science Division of Environmental Science and Technology Centre, Oil Properties Database; Fingas 2001; ITOPF 2011)

Category of Oil Type	Density g/mL	Viscosity cSt	Distillation Characteristics % boiling: below 200 ˚C above 370 ˚C	Pour Point ˚C
Volatile (e.g. gasoline)	0.75	1	100 0	–
Light (e.g. diesel)	0.85	1 to 5	30 100	-35 to -1
Medium (e.g. typical crude, including dilbit)	0.85 to 0.90	10 to 50	15 to 40 45 to 85	-40 to 30
Heavy (e.g. fuel oil)	0.95 to 0.98	1,500 to 15,000	2 to 5 30 to 40	-10 to 10
Solid (e.g. bitumen)	>1	>50,000	–	–
Water	1	1	100 0	0

4.3.1 Volatile

Oils in this category are non-persistent as they are highly volatile and evaporate rapidly. They have high concentrations of toxic compounds, some of which are soluble in water, that may result in localized effects in the water column and on shoreline resources. Since they are not persistent and pose potential safety issues for responders, there generally is less requirement for response activities to control, contain or recover the released oil.

4.3.2 Light

Light oils are characterized as being relatively volatile and persistent. They contain some concentrations of toxic compounds, which may be soluble in water. They may result in longer-term oiling of shoreline resources and have the potential for acute subaqueous effects due to dissolution, mixing and sorption onto suspended sediments. Light oils behave the same in all aqueous environments.

4.3.3 Medium

Medium oils are generally more persistent than lighter oil types. They typically have less than 1% soluble fraction and potentially may cause significant and long-lasting oiling of shorelines and effects to waterfowl and aquatic furbearers (e.g. beaver, muskrat) as they have a high adherence potential.

Unweathered diluted bitumens are included in this category. However, in comparison to other commonly transported oils, many of the chemical and physical properties of diluted bitumen, especially those relevant to environmental effects, differ substantially. Primarily, the differences are the high density, viscosity, and adhesion properties of the bitumen component of the diluted bitumen that become the dominant properties as the oil weathers.

4.3.4 Heavy

Heavy oils have few light fractions and there are few compounds that readily evaporate or dissolve. These viscous products spread more slowly than products with a lower viscosity and frequently break down into discrete patches and tar balls when dispersed rather than forming slicks. They weather slowly and may sink in freshwater, which makes them difficult to detect and recover. Oil persistence on shorelines may be long (months to years). Shoreline treatment is typically required.

4.3.5 Solid

Solid oils likely sink as the density exceeds that of freshwater. In waters with little current, product movement and transport may be minimal.

4.3.6 Introduction to Unconventional Oils and Biofuels

Conventional oil is typically referred to as crude oil (i.e. liquid petroleum), flowing naturally or capable of being pumped without further processing or dilution; this field guide deals primarily with crude oils and petroleum products derived from crude oils. Unconventional (or non-conventional) oil is derived from other sources, such as, light shale oil (e.g. Bakken) and oil sands bitumen, transported as diluted bitumen (dilbit); note that this field guide considers dilbit in the medium-heavy oil type categories, depending on its degree of weathering. Biofuels (e.g. ethanol-blended gasoline, biodiesel, and vegetable oil) are often promoted by some energy industries and governments as an alternative to conventional petroleum fuels. This section briefly summarizes the behaviours, fates, and potential response techniques for light shale oil, ethanol-blended gasoline, biodiesel, and vegetable oil, highlighting those differences from conventional oils.

Light Shale Oil
Light shale oil is a type of light crude oil recovered from shale oil reservoirs, typically by hydraulic fracturing (“fracking”) techniques. Shale oils occasionally have high hydrogen sulphide (H_2S) concentrations, thereby posing significant air quality risks early in the response. Bakken shale oil was the flammable product in the Lac-Mégantic, QC incident (2013; Section 9.1.6). Overall, Bakken oils tend to have increased levels of natural gas liquids relative to conventional crude oils due to the isolation of pockets of petroleum within the shale formation that are only recently “fracked”. The higher vapour pressure and lower boiling point are the reasons for the increased flammability risk of Bakken shale oil in comparison to other light crude oils; otherwise, the spill behaviours of light shale oil are not so very different from other types of light crude oil.

Ethanol-Blended Gasoline
Ethanol is an alcohol that has a very low viscosity and density in comparison to freshwater; however, it is very soluble in both gasoline and water. When spilled into the aquatic environment, ethanol will mix with the water and may enhance solubility of the gasoline. The introduction of ethanol into fuel changes the oil’s physical and chemical properties and therefore may alter the effectiveness of current spill response techniques.

One of the primary concerns associated with gasoline spills is groundwater contamination in areas where the water is extracted for human use. The ability of ethanol to increase the amount of petroleum hydrocarbons in the water is an important concern.

As ethanol is both volatile and highly soluble in water, spill response decisions typically are more concerned with managing effects and mitigating damages than with containment and recovery. Current best practices for response should follow typical procedures for gasoline fuels. However, the partitioning into surface water and co-solvent behaviour of ethanol-blended gasolines is not fully understood; toxicities of these mixtures to various organisms and the biodegradation of the gasoline portion of the mixtures require clarification.

Biodiesel
Biodiesel fuels can have varying chemical composition depending on the source material (e.g. canola oil, waste fry oils from restaurants, rendered animal or fish fats, etc.) and this is likely to influence their fate and behaviour in the aquatic environment.

Biodiesel is highly soluble in petroleum-based diesel and may be blended in a similar manner to ethanol with gasoline. Biodiesels have densities in the range of conventional diesels and float on freshwater; however, the viscosity of biodiesel tends to be higher, especially at lower temperatures. Some biodiesels can even become solid at temperatures approaching the freezing point of water. Biodiesels are not highly soluble in water but disperse readily. Biodiesel does not have a high vapour pressure and would not be expected to evaporate to a significant extent.

Petroleum diesels have been found to be 5-10 times more acutely toxic to aquatic organisms than pure biodiesels. Biodiesels degrade rapidly and may create a high oxygen demand in the receiving aquatic environment, which results in low oxygen conditions for aquatic organisms.

Current best practices for response should follow typical procedures for light oil; as biodiesels degrade rapidly, bioremediation may be a practical solution for treatment of biodiesel-affected shoreline substrates.

Vegetable Oil
Vegetable oils are not soluble in water, do not evaporate, do not form water-in-oil emulsions, and do not disperse in water.

These oils may have similar environmental effects to petroleum oil spills, such as: coating of fur, feathers and gills; creating high biological oxygen demand; and harmful alteration, disruption, or destruction of shoreline habitats. Constituents or metabolic products of vegetable oils (e.g. free fatty acids) may be toxic to biota.

Current best practices for response should follow typical procedures for light oils.

4.4 Ice and Snow and Effects of Winter Conditions on Oil Behaviour and Weathering

4.4.1 Freshwater Ice Formation

The process by which freshwater ice forms is very different from that of sea ice because, unlike most substances, freshwater becomes less dense as it nears the freezing point. Very cold, low-density freshwater stays at the surface of lakes and rivers, quickly forming an ice layer on the top. In contrast to freshwater, the salt in ocean water causes the density of the water to increase as it nears the freezing point, and very cold ocean water tends to sink. As a result, freshwater ice forms more quickly than sea ice because the saltwater must sink away from the cold surface before it cools enough to freeze. A fewer number of below-freezing temperature days are required to initiate ice growth in freshwater environments as compared to marine or brackish water (Sections 3.1.3 and 3.2.4).

4.4.2 Shoreline Ice Types

The range of shoreline ice types includes:

- glacial cliff;
- glaciers that reach a lake create an ice shoreline that can 'calve' as ice breaks off the glacier front;
- the ice front of a slow moving or retreating glacier may melt without calving.
- edges of seasonal land fast ice;
- ice that is 'fastened' to the shoreline or the bottom and does not move with currents or winds (Figure 4.4: top panel);
- surface ice layers (an "ice foot");
- layers of ice (or an "ice foot") form seasonally although in high latitudes may persist through the open water season – the lake-ward or river channel edge of the ice foot is often a vertical or steep face;
- frozen wave splash, spray, or swash can form a coat of ice on a shoreline or backshore surface (Figure 4.4: middle panel);
- freshwater flowing downslope from the backshore towards the shoreline can freeze.
- shoreline sediments in which the interstitial water is frozen;
- ice can form within a shoreline when water freezes in the interstitial spaces of sediment to effectively create an impermeable substrate.
- permafrost exposed in a cliff at the shoreline;
- erosion of the tundra can expose permafrost.
- individual ice floes, ice pressure ridges, granular or slush ice;
- ice floes (or sheets) of various sizes can be stranded on a shore – these originate from the break-up of lake or river ice;
- ridges form where solid ice grounds and buckles under the onshore pressure (Figure 4.4: bottom panel);
- many forms of ice can be driven against the shoreline by wind or current action, including granular or slush ice.

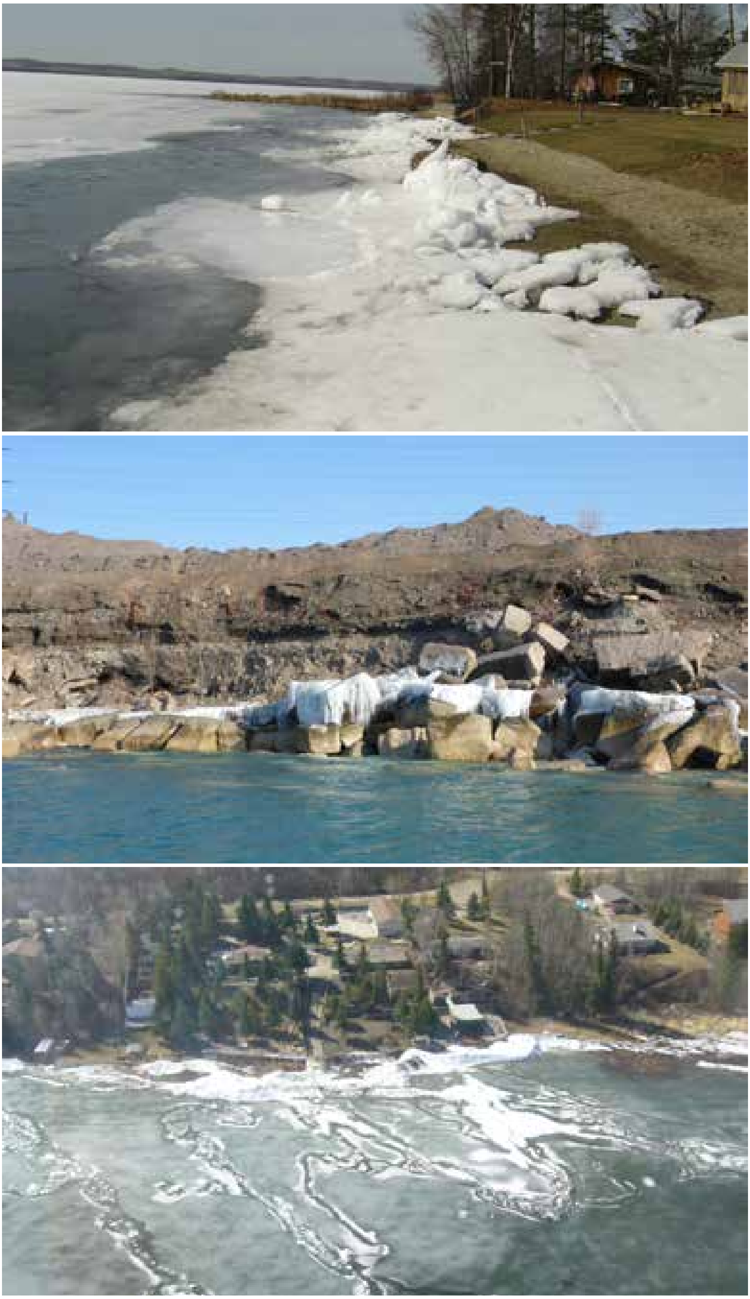


Figure 4.4 Ice and snow on freshwater shorelines: ice 'fastened' to shoreline (top panel); frozen wave splash (middle panel); ice ridges visible during spring thaw (bottom panel)

On shorelines with seasonal ice, the ice forms on the surface of the sediment or bedrock in the form of frozen swash or spray or an ice foot. In these situations, both the surface layer of ice and the underlying geological substrate of the shoreline are considered when planning a response. Ice surfaces do not support significant plant or animal life.

4.4.3 Snow-Covered Shorelines

Snow can be present on any shoreline type with seasonal snow that is layered on top of the sediment or bedrock of the shoreline. The character of the snow surface can be highly variable, ranging from:

- fresh powder with a soft surface, or drifting snow;
- a loose granular surface that results when powder or packed powder thaws then refreezes and re-crystallises, or from an accumulation of sleet;
- a hard, dry, crusty surface;
- wet slush.

As snow accumulates in depth over time, it is common to find a vertical variation in density and porosity. Typically, this steady accumulation is interrupted by the effects of freeze-thaw cycles and wind. As the air temperature oscillates around the freezing point, layers of ice are generated as snow melts during warm daylight temperatures and freezes at night when temperatures drop below zero. If this freeze-thaw cycle is accompanied by precipitation, a range of features can form that may include alternate layers of snow and ice.

Wind action can strip the loose crystals on the surface to expose denser layers of snow below. Blown, powdery snow accumulates in hollows, depressions, or wind shadows. The snow layer itself is not considered to be a sensitive environment. When selecting oil removal tactics, the nature and sensitivity of the underlying sediment, vegetated or bedrock substrates must be considered.

4.4.4 Effects of Winter Conditions on Oil Behaviour and Weathering

The transport and weathering processes summarized in Section 4.1 commence as soon as oil is spilled into the environment. However, their relative importance will vary depending mainly on the oil type and volume and environmental conditions. Winter conditions will have a significant effect on oil weathering processes. Generally, colder temperatures will increase oil viscosity, slow spreading on the water surface and reduce the evaporation rate. In cold weather, oil spills in ice-free water behave similarly to those in warmer conditions but with a reduced weathering rate. The effect on weathering processes in ice-covered water is more complex. In ice-covered water, the interaction of oil with ice affects the rate at which these processes are taking place. Generally, once oil is spilled in ice-covered waters, spreading is limited by the presence of ice, as ice acts as a natural barrier that keeps the oil more concentrated with a greater thickness. This reduction in spreading has far-reaching implications (mostly positive) in terms of extending response times and limiting the extent of the oiled area. In water with an ice coverage > 60%, ice provides natural containment significantly limiting oil movement and, in some cases, providing protection for sensitive resources on the shoreline (Figure 4.5). The presence of ice reduces natural dispersion and emulsification rates, as short waves are dampened by ice floes. Evaporation and biodegradation still take place in ice-covered waters, but the low temperatures usually associated with the presence of ice reduces the rate at which they occur.

Figure 4.5 Ice limits oil movement

Direct interaction of oil with ice will also affect oil behaviour and weathering. Figure 4.6 summarizes the various ways oil can interact with ice. When oil that naturally floats is spilled under the ice it can drift under the ice layer because of currents and movement of ice floes, potentially accumulating in naturally formed reservoirs due to ice roughness. These accumulations will vary in size, but significant quantities of oil could be trapped under the ice in this manner. Some of the oil could be dislodged by currents and continue to drift under the ice. Several studies have set the threshold for movement of oil under ice at 0.5 knots (0.25 m/s). Oil can become encapsulated within the ice structure in winter conditions when new ice is being formed. In some cases, this process can happen rapidly (between 18 and 72 hours) once oil is trapped under the ice surface. As soon as oil is encapsulated, the normal weathering processes cease keeping the oil fresh. The crystal structure of freshwater ice is very different than sea ice and the lack or paucity of brine channels typically affect the timing and process of oil migration during the thaw periods.

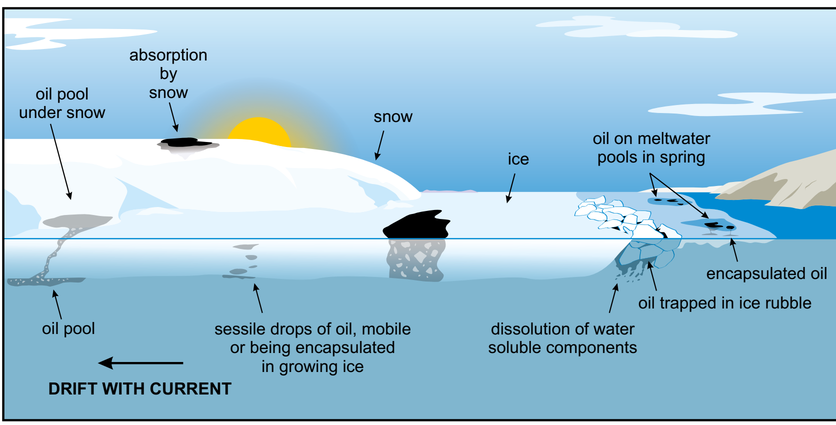


Figure 4.6 Oil and freshwater ice interaction processes

In springtime conditions with melting and warming of the ice, encapsulated and trapped oil can vertically migrate through leads in the ice and reach the surface of the ice forming pools of fresh oil (Figure 4.7). The rate of vertical migration will depend largely on the oil viscosity (i.e. less migration for higher viscosity oil).

Figure 4.7 Oil surfacing through a lead in a lake

The lower oil weathering rate generally observed in ice-covered waters could represent an advantage for response effectiveness in some spill scenarios. However, the presence of ice creates operational difficulties that can offset the advantages provided by the reduced weathering rate. Section 6.1.3 introduces response to oil in ice on shorelines and oil under ice.

If oil is spilled on ice, evaporative loss will be the main weathering process as spreading will be limited by surface ice roughness and by snow absorption. Because of this, oil accumulations on the ice surface are expected to be limited in size and fairly thick. Ice is essentially impermeable; however, oil may penetrate where surface cracks are present. The presence of an ice foot or a frozen layer of ice prevents oil from contacting the shoreline substrate. Oil washed onto the exposed surface of ice, in any of the various forms, is not likely to adhere except when the air temperature is below freezing. Oil on the shore or stranded on the shore-zone ice during a period of freezing temperatures can also become covered and encapsulated within the ice. During a thaw cycle or if the surface of the ice is melting and wet, oil is unlikely to adhere to the ice surface and remains on the water surface or in shore leads.

Oil may be splashed over the ice edge or stranded above the limit of normal wave or current action. The stranded oil can then be incorporated into the shore-fast ice if temperatures fall below freezing again. If oil becomes stranded on the substrate in between ice floes and on the floes themselves, its behaviour would be influenced by a combination of ice and that substrate material. Ice in shoreline sediments, either frozen interstitial or groundwater, can prevent the penetration of stranded oil.

The behaviour of oil on a snow-covered surface depends on the:

- type of oil;
- type of snow (fresh, compacted, or containing ice layers);
- air temperature;
- surface character (i.e. flat or sloping).

If a spill is on the surface of the snow, oil that is above its pour point migrates vertically and horizontally. Oil migrates horizontally from a spill at the base of the snow cover. Oil that is below its pour point could penetrate minimally and run off laterally across the snow's surface. Oil usually penetrates rapidly into the snow column but may be hindered by layers of ice in the snow column that have formed as a result of the freeze-thaw process. As light oil can migrate laterally tens or hundreds of metres within snow, it may be difficult to detect. Oil detection canines (dogs) have been used to successfully locate subsurface oil in snow (Section 7.4).

Snow is an effective natural oil sorbent. The oil content may be very low (less than 1%) in the case of light oils or if the oil has spread over a wide area. The proportion of oil to snow depends on the type of oil and the character of the snow. Snow absorbs more medium crude oils than light products. For example, one cubic metre (m^3) of snow can absorb up to 200 L of light oil and as much as 400 L of medium oil. Oil content is lowest for firm, compacted snow surfaces in below freezing temperatures and highest for fresh snow conditions.

Oil causes snow to melt. Crude oils cause more melting but spread less than gasoline, which spreads faster in snow and over a larger area. Light oils, such as diesel, can move upslope in snow through capillary action as they spread. Fresh snow blowing over oil tends to stick to the oil and migrate down into it, which increases the amount of material to be recovered.

Evaporation is the single most important weathering process for oil trapped in snow. The limited available test data show that oil covered by snow continues to evaporate, although at a lower rate than oil directly exposed to air, and eventually to approximately the same degree as it would if spilled on the water during summer. The actual rate of evaporation is a complex function of several variables including snow diffusivity (related to the degree of packing), oil properties, air temperature, wind speed, and the thickness of the oiled layer.

4.5 Overview of Differences between Freshwater and Marine Environments

Fundamental aspects of shoreline treatment decision-making and response (including SCAT and shoreline treatment objectives, strategies, and tactics) apply in all environments. There are however important differences between freshwater and marine environments due to variations in water levels and water exposure/processes in tidal, lake and flowing water environments, which in turn affect oil stranding, oiling band width and behaviour, and natural removal potential and treatment tactics. Some of the basic differences between fresh and marine environments that may affect oil behaviour and oil spill response include water density, fetch, water levels and flow, biological environment, and water intakes. These differences are introduced in the following sections.

4.5.1 Water Density

The average density of sea water at the surface is 1.025 kg/L, which is denser than freshwater and pure water (density 1.0 kg/L at 4 ºC) due to the presence of dissolved salts. The freezing point of sea water decreases as salt concentration increases, and the likelihood of oil density exceeding that of water increases as the water density decreases. The result is that denser oils can sink more readily in freshwater.

4.5.2 Fetch

Fetch (i.e. the extent of the shorelines exposure to waves/energy) in freshwater environments is typically much smaller in comparison to marine environments, where waves are unimpeded by landforms/barriers for greater distances. Wave heights in freshwater are therefore not typically able to increase to the size of those achieved in the marine environment; however, waves heights of approximately 9 m have been recorded in Lake Superior. Wave height affects response operations with respect to safety, equipment suitability and efficacy, and affects oil behaviour.

4.5.3 Water Levels and Flow

The fluctuation of water levels in the marine environment is dominated by tides, i.e. predictable changes in water levels as a result of gravitational forces of the moon and the sun. Large bodies of freshwater like the Great Lakes are affected by tides, however this effect is small (on the order of cm) and is masked by seiches. Seiches occur when strong winds and rapid changes in atmospheric pressure push water from one end of the lake to the other resulting in an oscillating wave which can be a few metres high (Figure 3.5). In freshwater environments, water levels have long-term, annual, and short-term variations that are affected by factors such as precipitation, water storage over many years, and variations that occur with the changing seasons. Additionally, physical structures (e.g. dams, weirs) may be used to regulate water level and flow (Figure 3.11). Ice melt and spring freshet can cause extremes in water levels and flow, moving oil large distances down rivers and into backshore areas.

4.5.4 Biological Environment

Similar shoreline types in different environments (i.e. marine, lake, river) typically have different productivity and sensitivity characteristics. Biota (i.e. plants and animals) vary from marine, to brackish to freshwater environments. The plant and animal species of any given environment must be considered during the decision-making process in a response, particularly if there are species-at-risk. It should be kept in mind that the majority of scientific and technical knowledge and experience with respect to biological effects and shoreline sensitivity to oil comes from marine oil spills.

4.5.5 Water Intakes

Water intakes, used in both marine and freshwater environments, are at risk of contamination during an oil spill. Water intakes may be used for cooling water for power plants and process water for various industrial sites. Shutting down of water intakes during an oil spill may have a major effect on the facility. Municipal drinking water intakes commonly used in freshwater environments (canals, rivers, lakes, reservoirs) are a high priority as they are directly related to public safety.

5 | Response – Planning

5.1 Net Environmental Benefit Analysis

During an oil spill response, a key objective is to minimize any effects on resources at risk – resources may be ecological, socio-economic, or cultural/historical. Net Environmental Benefit Analysis (NEBA) is a process used by both contingency planners and incident managers to aid in decision-making on the best response tools to use, allowing comparison of different tools, as well as the consideration of any ecological damage that might be caused by the treatment methods available (IPIECA-IOGP 2015).

NEBA is a structured approach allowing for the comparison of the advantages and disadvantages of each response tool, including allowing the oil to naturally attenuate, to limit overall ecological, socioeconomic and cultural effects. The decision-making process must also involve consideration of and compliance with government regulations. Often the best approach might be to allow the affected resource to recover naturally without any treatment, especially where the damage was light or where the available treatment options might cause more harm than the oil itself.

A NEBA for response tool selection is carried out using four steps:

Compile and evaluate data: During this first step the important resources that could be affected by the oil spill are identified and prioritized for protection based on environmental sensitivities and social values.

Predict outcomes: The oil spill planning scenarios are then used to assess potential effects and response options for specific plants and animals, habitats, and other resources that have been identified as important. Fate and trajectory model inputs (from OILMAP, OSCAR, or GNOME/ADIOS 2) are used for various spill scenarios.

Consider trade-offs: The potential environmental and social effects are then weighed against one another to determine the most effective oil spill response tools and balance trade-offs. The trade-off for each segment or section of shoreline typically considers: the predicted fate and persistence of the residual oil; the estimated rate of natural recovery (time element); the possible benefits of a treatment in terms of accelerating recovery; the risks associated with the presence of the oil as it weathers; and the possible delays to recovery that may be caused by response activities. An important component of this process is the methodology used for the risk assessment to determine the net environmental benefit of a response tool (Table 5.1).

Select best options: Each response tool will have different effects on the variety of resources also affected by the oil spill (e.g. shorelines, waterfowl, fisheries, marinas). Local stakeholders and response partners work together to choose the best tools (or combination of tools) available to minimize the effect on the environment and the community. The optimal treatment technique would: have a minimal effect on the affected resources (i.e. the benefits outweigh the effects of the response technique); involve minimal labour and logistical requirements; provide rapid treatment rates; and generate no/minimal oiled waste.

Table 5.1 Overview of methodologies for conducting a formal Net Environmental Benefit Analysis (NEBA)

Methodology	Advantages	Potential Limitations
Consensus Ecological Risk Assessment (CERA)	– commonly used by USCG, US EPA, and the National Oceanic and Atmospheric Administration (NOAA) – has been modified to consider socioeconomic factors and worker health and safety, in addition to ecological resources at risk	– only uses inputs from fate/trajectory model – relies on stakeholders and subject-matter experts to qualitatively score the effects on resources of concern – requires considerable time and planning for stakeholder participation at consensus-building workshops – may be better suited for contingency planning
Spill Impact Mitigation Assessment (SIMA)	– advanced internationally as a consistent approach for conducting formal NEBAs – considers ecological, socioeconomic and cultural elements – accelerates the process of gaining stakeholder consensus on resource priorities during an incident by assigning a weighting factor from assessments conducted during the permitting process of a project – can be quickly reassessed to support changes in spill conditions over time	– only uses inputs from fate/trajectory model – relies on stakeholders and subject-matter experts to qualitatively score the effects on resources of concern
Comparative Risk Assessment (CRA)	– uses inputs from both fate/trajectory and effects models – effects of the spill may be objectively quantified – allows the weighting of certain resources above others (e.g. species at risk present in response area)	– scenario dependent and results may take multiple days of computer processing time to be available – may be better suited for contingency planning

Multiple stakeholders are involved in the NEBA process, which relies on cooperation among various levels of government, industry and communities to ensure that informed response decisions can be made which take all perspectives and viewpoints into account. Response options should be reviewed and fine-tuned throughout the response as information about the distribution and degree of oiling is updated.

NEBA may be used during pre-spill planning and during an oil spill response:

- NEBA is an important part of the pre-spill planning process and is used to ensure that all potential stakeholders and response partners are engaged and response options for different planning scenarios are well thought out.
- During a response, the process is used to ensure that evolving conditions are understood so that the response options can be adjusted as needed.

The process conducted during an oil spill is the same as that conducted during pre-spill planning, however:

- There is only one spill scenario to address during an actual spill and known spill conditions mean some uncertainties are reduced (e.g. the type and amount of oil released is typically known).
- Decisions need to be made quickly and data may be incomplete. Decisions may rely more heavily on expert opinion and professional judgment in comparison to pre-spill planning. Delays in decision-making may limit the feasibility of a response tool during an oil spill (e.g. the ‘window of opportunity’ may close).
- Specifics of the actual oil spill may change previously agreed to priorities for protection or acceptable trade-offs, so these will need to be revisited on an ongoing basis for the duration of spill response.

The NEBA process can also be used to help make decisions concerning restoration activities that may be planned and undertaken after an oil spill response.

5.2 Shoreline Response Programs

There exist clear differences between the scope of response plans for spills to small creeks and streams, rivers, and lake or marine coasts (Figure 5.1). The primary difference is that the planning for spills into ditches, creeks and streams can be quite site-specific and focus on identifiable potential risks and effects, more so than river, coastal, or open lake and marine spills as forecasting of spill movements are typically more accurate. From a response standpoint, the consequences as oil transitions from the creeks and streams, to rivers, and then open lake and marine coasts are that the scale of the survey strategy and the size of response area increase with the spreading of the oil.

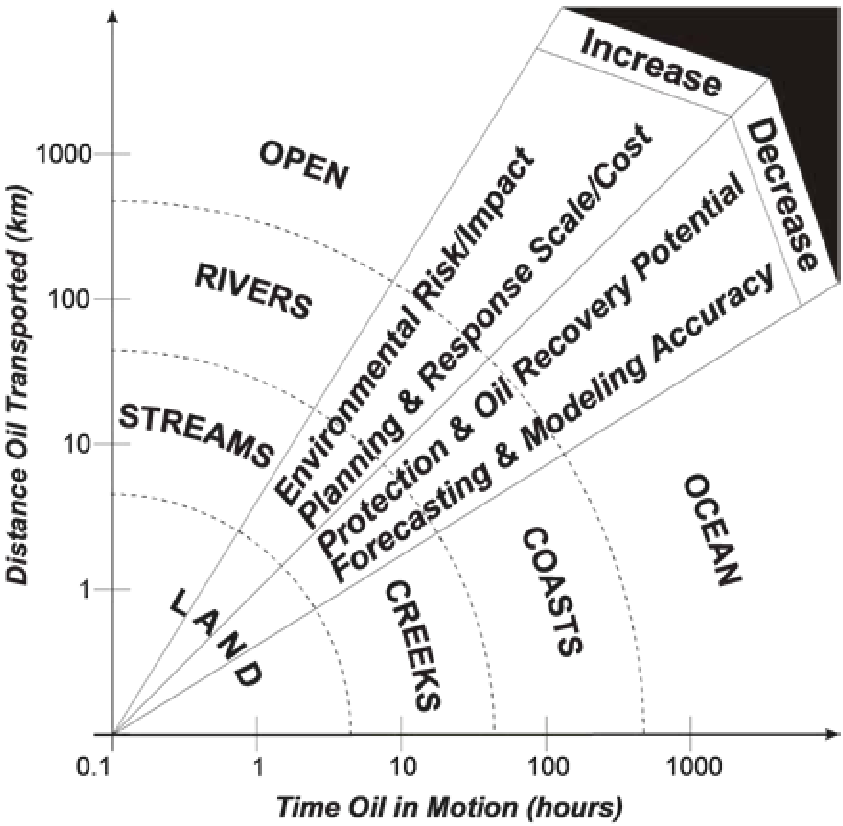


Figure 5.1 Time-space schematic for spills in different environments (from Owens 2017)

The scale of the response has a direct effect on shoreline response planning in terms of the span of control and the size of the SCAT program. The size of affected area for a spill into a stream or creek may be on the order of a few hundreds of metres to tens of kilometres, whereas oil that reaches a large river channel or an open lake shoreline can affect tens to hundreds of kilometres. The issue is compounded in rivers by the potential for oiling on both banks and on mid-channel islands or bars.

A Shoreline Response Plan (SRP) is intended to integrate all aspects of a response from the initial oiling assessment, SCAT field surveys, operational activities to treat or remove stranded oil, through to the inspection process that provides closure to the response. An SRP is established as soon as it is evident that lake shores or river banks have been oiled or potentially would be oiled. A SCAT program is a key component of an SRP that provides data on the oiling conditions, recommendations for treatment activities and a mechanism to determine that treatment criteria have been achieved (ECCC 2018). Refer to Section 8.1 for additional discussion of shoreline treatment criteria.

The primary functions of an SRP are to:

- Focus on the shoreline component of a response;
- Maintain span of control;
- Develop long-term strategies;
- Initiate, implement and manage a SCAT program within the SRP;
- Provide survey data to the spill management team decision makers;
- Coordinate between the decision makers, the command staff, planning and environmental managers and Operations to generate, implement and manage the SRP;
- Incorporate Shoreline Treatment Recommendations (STRs), which are generated by the SCAT teams and approved by the command staff, into the SRP;
- Liaise with Operations in the Command Post and in the field to ensure that the SRP and the STRs are understood and implemented appropriately;
- Develop and test new or improvised treatment tactics;
- Track STRs and operational progress;
- Manage segment inspections and treatment completion determinations (removal of signed off/approved segments from the response).

An SRP integrates the various aspects of a treatment program such as the field SCAT surveys, data management, the treatment decision process, generation of treatment recommendations, operations support and liaison, and post-treatment inspections (ECCC 2018).

Key components of an SRP include:

- Health and safety;
- Program objectives;
- Program management;
- Field team participants;
- Field methods and forms (aerial reconnaissance during initial stages; shoreline inspections);

- Shoreline treatment process;
- Data management and reporting;
- Logistics;
- Spill management support;
- Liaison with the Operations Section;
- Treatment criteria;
- Shoreline treatment options;
- Prioritization of treatment by segments;
- The sign-off and completion process.

5.3 Segmentation and Mapping

Segmentation is the backbone of a SCAT mapping and data framework. All information collected, whether for pre-SCAT, or during SCAT surveys, monitoring, or inspection surveys are managed and processed within this framework. Each segment (or sub-segment) has a set of criteria and conditions (treatment criteria, priorities, tactics and constraints) that are used by Planning and Operations throughout a response.

Shoreline segmentation, wherever possible and appropriate, should consider the parameters described in the following sections.

5.3.1 Lakes

Lake Shoreline Character

The primary rationale for shoreline segmentation is based on the division of along-shore sections within which the shoreline character is relatively homogeneous in terms of physical features, sediment type, vegetation cover, and wave exposure, as they relate directly to oil behaviour and treatment options (Figure 5.2). Treatment approaches for different types of shoreline substrates are provided in Section 6.3.

Figure 5.2 An example of primary segmentation for shoreline

Backshore Character

The backshore character and land use are frequently important for response decisions as well as logistics. Changes in the backshore can be an important consideration in segmentation as they may affect access, staging and treatment options; i.e. is the backshore character a cliff, forested lowland, wetland, agricultural field, public park, or parking lot?

Jurisdiction

Segments that span jurisdictional boundaries often can necessitate the inclusion of multiple stakeholders and Indigenous communities with different objectives and concerns that could be avoided if segments or sub-segments are delineated according to these boundaries. These boundaries can be administrative, political or related to land ownership or management.

Rivers and Streams at the Shoreline

A guiding principle for segmentation along a lake shoreline is to avoid the use of a river and stream for segment breaks. Rivers and streams often have fisheries or other wildlife concerns and a segment break in the channel places all related restrictions into two separate segments when those may apply equally to both banks of the channel. It is preferable to make the stream or river channel and the adjacent shoreline a single unit so that the segment has its own physical and ecological identity (Figure 5.3).

Figure 5.3 Segmentation at rivers and streams

Lake Shoreline Segmentation Naming Convention

In order to provide shoreline segmentation that can be used by all response personnel, a segment naming convention must be systematic, easy to adapt, and intuitive to use. On small local spills with only a few segments, this can be a simple sequence of numbers, i.e. 1-10. On larger spills with more extended coverage, segments are broken into operational groups, i.e. ABC-01 to ABC-10. Segmentation may have to include regional as well as local geographic naming to provide a unique reference name to all shorelines within response plans.

A hierarchical structure, starting at the highest level and subsequently broken into smaller sections down to the individual shoreline segments or sub-segments, provides a method to collect and manage data at different levels of detail (geographic scale) within the same segmentation framework. Each segment or sub-segment would have a unique reference name within the hierarchy, no matter how large the response area (Table 5.2).

Table 5.2 Lake shoreline segment naming hierarchy

Lake Shoreline Pre-Incident Naming Convention Hierarchy		Example CODE
Geopolitical Reference Codes	**(1) Global:** Province or Territory, e.g. Ontario	ON
	(2) Regional: Smaller Scale, e.g. Lake Huron	HUR
	(3) Area: Larger Scale, e.g. Nottawasaga Bay	NTW
Mapping Unit Codes	**(4) Group:** Local Geographic Reference, e.g. New Wasaga Beach	NWB
	(5) Segment: Individual section of shoreline	01
	(6) Sub-Segment: Secondary response features or condition	a

The higher levels in the hierarchy (1-3) provide a **Geopolitical Reference** (ON/HUR/NTW), and the lower levels (4-6) define the individual sections of shoreline or **Mapping Units** (NWB-01). The resulting hierarchical naming, for example ON/HUR/NTW/NWB-01, would define a section of shoreline at Wasaga, Ontario, in Lake Huron. A **Sub-segment** identifier (6) can be added if it is important to further define and describe unique features or conditions within a segment.

Minimizing the segment numbering to a small count within local geographic groups is more intuitive for operational segments. Depending on the size and location of a spill, only the last section(s) of the naming reference would be used in a response, i.e. NWB-01.

Oiled zones are not traditionally part of the "segmentation" convention. They are a point-in-time division of observed conditions across and along the shoreline, ephemeral often changing in time and space from survey to survey. Zones are documented within the established segmentation structure for all SCAT surveys, including lakes, rivers, and streams (and marine), regardless of existing segmentation or mapping, as discussed in Sections 5.3.1 and 5.3.2. Although zones are linked to segments, they are separate from the "segmentation" and represented separately on forms, and in databases and Geographic Information Systems (GIS).

During an incident, oiled zones provide the actionable shoreline data sets used to generate Shoreline Treatment Recommendations (STRs) and describe and categorize the oiling to help determine the best response actions.

5.3.2 Rivers

The segmentation process for rivers, streams, and creeks is slightly different as the "shorelines" include the two river/stream banks as well as mid-channel islands or bars. For the purpose of a SCAT survey, a distinction is made between rivers and streams, creeks or ditches based on survey and operational factors:

- **Rivers:** Surveys and operations are conducted separately for each of the right bank, left bank, and mid-channel island, etc. This typically involves access to the shoreline from different backshore locations or by water.
- **Streams, Creeks, and Ditches:** A survey or an operations activity may be conducted for both banks at the same time. Access to adjacent banks is the same, typically from the backshore.

The choice to use the River or Stream SOS form will often be a factor of scale and water conditions. During high water flow, both banks of smaller streams may not be assessed as a single survey (i.e. the left and right banks may be assessed on separate occasions) – may use River SOS form. In the case of relatively small uniform features, such as ditches, it may be more practical to consider each segmented section as a single entity and not record left and right banks separately – may use River SOS form, indicating the survey covers both banks in Section 1 of the form.

River segmentation may differ depending on whether pre-SCAT mapping has been completed and segments pre-identified or if segments are created at the time of a response. In the absence of pre-incident segmentation and mapping the most practical approach is based on fixed-length downstream subdivision for the response area (Section River KP Segments and Sub-Segments). Pre-incident segmentation and mapping does not have a "starting point" and is based on a hierarchy of subdivisions creating unique Segments within a larger mapping framework (Section River Segmentation Naming Convention).

River KP Segments and Sub-Segments

In the absence of segmentation at the time of an incident, the KP (Kilometre Post) Segment and Sub-Segment concept is practical and straightforward for all rivers, streams and creeks. The segmentation system follows a simple downstream fixed-length KP sequence starting at the Point of Entry (POE = KP 00). The fixed lengths follow the midstream of the channel and can be generated by a GIS or by hand on maps:

– For streams and creeks this fixed-length segmentation system typically is sufficient (Figure 5.4).

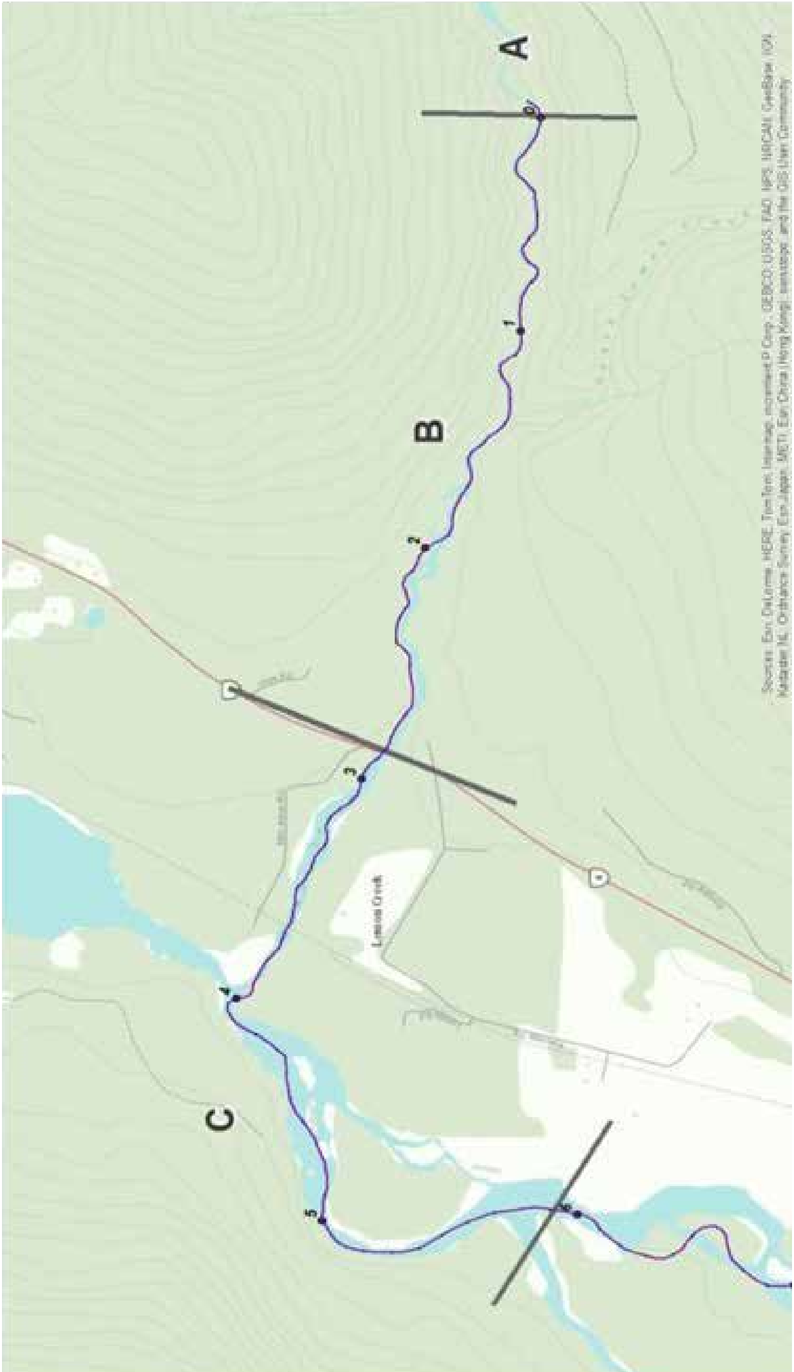


Figure 5.4 Single-channel stream or creek KP segmentation

- For single channel rivers, with small bars and small islands that may be seasonal in character, the same simple downstream KP segmentation sequence starting at the POE is sufficient with segments based on location within the KP channel section; for example, KP 04, with Right Bank, Middle Channel, and Left Bank (RB, MC, LB) segments facing downstream; e.g. 004-RB, 004-MC, 004-LB.

Even a single channel system may have some complexity if islands are present (Figure 5.5):

- Island banks have a sub-segment alphabetic designation in addition to the segment number, to allow for coding multiple separate islands within a 1 km section of river; e.g. 001a-MC, 001b-MC, etc.
- Where islands cross KP segment boundaries, the section of river that contains the majority of the island bank is used in the naming convention (e.g. 003a-MC).
- Where islands span a longer section of river (> 1 km) the left bank and right bank of the island are given a separate alpha-numeric designation to minimize long segment lengths and simplify SCAT survey logistics (e.g. 004a-MC, 004b-MC).
- Under certain circumstances, subdivision into sub-segments may be appropriate to identify changes in land ownership or management (such, as stakeholder lands, parks or industrial facilities).

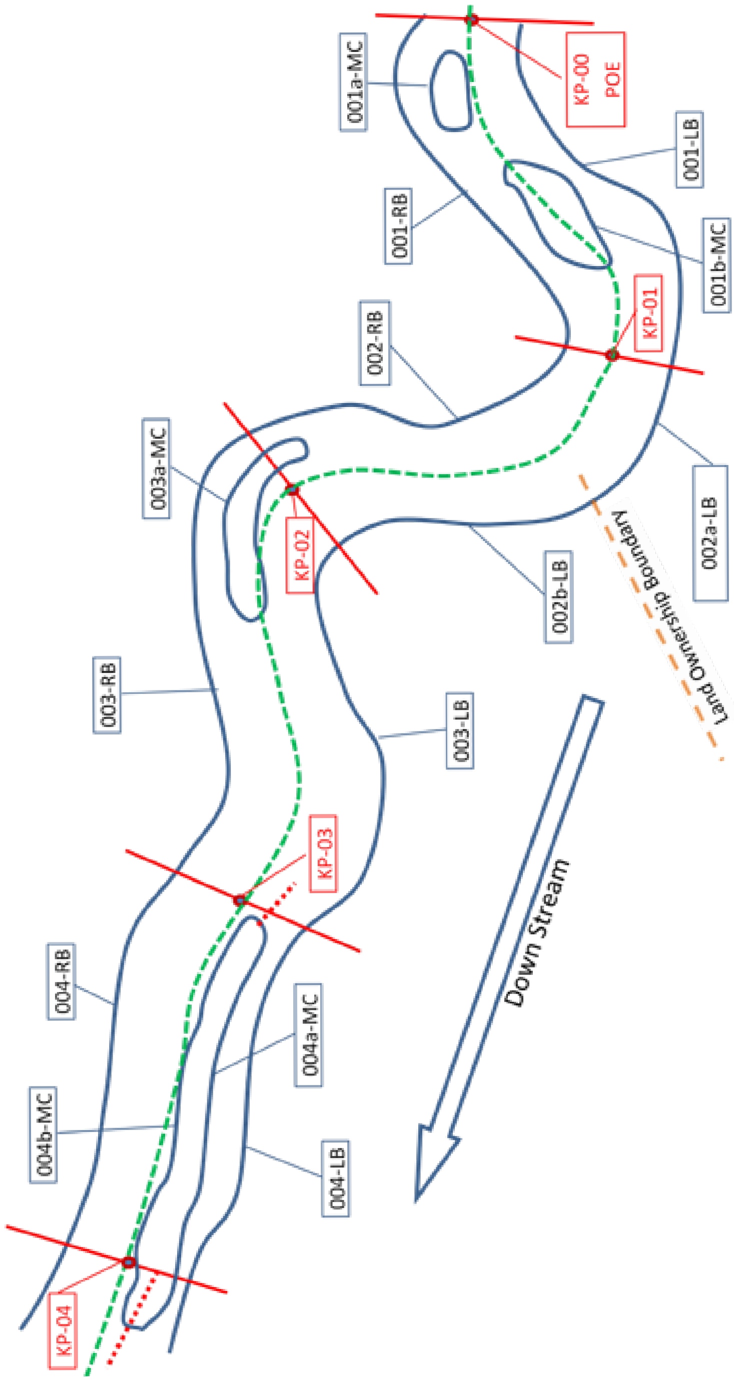


Figure 5.5 Single-channel river segmentation with sub-segments

For a multi-channel river, the same KP segmentation approach can be used based on a single major channel, if there are two channels, or the median channel, if there are more than two channels (Figure 5.6). The major or median channel retains the 1-kilometre KP segment numbering system based on starting at the POE with an "A" prefix; for example, A-001. The segmentation within the main channel (A) represents the overall distance (km) downstream from the POE.

- The first diverging, or side, channel is assigned a "B" alphabet prefix based on the KP at the point of divergence (e.g. B-005) and is numbered through to the KP where the channel reconnects the major or median channel (B-045).
- The KP sequence number of the divergent channel may be less or greater than that of the major channel where they reconnect, as is the case for the "B" channel in Figure 5.6.
- The alphabet prefix is then used sequentially downstream with each new divergent channel number beginning at the main ("A") channel divergent KP; e.g. C-010, which reconnects at C-033.
- This means that all segment numbers, regardless of channel, represent the distance (km) downstream from the POE within each designated channel.
- If a channel diverges from a secondary channel, a system could be developed with a similar numbering concept, for example, BA and BB for channels diverging from the secondary B channel.

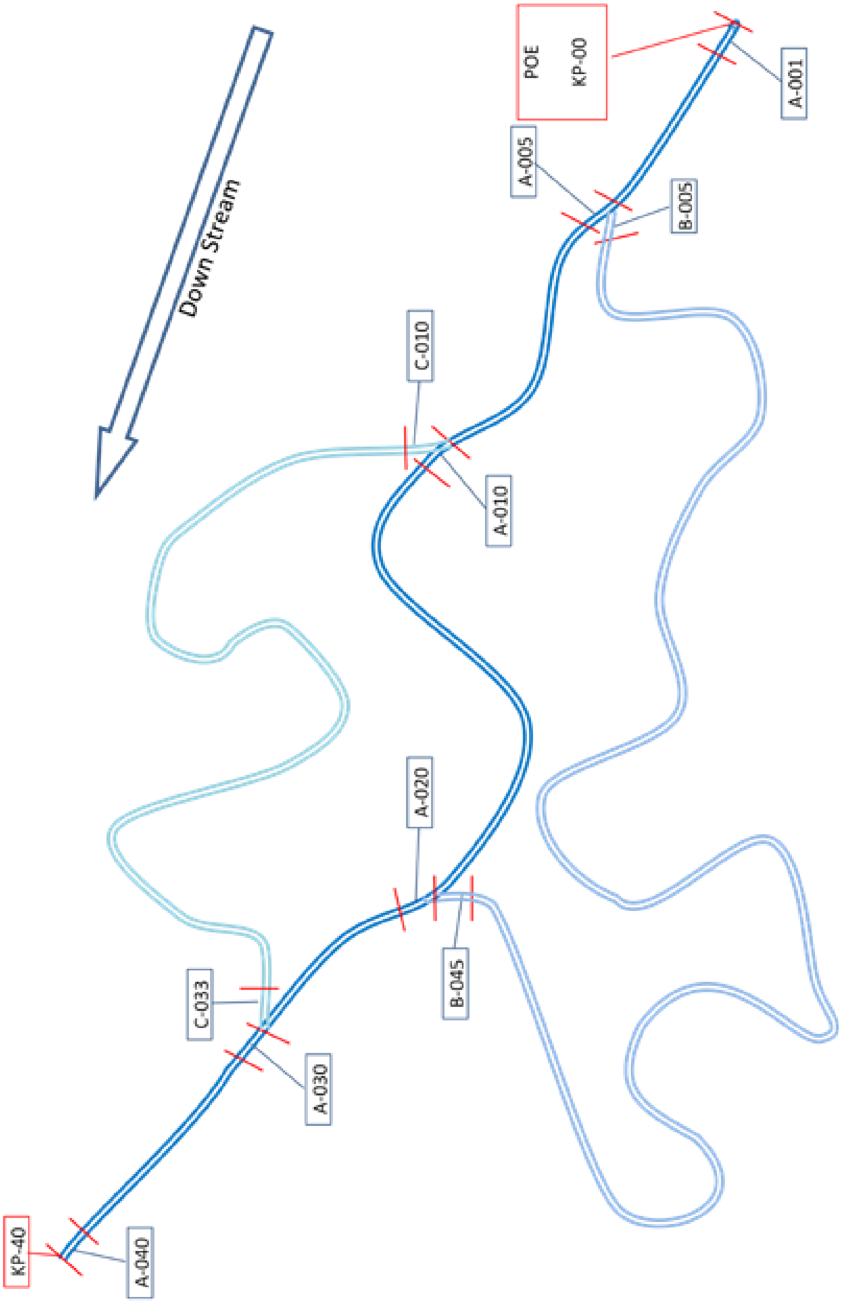


Figure 5.6 Multiple-channel river segmentation with one primary ("A") and multiple secondary channels ("B" and "C")

This river segmentation concept, whether for single- or multiple-channel systems, is based on fixed distances downstream and runs counter to the standard marine or lake shoreline segmentation process, which is typically based on changes in substrate and morphology (form). However, shoreline substrate and form parameters are reintroduced into mapping and the database as they are coded on a SOS form as part of the individual zone information within each segment or sub-segment. Standard procedures, where pre-spill mapping is not available (or if existing mapping is of poor detail, out of date, or there are observed conditions that may affect treatment considerations not documented on existing mapping), are to break zones within segments if the shoreline character changes significantly (e.g. from vegetated flat to erosional cut bank), even if the oiling conditions do not change. This allows the data management team to provide documentation on river form and substrate as relates to different bank/bar types, oiling conditions, and treatment options, as the surveys progress without the need to pre-map the river system. Additionally, zones that identify undocumented changes in land use or operational constraints that may affect long-term response decisions and achievement of shoreline treatment criteria can be used to delineate sub-segments for the remainder of the response to facilitate future surveys and operational actions.

River Segmentation Naming Convention

For SCAT surveys on rivers, streams or creeks that have not been pre-segmented or mapped the most practical approach at the outset of a survey program is to begin segmentation at the POE of the spilled oil into the river system using the approaches described in the preceding section. The segmentation naming convention or hierarchy for rivers, streams, and creeks in this situation differs from that practised on marine and freshwater shorelines as the extent of the affected area is clearly defined. A typical hierarchy would have large-scale Operations Divisions created initially for strategic and logistics planning (Table 5.3). These divisions are independent of a SCAT segmentation process but nevertheless important as they are recognized by managers at the strategic decision level. Reach Groups are created during the survey program by the SCAT team to summarize large scale (multi-kilometre) river regions or oiling characteristics; as an example, the segments immediately downstream of the POE typically are an area with highest oil concentrations on the banks and can be grouped for specific operational planning purposes.

Table 5.3 River system incident-specific segment naming hierarchy

Incident-Specific Hierarchy	Purpose
Operations Divisions	Created at the outset of the response by Operations for strategic and logistics management
Reach Groups	River divided into hydrological/geomorphological regions to compartmentalize the SCAT data to interpret oiling conditions
KP (Reach) Sections	Fixed-length channel sections based on Kilometre Post (KP) units downstream and mid-channel from the Point of Entry (POE) of oil into the river
KP Segments	Left and right bank or mid-channel (island) shorelines within a KP Section
Sub-Segments	Further division of KP Segments to delineate secondary shoreline conditions and to identify multiple mid-channel island banks

By contrast, pre-incident segmentation and mapping does not have a “starting point” and is based on a hierarchy of subdivisions creating unique Segments within a larger mapping framework. The segmentation naming convention or hierarchy for rivers, streams, and creeks does not differ significantly from that practised on marine and freshwater shorelines (Section 5.3.1). The higher levels in the hierarchy (1-2) provide a **Geopolitical Reference** (SK/ASB), and the lower levels (3-6) define the individual sections of shoreline or **Mapping Units** (KLV-01-RB) (Table 5.4).

Table 5.4 River system pre-incident segment naming hierarchy

River Channel Pre-Incident Naming Convention Hierarchy		Example CODE
Geopolitical Reference Codes	**(1) Global:** Province or Territory, e.g. Saskatchewan	SK
	(2) Regional: Smaller Scale, e.g. Assiniboine River	ASB
Mapping Unit Codes	**(3) Group:** Local Geographic Reference, e.g. Kelvington	KLV
	(4) Section: Individual section of shoreline	01
	(5) Segment: Left or right bank or mid-channel	RB
	(6) Sub-Segment: Secondary response features or condition	a

5.4 Geographic Response Plans

A Geographic Response Plan (GRP) is a document that provides geographic-specific information intended to assist responders during the initial phase of a spill response. The availability of this information enables responders to take appropriate response actions at the onset of an incident. A GRP may be a component of an Area Response Plan (ARP) or other Emergency Response Plan (ERP) which encompass a larger area and provides the overarching structure for an integrated response.

The overall objective of a GRP is to provide proven tactical direction and response actions for the initial response, and to assist responders by identifying the location of sensitive resources and spill management points. Maps and tactical sheets [i.e. Tactical Response Plans (TRP)] are used to provide relevant spill management point information, such as best locations to deploy containment and recovery equipment and logistical and operational response features, such as boat launches and staging areas. The GRP also contains logistical information, such as hotels, restaurants, heliports, airports and potential Command Post (CP) locations.

GRPs and TRPs are highly operational plans to ensure swift and efficient response in case of an incident. They provide advanced emergency response planning information to response crews principally in the form of Spill Management Points (SMPs) or Tactical Control Points (TCPs). These are strategic locations where response equipment may be deployed safely and efficiently to prevent further oil migration and facilitate recovery or protect sensitive resources. Typically, each point has its own tactical sheet of site-specific information including location, access considerations, characteristics of the waterway, recommended response tactics and necessary equipment as summarized in Table 5.5.

Table 5.5 Broad categories of information provided for each Spill Management Points (SMP) and Tactical Control Points (TCP)

Category	Description
Operational Information	Location of SMP, modes for access and other considerations, etc.
Site Characteristics	General nature of the waterway at or near the SMP, physical characteristics, etc.
Response Objectives	Main purpose of the response
Tactical Considerations	Description of the methods used to achieve the response objectives and equipment/personnel needed
Safety	Potential issues and mitigation
Winter Response	Winter response considerations and methods
Environmental Sensitivities	Sensitive elements that could be affected by the incident or response
Aerial Overviews	Aerial overviews with diagrams showing access, tactics, etc.

Culturally and environmentally sensitive receptors need to be protected and preserved in the event of a release. Receptors in freshwater environments may include a wide variety of sensitivities, such as drinking water intakes, water wells, protected areas, federal, provincial, and municipal parks, aboriginal reserves, wetlands, and species of concern. The sensitivity information found in GRPs is intended to support the Environmental Unit (EU) and help ensure consistency and coordination in the approach taken to protect sensitive resources during oil spills. Engaging stakeholders and Indigenous communities during the development of a GRP is an important process and can ensure that vital local knowledge is captured.

A key challenge for freshwater response planning, particularly on rivers, is identifying suitable access points. Access points may be rare in remote areas or where river access is difficult, making vessel transit times and therefore response times longer.

All actions in a response should be modified to meet the demands of a specific incident. The GRP plan does not direct actions, but merely serves as a resource to responders. The strategies and tactics described in a GRP document may need to be adjusted to consider environmental conditions observed at the time of an incident.

6 | Response – Operations

The presence of oil on a shoreline does not necessarily result in shoreline treatment. Non-persistent oils, such as gasoline or diesel, can pose safety issues for responders. If exposed to higher-energy conditions, such oils typically weather rapidly, over a period of hours to days, so that natural recovery may be the most appropriate course of action. The shoreline treatment decision process involves an evaluation of:

- the safety of field teams;
- the type and amount of oil on a segment or section of shoreline;
- whether the oil is on the surface or has penetrated sediments;
- the likely residence time (persistence) of the oil;
- the resources (environmental, socio-economic) that would be at risk during that time period;
- the sensitivity and vulnerability of those resources (refer to text box);
- logistics and access to the affected area or sites;
- relative operation rate of treatment technique;
- the likely effectiveness of treatment to reduce environmental effects and risk;
- waste volumes and types generated.

There is a distinction between "sensitivity", which is the response or reaction of a resource to the presence of oil and "vulnerability", which is the probability that a resource would be exposed to or affected by the oil. For example, waterfowl are very vulnerable to an oil spill as they spend much of their time on the water surface.

6.1 Useful Tips for Responders in the Field

Spill response considerations for each incident will be unique. Responders must assess each situation, obtain key information, and determine the oil's trajectory before deciding on the best location to intercept the oil and on which strategies and tactics will be most effective. In lakes or slow-moving water there is more time to make such decisions, however, in fast-moving water this assessment must be done relatively quickly. The following provides useful tips for responders in the field, and as previously stated, safety of field personnel is always the priority.

6.1.1 Estimating River Speed

Due to the variations in river levels and flow, the strategies identified in a GRP may or may not be effective. The water velocity will affect decisions on where best to contain and recover product, what type of equipment may be used, and boom performance. Responders will need to factor in their transit time to the best spill management point and be able to deploy the equipment in advance of product arrival at that location. The water velocity will influence how effective boom is in containing product and the angle that boom should be deployed at in relation to the shoreline. Current meters can be used to determine the water velocity. If this instrumentation is not readily available, responders can use the following quick, easy speed test to estimate the water velocity on-site.

Simple Method for Estimating River Speed

1. Select a few branches or other small floating objects
2. Measure off a distance along the shoreline (e.g. 10 m) – Point A and Point B
3. Place a stick in the water and record the time between Point A and Point B
4. Repeat for accuracy then take an average time

Examples of results:

a. Travel time between A and B: # 1 = 20 seconds (s); # 2 = 24 s

b. Average travel time: (20 + 24) / 2 = 22 s

c. Speed estimated: Distance travelled / average time = 10 m / 22 s = 0.45 m/s = 0.90 knots

6.1.2 Natural Collection Areas

Current velocities are highest in the deeper channels of a river and diminish as depth decreases near shore, due to bottom friction effects. Floating oil will tend to collect in areas where floating debris accumulates and strands and the current has slowed, making containment and recovery more feasible (Figure 6.1). Natural collection areas should be identified during the development of a GRP as a part of the identification of the most effective spill management points. Ideally, spill management points are located where: current speed is reduced; the prevailing patterns of water circulation or wind direction promote accumulation; there is good access for responders; there is adequate depth for boom and vessel operations; and there are good mooring locations for booms and anchors. Pre-debris removal should be considered at these sites in advance of product arrival to minimize the amount of debris that may become oiled or that could damage equipment. Local knowledge is an invaluable resource when determining locations for spill management points and natural collection areas. Responders will benefit from consulting with local fishermen, local boat operators, and other water users.

Figure 6.1 Natural collection areas along a channel (top panel) and accumulated woody material (bottom panel)

6.1.3 Response in Winter Conditions

Responding to spills during winter also imposes additional hazards due to the cold temperatures, slippery conditions, the bearing capacity of ice, and shifting ice which can move quickly with changes in wind and currents. Safety of responders must always be assessed before attempting to deploy equipment on or around ice. Oil can be held away from shoreline by ice acting as a barrier, mixed with broken ice on the shoreline or oil can be under the ice along the shoreline (Section 4.4). Weathering of oil will occur more slowly in cold temperatures. This is a safety consideration as light ends will persist longer, but it also means that the window of opportunity for burning is lengthened. Cold temperatures may affect the ability to skim/pump oil due to pour point and viscosity and can affect the operation of machinery causing them to be less efficient, or have issues with freezing, condensation, etc. Vessel operations may be limited/not feasible, and the use of boom is limited in broken ice. Intakes on pumps or outboard engines can freeze-up and pumps or engines may have to run continuously. Skimmers may require screens to keep ice out and can only be used if there is enough open water to deploy. In addition, skimmers may be winterized (e.g. with heated hopper and scraper and hot water injection system to improve recovery) for use in harsh conditions. Adequate warming facilities and breaks must be provided to responders to ensure their health and safety.

For additional information on response operations during winter conditions, there are several recent manuals available that detail response options (on-water and shoreline) and safety considerations for operations in ice and snow (Owens and Dickens 2015; EPPR 2017; IMO 2017).

6.1.4 Specialized Response Equipment for Freshwater Environments

Freshwater environments vary greatly from wetlands to rivers to the Great Lakes. The response equipment used must be safe and effective for the environmental conditions. Table 6.1 below lists some of this specialized equipment by working environment. In all cases responders must be properly trained to use the equipment.

Table 6.1 Specialized equipment by freshwater environment

Freshwater Environment	Response Equipment
Wetlands, low-lying inundated areas, flooded uplands	– Walking boards – Cutting tools – Reed harvesters – Kayaks/canoes – Airboats
Small streams, creeks	– Culvert blocks – Underflow dams – Sorbent boom – Filter fences – Walking excavator (to access along steep shorelines) – Skimmer designed for flowing water (e.g. advancing, circular)
Larger rivers	– River boom – Boom deflector – BoomVane™ (self-deploying current rudder) – Flow-Diverter – NOFI Current Buster® Technology systems or other specialized sweep/buster systems – Anchor systems – Shoreline anchors/anchor plates – Walking excavator (to access along steep shorelines) – Skimmer designed for flowing water (e.g. advancing, circular)
Large lakes	– Open/unsheltered water boom – Weir skimmers – Sweep systems – NOFI Current Buster® Technology systems or other specialized sweep/buster systems – Larger vessels
Ice	– Winterized skimmers and equipment – Chainsaws/cutting tools – Ice picks and hooks – Augers – Safety harnesses and rescue lines

6.1.5 Sources of Information for Responders

The following Table 6.2 provides an initial list of valuable information sources for responders – there will likely be additional site-specific information relevant for the area responders are working in.

Table 6.2 Information sources

Weather Forecasting
Environment and Climate Change Canada
Canadian Coast Guard MCTS
Wind Chill and Humidex Calculator
Environment and Climate Change Canada
Hydrometric Data
Water Survey of Canada (WSC) – real time; historical
Ice Conditions (Great Lakes)
Canadian Ice Services (Great Lakes)

6.2 Shoreline Protection

This section of the field guide addresses the physical or mechanical tactics and techniques that can be used in the nearshore and at the shoreline to implement a shoreline protection strategy in open-water conditions. Response options for submerged and sunken oil are discussed in Section 7.3.

The overall objective of shoreline protection is to prevent or minimize the amount of oil becoming stranded that could potentially affect sensitive resources. If oil cannot be contained or recovered on the open-water due to feasibility, practicality, or safety factors, control strategies near or at the shoreline may be implemented to protect site-specific sensitive and vulnerable resources or habitats at risk.

The objectives of a nearshore, on-water protection strategy are to:

- contain and recover oil;
- exclude oil from a sensitive resource (e.g. wetlands, municipal water intakes, harvesting sites);
- divert oil away from the shoreline; and/or
- deflect oil to strand on a section of shoreline that either has less sensitive resources or where recovery may be more effective.

On-water protection can be shore- or water-based and typically focusses on booming strategies to contain, exclude, or redirect (divert, deflect) floating oil. On-water strategies are typically implemented by water-based Operations teams.

Protection strategies at a shoreline are typically land-based and may involve a variety of techniques to contain or exclude the oil depending on the shoreline type and oiling character:

- moveable barriers and booms – water-ballasted (i.e. shore-seal) boom; conventional boom; sorbent boom;
- fixed barriers and dams – sandbags; geotextile or plastic barriers; solid barriers;
- sumps – trenches.

Shoreline protection tactics appropriate for freshwater environments are shown in Table 6.3 and are detailed in the following **Shoreline Protection Information Sheets (Section 6.2.1).**

Table 6.3 Shoreline protection tactics

Shoreline Protection Tactic	Shoreline Protection Information	
	Sheet #	Page #
On-water Tactics		
Containment and recovery	1	Page 92
Deflection (redirection away from shore)	2	Page 94
Diversion (redirection towards shore)	3	Page 97
Exclusion by boom or barrier	4	Page 100
Onshore Tactics		
Containment with shore-seal boom	5	Page 102
Containment by barriers, berms, sorbents, or sumps	6	Page 104
Exclusion by contact barrier	7	Page 106
Exclusion by booms, barriers, or dams	8	Page 108

Each of the eight (8) shoreline protection tactics are described using the following sections:

- Objective;
- Description;
- Safety Notes;
- Applications;
- Overview of Tactic Consideration(s) for Specific Conditions;
- Operational Limiting Factors and Potential Solutions.

The following **Shoreline Protection Decision Guides** provide a quick reference for selecting shoreline protection tactics for lakes and ponds (Figure 6.2) and rivers and streams (Figure 6.3). In practice, two or more protection tactics or techniques are usually used to achieve the operational objectives. Safety must be assessed at each step within a **Shoreline Protection Decision Guide** – safety is always the highest priority. If shoreline oiling does occur, refer to the **Shoreline Treatment Decision Guides** (Figures 6.4, 6.5 and 6.6).

SHORELINE PROTECTION
INFORMATION SHEETS

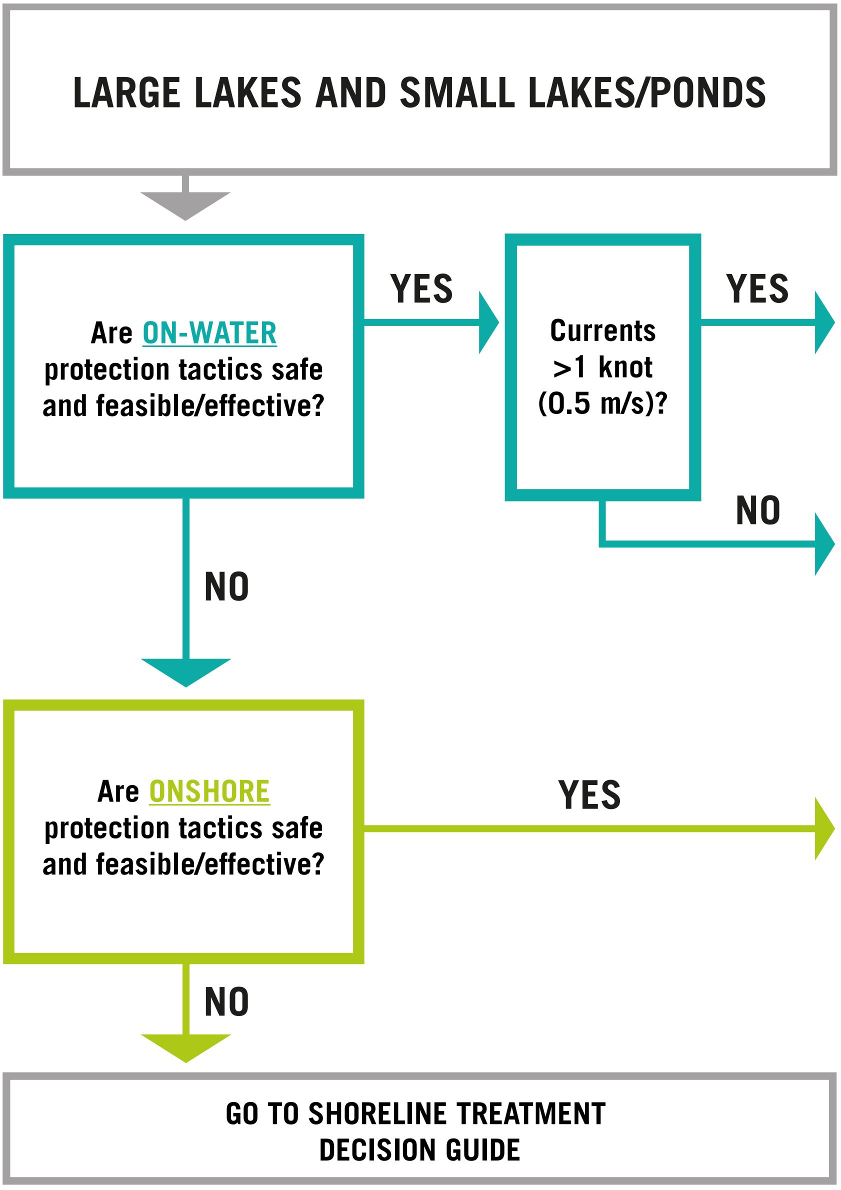


Figure 6.2 Shoreline Protection Decision Guide: lakes and ponds

Shoreline Protection Tactic		Shoreline Protection Information	
		Sheet #	Page #
On-water Tactics			
YES	Containment and recovery **(Use fast water strategies, Section 7.1.2)**	1	Page 92
	Deflection **(fast water)**	2	Page 94
	Diversion **(fast water)**	3	Page 97
NO	Containment and recovery	1	Page 92
	Deflection	2	Page 94
	Diversion	3	Page 97
	Exclusion by boom or barrier	4	Page 100
Onshore Tactics			
YES	Containment with shore-seal boom	5	Page 102
	Containement by barriers, berms, sorbents and sumps.	6	Page 104
	Exclusion by contact barrier	7	Page 106
	Exclusion by booms, barriers, or dams	8	Page 108

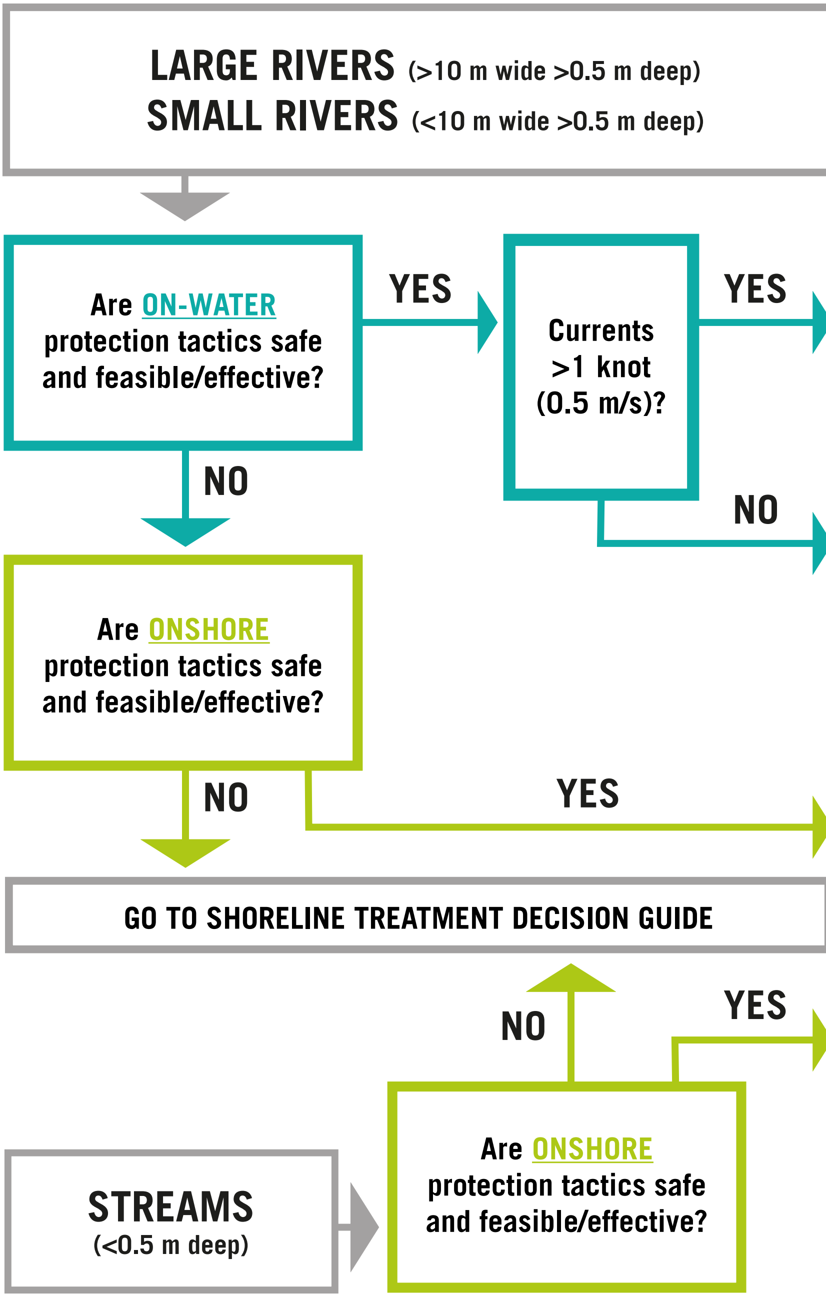


Figure 6.3 Shoreline Protection Decision Guide: rivers and streams

	Shoreline Protection Tactic	Shoreline Protection Information	
		Sheet #	Page #
On-water Tactics			
YES	Containment and recovery **(Use fast water strategies, Section 7.1.2)**	1	Page 92
	Deflection **(fast water)**	2	Page 94
	Diversion **(fast water)**	3	Page 97
NO	Containment and recovery	1	Page 92
	Deflection	2	Page 94
	Diversion	3	Page 97
	Exclusion by boom or barrier	4	Page 100
Onshore Tactics			
YES	Containment with shore-seal boom	5	Page 102
	Containment by barriers, berms, sorbents and pumps	6	Page 104
	Exclusion by contact barrier	7	Page 106
	Exclusion by booms, barriers, or dams	8	Page 108
YES	Containment by barriers, berms, sorbents and pumps	6	Page 104
	Exclusion by contact barrier	7	Page 106
	Exclusion by booms, barriers, or dams	8	Page 108

6.2.1 Shoreline Protection Information Sheets

Shoreline Protection - Information Sheet 1

On-water Tactics: Containment and recovery

Shoreline Protection Information Sheet 1

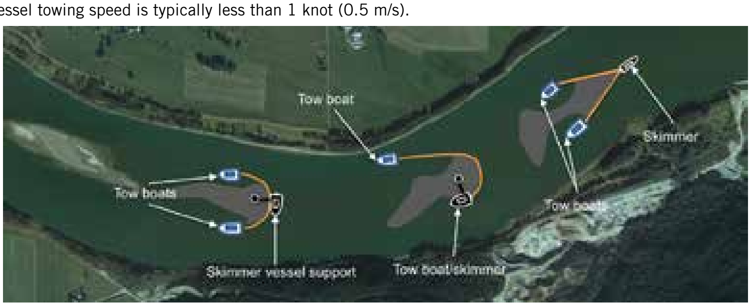
ON-WATER: CONTAINMENT & RECOVERY

OBJECTIVE

– Utilize booming and mechanical recovery (skimming or other recovery tactics) in nearshore areas to prevent or limit oil from reaching a specific section of shoreline or sensitive resource.

DESCRIPTION

– Booms surround or contain portions of an oil slick for mechanical recovery.
– Boom is pulled by work vessels in various configurations to contain and recover slick.
– Shallow-draft vessels are often used for nearshore operations and are equipped with:
  › Boom types suitable for forecasted wave and current conditions;
  › Skimmers or other recovery devices appropriate for the type(s) of oil to be recovered.
– Vessel towing speed is typically less than 1 knot (0.5 m/s).



TOWING A SPECIALIZED SWEEP/BUSTER SYSTEM

SAFETY NOTES

– Booming, skimming, and oil storage or transfer are specialized activities best conducted by trained and experienced responders.
– For substantial spills in larger bodies of fresh water (e.g. the Great Lakes), containment and recovery operations will be conducted by either sheltered or unsheltered waters recovery teams equipped with appropriate vessels and equipment. Specialized sweep/buster systems can be towed at greater speeds, ranging from 3 knots up to approximately 5 knots

Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

Shoreline Protection - Information Sheet 1

On-water Tactics: Containment and recovery

APPLICATIONS
– Potential for floating oil recovery is high under favourable operating conditions. – Tactic is appropriate anywhere if it is safe and practical to recover oil.

TOWING A SPECIALIZED SWEEP/BUSTER SYSTEM

OVERVIEW OF TACTIC CONSIDERATION(S) FOR SPECIFIC CONDITIONS
Flowing Water: – For currents of 0.7-1.0 knots (0.4-0.5 m/s) and more, consider use of NOFI Current Buster® Technology systems (up to 5 knots towing speed) and other specialized sweep/buster systems.
Winter: – If operations are to be completed on ice, an Ice Safety Plan must be prepared and implemented. – Broken or pack ice on nearshore waters constrains the deployment and operation of mechanical recovery systems (booms and skimmers) (Section 6.1.3). – The most appropriate skimmers for ice-laden waters are oleophilic – units with a recovery mechanism to which oil adheres (e.g. brushes, rope mop). – Cold temperatures may affect the operation of pumps and other machinery.
Remote Areas: – In locations with little or no local infrastructure to support response operations, on-water containment and recovery is desirable as it limits oil from reaching shorelines where treatment would be required and minimizes the generation of waste

OPERATIONAL LIMITING FACTORS AND POTENTIAL SOLUTIONS	
Limitation: Conventional boom tow speed is limited due to entrainment failure [typically occurs at current speeds between 0.7-1.0 knots (0.4-0.5 m/s)]	**Solution:** NOFI Current Buster® Technology systems (up to 5 knots towing speed) and other specialized sweep/buster systems available in multiple sizes

Shoreline Protection Information Sheet 2

ON-WATER: DEFLECTION (REDIRECTION AWAY FROM SHORE)

OBJECTIVE

– Utilize boom or other barriers to deflect or redirect oil (i.e. change the direction of oil movement) away from a specific section of shoreline or a vulnerable resource at risk.

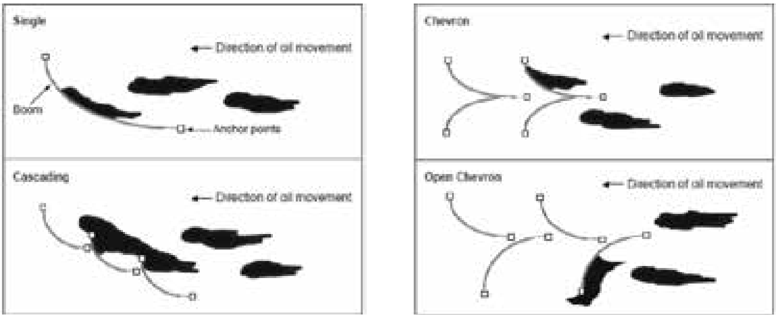
DESCRIPTION

– Redirection booming involves deflecting oil either in nearshore areas or at the shoreline so that it travels in a different direction.

– Boom sections may be deployed in a variety of configurations (single, cascade, chevron, open chevron) to deflect oil depending on:

- › Size/area of approaching slick;
- › Amount of deflection needed;
- › Flow/current conditions in the boom deployment area.

– Deflection of oil may be done in association with containment and recovery on water (e.g. using skimmers; Shoreline Protection Information Sheet 1).



BOOM CONFIGURATIONS FOR DEFLECTING OIL ON WATER

SAFETY NOTES

– Shorter sections of boom are typically easier to handle and maintain, thereby increasing safety and efficiency.

Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

Shoreline Protection - Information Sheet 2

On-water Tactics: Deflection (redirection away from shore)

APPLICATIONS

– Used to deflect/redirect oil away from a specific section of shoreline or a vulnerable resource(s) at risk.
– May be used when current speeds or breaking waves preclude exclusion boom (Shoreline Protection Information Sheet 4) or there is insufficient boom available for exclusion.
– Primarily used for:
  › Inland streams with currents >1 knot (0.5 m/s);
  › Across small bays, marina entrances, inlets, river and creek mouths with currents <1 knot (0.5 m/s) and breaking waves <0.5 m;
  › On straight shorelines to protect specific areas, where breaking waves are <0.5 m.

DEFLECTION OF OIL AWAY FROM A HIGHLY SENSITIVE AREA

OVERVIEW OF TACTIC CONSIDERATION(S) FOR SPECIFIC CONDITIONS

Flowing Water:
– In higher flow conditions, deflection is usually more effective than exclusion booming (Shoreline Protection Information Sheet 4), as boom(s) can be set at a higher angle.
– Deploying boom in currents of 0.5 knots (0.25 m/s) or more requires special anchoring techniques.
– Boom with a draft greater than 6 inches (15 cm) is not recommended for currents above 1.5 knots (0.77 m/s).
– For currents of 3 knots (1.5 m/s) and more, a high current sweep system may be required or boom with only a short chain pocket and no more than a 3 inch (8 cm) draft is recommended to maintain a low deflection angle in relation to the current.

Winter:
– If operations are to be completed on ice, an Ice Safety Plan must be prepared and implemented.
– Broken or pack ice on nearshore waters constrains the deployment and operation of mechanical recovery systems (booms and skimmers) (Section 6.1.3).

OPERATIONAL LIMITING FACTORS AND POTENTIAL SOLUTIONS	
Limitation: Increasing current speed	**Solution:** As speed increases, decrease boom angle with respect to the shoreline (Section 7.1.2); a BoomVane™ (self-deploying current rudder) may be used in currents as high as 10 knots to help with boom deployment in relatively narrow rivers (wide deployments would require large anchoring gear and mooring lines)
Decreasing boom angle reduces area of oil that may be deflected	Increase length of boom or implement cascade of boom sections; boom deflectors are useful for long lengths of boom and in wider rivers (multiple anchors are needed in currents greater than 3 knots)
Presence of woody material	Increased frequency of boom maintenance; use of Flow-Diverters that are heavier than other systems and function better than standard boom when woody material is present
Protection of sensitive area	Utilize layers of boom (i.e. back up booms)
Deflected oil may cause shoreline oiling downwind/down current	As part of preparedness planning, identify suitable recovery sites, use exclusion by contact barrier protection downstream (Shoreline Protection Information Sheet 7)

Shoreline Protection Information Sheet 3

ON-WATER: DIVERSION (REDIRECTION TOWARDS SHORE)

OBJECTIVE

– Utilize boom or other barriers to divert or redirect oil (i.e. change the direction of oil movement) to a pre-selected shoreline area.
– Oil is typically diverted towards the shoreline for containment and recovery.

DESCRIPTION

– Diversion booming involves redirecting oil at the shoreline.
– Boom sections may be deployed in a variety of configurations to redirect oil depending on:
  › Size/area of approaching slick;
  › Amount of redirection needed;
  › Flow/current conditions in the boom deployment area.
– Diversion may be used in combination with shore-seal boom to limit contact between the oil and shoreline (Shoreline Protection Information Sheet 5).
– Diversion of oil is typically done in association with containment and recovery either on water (e.g. using skimmers; Shoreline Protection Information Sheet 1) or at the shoreline (e.g. using trenches or sumps to prevent remobilization of oil; Shoreline Protection Information Sheet 6).

ON-WATER DIVERSION OF OIL TOWARDS THE SHORELINE

SAFETY NOTES

– Shorter sections of boom are typically easier to handle and maintain, thereby increasing safety and efficiency.

Environment and Climate Change Canada
Environnement et Changement climatique Canada
Canada

Shoreline Protection - Information Sheet 3

On-water Tactics: Diversion (redirection towards shore)

APPLICATIONS

- Used to divert/redirect oil towards a location(s) where shoreline treatment may be easier and/or more effective, or to protect specific vulnerable area(s) or resource(s) at risk.
- Primarily used for: inland streams with currents >1 knot (0.5 m/s); across small bays, marina entrances, inlets, river and creek mouths with currents <1 knot (0.5 m/s) and breaking waves <0.5 m; on straight shoreline to protect specific areas, where breaking waves are <0.5 m.

DIVERSION OF OIL TO A PRE-SELECTED SHORELINE AREA

OVERVIEW OF TACTIC CONSIDERATION(S) FOR SPECIFIC CONDITIONS

Flowing Water:
- Install in areas where the current is slowest (i.e. along a straight section rather than a meander).
- Deploying boom in currents of 0.5 knots (0.25 m/s) or more requires special anchoring techniques.
- Boom with a draft greater than 6 inches (15 cm) is not recommended for currents above 1.5 knots (0.77 m/s).
- For currents of 3 knots (1.5 m/s) and more, a high current sweep system may be required or boom with only a short chain pocket and no more than a 3 inch (8 cm) draft is recommended to maintain a low deflection angle in relation to the current.

Winter:
- If operations are to be completed on ice, an Ice Safety Plan must be prepared and implemented.
- Broken or pack ice on nearshore waters constrains the deployment and operation of mechanical recovery systems (booms and skimmers) (Section 6.1.3).

OPERATIONAL LIMITING FACTORS AND POTENTIAL SOLUTIONS	
Limitation: Increasing current speed	**Solution:** As speed increases, decrease boom angle with respect to the shoreline (Section 7.1.2); a BoomVane™ (self-deploying current rudder) may be used in currents as high as 10 knots to help with boom deployment in relatively narrow rivers (wide deployments would require large anchoring gear and mooring lines)
Decreasing boom angle reduces area of oil that may be redirected	Increase length of boom or implement cascade of boom sections; boom deflectors are useful for long lengths of boom and in wider rivers (multiple anchors are needed in currents greater than 3 knots)
Presence of woody material	Increased frequency of boom maintenance; use of Flow-Diverters that are heavier than other systems and function better than standard boom when woody material is present
Protection of sensitive area	Utilize layers of boom (i.e. back up booms)

Shoreline Protection Information Sheet 4

ON-WATER: EXCLUSION BY BOOM OR BARRIER

OBJECTIVE

– Utilize boom or other barriers adjacent to the shoreline or around a resource on water to prevent or limit oil from encountering a specific section of shore or a vulnerable resource at risk.

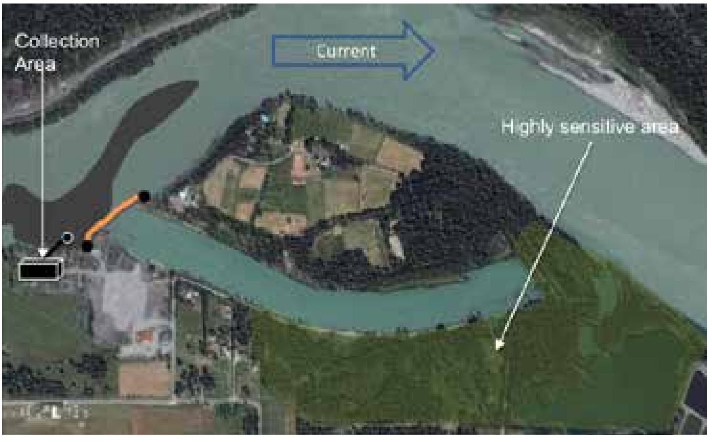
DESCRIPTION

– Exclusion of oil can include nearshore, conventional boom strategies to either provide protection around a specific section of shore or resource at risk or across an embayment or river/creek mouth – oil is excluded and moves in a different direction from what it would follow naturally.

– Other types of barriers include:
  › Bubble barriers – exclude oil from channels (e.g. water intakes) using pumped air;
  › Textile barriers – exclude oil from wetlands/emergent aquatic vegetation beds in low-energy environments using textile sheets (e.g. landscape fabric).

– Barriers may also be deployed to contain oil released during flooding or flushing/washing for recovery (Section 6.4).

– Exclusion of oil may be done in association with containment and recovery on water (e.g. using skimmers; Shoreline Protection Information Sheet 1).



EXCLUSION OF OIL TO PROTECT A HIGHLY SENSITIVE AREA

Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

Shoreline Protection - Information Sheet 4

On-water Tactics: Exclusion by boom or barrier

SAFETY NOTES
– Shorter sections of boom are typically easier to handle and maintain, thereby increasing safety and efficiency.

APPLICATIONS
– Exclusion booms are deployed across or around sensitive areas and anchored in place to limit contact with oil. – Primarily used across small bays, marina entrances, inlets, river and creek mouths with currents <1 knot (0.5 m/s) and breaking waves <0.5 m. – Feasibility limited by water depths and the accumulation or presence of floating material and ice.

EXCLUSION OF OIL FROM ENTERING A LAKE (LEFT) AND A WETLAND (RIGHT)

OVERVIEW OF TACTIC CONSIDERATION(S) FOR SPECIFIC CONDITIONS
Flowing Water: – Deploying boom in currents of 0.5 knots (0.25 m/s) or more requires special anchoring techniques. – Boom with a draft greater than 6 inches (15 cm) is not recommended for currents above 1.5 knots (0.77 m/s). – For currents of 3 knots (1.5 m/s) and more, boom with only a short chain pocket and no more than a 3 inch (8 cm) draft is recommended to maintain a low deflection angle in relation to the current. **Winter:** – If operations are to be completed on ice, an Ice Safety Plan must be prepared and implemented. – Broken or pack ice on nearshore waters constrains the deployment and operation of mechanical recovery systems (booms and skimmers) (Section 6.1.3).

OPERATIONAL LIMITING FACTORS AND POTENTIAL SOLUTIONS	
Limitation: Increasing wave height/current speed	**Solution:** Use a multiple set of booms to help ensure exclusion
Protection of sensitive area	Utilize layers of boom (i.e. back up booms)
Excluded oil may cause shoreline oiling downwind/down current	As part of preparedness planning, identify suitable recovery sites

Shoreline Protection Information Sheet 5

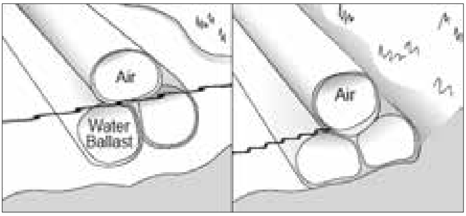
ONSHORE: CONTAINMENT WITH SHORE-SEAL BOOM

OBJECTIVE

- Shore-seal boom (also known as shoreline boom) is used to contain and recover oil at the shoreline.
- This type of boom also reduces the amount of contact between the oil and the shore by creating a barrier that is effective with changing water levels (e.g. wind-driven, increasing/decreasing river discharge). It conforms to the shape of the shoreline, preventing oil from passing underneath at the water's edge.
- This tactic may also limit the remobilization of stranded oil and oiling or re-oiling at down-drift/downstream locations.

DESCRIPTION

- This type of boom is designed to maintain a barrier against oil movement as the water level rises or falls.
- Water-filled lower chambers provide ballast and assume the contour of the shore when grounded – the lower chambers also provide a sub-surface oil barrier when afloat.
- Set perpendicular to (i.e. across) the shore to act as a barrier to alongshore oil movement.
- Deploy parallel to the water line to minimize contact between the oil and the shore or to limit stranded oil from remobilizing.



AFLOAT (LEFT) AND AGROUND (RIGHT) SHORELINE BOOM DEPLOYED AT THE SHORE-WATER INTERFACE

SAFETY NOTES

- Shorter sections of boom are typically easier to handle and maintain, thereby increasing safety and efficiency.

Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

Onshore Tactics: Containment with shore-seal boom

APPLICATIONS

– Shoreline boom provides a seal at the land/water interface that is generally better than that achieved by conventional booms, even in calm water conditions.
– When oil is diverted towards a selected shoreline location(s) for collection and recovery using conventional boom, it may be advantageous to attach one section of shoreline boom to provide a seal at the land/water interface to minimize contact with the shore.
– Primarily on gently sloping shorelines where substrate will not damage/puncture the material.
– Feasibility limited by the accumulation or presence of floating material and ice.

DEPLOYING SHORELINE BOOM

SHORELINE BOOM WITH OIL AND WRACK

OVERVIEW OF TACTIC CONSIDERATION(S) FOR SPECIFIC CONDITIONS

Flowing Water:
– Effectiveness of shoreline boom decreases with increasing current speed and shoreline slope.

Winter:
– If operations are to be completed on ice, an Ice Safety Plan must be prepared and implemented.
– Water in ballast chambers may freeze reducing its ability to contour to the shore – fabric will be damaged if ice pieces puncture the boom.

OPERATIONAL LIMITING FACTORS AND POTENTIAL SOLUTIONS

Limitation:	Solution:
Boom is susceptible to rolling over	Implement routine monitoring as currents, wind, and waves may move/twist boom
Grounded boom cannot be repositioned when the ballast chambers are filled with water	Anchor the boom to allow for vertical movement, but for very little lateral movement as water level rises/falls
Oil leaking under the boom	Avoid sites with boulders, riprap and other features that will result in oil leaking under the boom when water level changes

Shoreline Protection Information Sheet 6

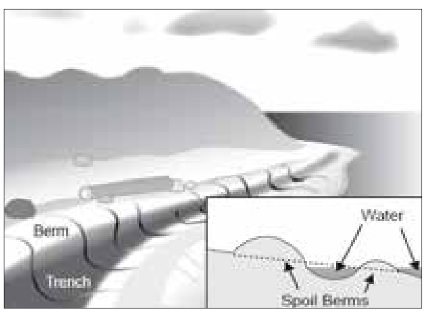
ONSHORE: CONTAINMENT BY BARRIERS, BERMS, SORBENTS, OR SUMPS

OBJECTIVE

– Barriers, berms, sorbents, or sumps are used to contain oil on a shoreline for recovery:
  › As oil strands on the shoreline;
  › To limit remobilization of stranded oil;
  › To limit waves or rising water levels from over-washing a beach or bank and carrying oil into backshore areas.

DESCRIPTION

– Berms can be constructed on a sandy or gravel beach parallel to the waterline to contain oil, with or without a ditch or trench to collect oil as it is washed ashore.
– Ditches, trenches, or sumps can collect oil as it is washed ashore for recovery by skimmers or other physical removal techniques.
– Sorbents can be placed along the shoreline to collect oil as it is washed ashore.
– Barriers or dams can be built across over wash channels to prevent oil from being carried by waves over a beach into a backshore wetland.



SUBSTRATE BERM AND TRENCH PARALLEL TO THE SHORELINE

SAFETY NOTES

– During operation of heavy equipment, a spotter should be present to ensure safe operations.
– Be aware of vapor ignition hazards in areas where oil has been contained by berms or in trenches

Environment and Climate Change Canada / Environnement et Changement climatique Canada

Canada

Onshore Tactics: Containment by barriers, berms, sorbents, or sumps

APPLICATIONS

– Berms or barriers limit oil from being carried over a beach onto backshore areas.
– Oil that is collected in ditches, trenches, or sumps is easier to recover than oiled substrate.
– The feasibility and effectiveness of berms are limited by the size of the area to be protected, the time available to deploy equipment or to construct berms and the substrate type with respect to permeability and porosity.
– Sorbents put on a shore and kept in place by stakes or other anchoring devices may require frequent change-outs – this is labour intensive and can generate a large volume of oily waste materials.

BARRIER FENCE WITH SORBENT USED TO LIMIT REMOBILIZATION OF OIL FROM SHORELINE

OVERVIEW OF TACTIC CONSIDERATION(S) FOR SPECIFIC CONDITIONS

Flowing Water:
– May be appropriate to utilize in natural collection area(s) with suitable substrate(s).

Winter:
– If operations are to be completed on ice, an Ice Safety Plan must be prepared and implemented.
– Oil may be contained in a trench on solid ice.
– Snow and ice may be used to form effective barriers or berms to temporarily contain oil.

OPERATIONAL LIMITING FACTORS AND POTENTIAL SOLUTIONS

Limitation:	Solution:
Time available to deploy equipment and construct berms	As part of preparedness planning, identify suitable recovery sites
Penetration of oil into the substrate and mixing by swash action	Line the trench or sump with impermeable material

Shoreline Protection Information Sheet 7

ONSHORE: EXCLUSION BY CONTACT BARRIER

OBJECTIVE

– Specific vulnerable resources or small sections of shoreline can be protected from contact with oil by using a water barrier, or a physical barrier or cover placed over the shoreline.

DESCRIPTION

– This tactic includes the following options:
  › Flooding (deluge) or low-pressure (high volume) washing hoses are used to form a water barrier and simultaneously move oil away from the shoreline (Shoreline Treatment Information Sheets 1 and 2);
  › A physical barrier, such as plastic sheeting, geotextile, or sorbent material, can prevent contact and protect underlying materials;
  › Under the appropriate circumstances and with regulatory approval, chemicals may be applied to either a natural shoreline or manmade shoreline structures to form either a contact barrier or a surface that reduces the adhesion of oil (Shoreline Treatment Information Sheet 15).
– This tactic is only effective if barriers are put in place ahead of oil arrival.

SAFETY NOTES

– Make sure all personnel are properly trained to use the equipment and are wearing the right PPE.

APPLICATIONS

– Water or hydraulic barriers use pumps and hoses with a header placed above the high-water level – nearshore and/or shore-seal booms can be used to contain the oil for recovery (Shoreline Protection Information Sheet 5).
– Physical barriers, such as plastic sheeting, rolls of sorbent materials, or other fabrics (e.g. landscape fabric) may be used – this type of barrier is primarily used for riprap, docks, crib work and other manmade structures where oil would be difficult to access or remove – these permeable structures act as reservoirs for the oil to gradually leach out of if the shoreline is not protected or treated.
– This type of barrier also limits oil from stranding on the shore where logs, branches, or vegetation may be present – it is a slow and difficult process to treat large oiled logs and beaver lodges/dams, particularly in remote areas.

Environment and Climate Change Canada
Environnement et Changement climatique Canada
Canada

Onshore Tactics: Exclusion by contact barrier

WATER BARRIER (LEFT) AND PHYSICAL BARRIER (RIGHT) TO PROTECT SHORELINE AREA FROM CONTACT WITH OIL

OVERVIEW OF TACTIC CONSIDERATION(S) FOR SPECIFIC CONDITIONS

Flowing Water:
– Oil movement is very rapid – ensure adequate containment and recovery are in place.

Winter:
– If operations are to be completed on ice, an Ice Safety Plan must be prepared and implemented.

OPERATIONAL LIMITING FACTORS AND POTENTIAL SOLUTIONS

Limitation:	**Solution:**
Limited practicality for protecting extensive lengths of shoreline	Physical barriers are most suited to marinas and other manmade shorelines, or specific vulnerable resources at risk, that are limited in extent
Flooding and washing may cause turbidity issues along a watercourse	Use appropriate mitigation measures, such as silt fences, near treated area(s)
Excluded oil may cause shoreline oiling downwind/ down current	Adequate containment and recovery in place prior to flooding or washing to limit migration

Shoreline Protection Information Sheet 8

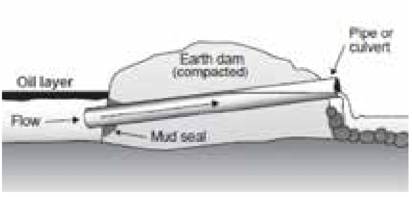
ONSHORE: EXCLUSION BY BOOMS, BARRIERS, OR DAMS

OBJECTIVE

– Boom or stationary barriers are used to stop and concentrate moving oil for recovery while allowing water to continue to flow unimpeded.
– Typically used as spill control devices in streams, channels, or inlets where there is a constriction through which the oil must pass.
– May be constructed using locally available materials.

DESCRIPTION

– Boom may be deployed across a calm, shallow water watercourse with a channel width <25 m or downstream of stationary barriers on smaller watercourses as secondary containment.
– Filter fence can be fabricated from available materials, such as fencing or nets, combined with sorbent materials.
– Underflow dam/inverted weir can be built using available materials, such as fill, planks, or sandbags – single or multiple culverts, pipes, and siphons should be designed based on the lowest anticipated water level, flow volumes, and the potential for oil to build up against the dam and become entrained with the water passing through the pipe system.
– Culvert block at the upstream end using impermeable material, such as plywood, sheet metal, culvert plug, clay, etc. – need to monitor water levels to prevent wash out.
– Water-Gates™ function similarly to inverted weirs, but are portable, reusable, easy to install, flexible (i.e. contour to the bed of the watercourse) and reduce environmental effects as they do not require berm construction – require adequate flow to be functional.



CHANNEL BARRIER – UNDERFLOW DAM

Environment and Climate Change Canada
Environnement et Changement climatique Canada
Canada

Shoreline Protection - Information Sheet 8

Onshore Tactics: Exclusion by booms, barriers, or dams

SAFETY NOTES

– During operation of heavy equipment, a spotter should be present to ensure safe operations.
– Be aware of vapor ignition hazards in areas where oil has been stopped and concentrated.

APPLICATIONS

– Limit oil from entering backshore or backwater areas through narrow or small inlets.
– Used along stream channels, canals, or ditches to stop and concentrate moving oil for recovery.
– Water flow is maintained using underwater pipes or underflow techniques.

BOOM (LEFT) AND WATER-GATE™ (RIGHT) DEPLOYED ACROSS A SMALL WATERCOURSE

OVERVIEW OF TACTIC CONSIDERATION(S) FOR SPECIFIC CONDITIONS

Flowing Water:
– Oil movement is very rapid – ensure adequate containment and recovery are in place.

Winter:
– If operations are to be completed on ice, an Ice Safety Plan must be prepared and implemented.
– Ice, snow and cold temperatures may adversely affect these techniques.

OPERATIONAL LIMITING FACTORS AND POTENTIAL SOLUTIONS

Limitation:	Solution:
Deployment and effectiveness of barriers and booms are limited by current speed	Well-designed filter barriers are generally more effective in higher velocity currents than conventional booms
Time available to deploy equipment and construct barriers	As part of preparedness planning, identify suitable spill management points
Protection of sensitive area	Utilize two or more barriers (i.e. back up)

6.3 Treatment Approaches for Different Types of Substrate

This section provides guidance for selecting and applying appropriate response and treatment options for the basic types of substrate found along freshwater shorelines in Canada. Submerged and sunken oil in nearshore environments are discussed in Section 7.3 as these may be included within shoreline treatment operations.

The types of substrates referred to in this field guide follow ECCC's shoreline classification system, which is based on substrate character (material) and secondarily on shoreline morphology (form). Historically, for national oil spill response in Canada, this classification has been the common standard for the physical description of shoreline types, backshore types, coastal character and substrate types. Further details on the ECCC shoreline standards are documented and defined in Sergy (2008) and updated in ECCC (2016). Where sediments are present, the substrate classification is based on the grain size (diameter) of the sediment (Section A.1d, ECCC 2018)

Different types of freshwater shoreline substrates considered are shown in Table 6.4 and are detailed in the following **Freshwater Substrate Information Sheets (Section 6.3.1).**

Table 6.4 Freshwater substrate types

General Freshwater Substrate Type	Lake: Swash Zone Shore Types	River: Active Channel Margin Types	Freshwater Substrate Information Sheet #	 Page #
Bedrock	Bedrock Cliff/Ramp	Bedrock Cliff/Ramp	1	Page 118
	Bedrock Platform/ Shelf	Bedrock Platform/ Shelf		
Man-made Solid (Impermeable)	Man-made Solid	Man-made Solid	2	Page 122
Man-made Permeable	Man-made Permeable	Man-made Permeable	3	Page 126
Unconsolidated Sediments - Steep	Sediment Cliff/Bluff	Sediment Cut Bank	4	Page 128
Mud	Mud Flat	Mud Flat	5	Page 131
	—	Mud Bank/ Bar		
Sand	Sand Flat	Sand Flat	6	Page 135
	Sand Beach	Sand Bank/ Bar		
Mixed Sediments	Mixed Sediment Flat	Mixed Sediment Flat	7	Page 140
	Mixed Sediment Beach	Mixed Sediment Bank/Bar		
Pebble/Cobble	Pebble/ Cobble Beach	Pebble/ Cobble Bank/Bar	8	Page 145
Boulder	Boulder Beach	Boulder Bank/Bar	9	Page 149

General Freshwater Substrate Type	Lake: Swash Zone	River: Active Channel	Freshwater Substrate Information	
	Shore Types	Margin Types	Sheet #	Page #
Vegetated	Vegetated Shore	Vegetated Bank	10	Page 152
Wetland	Wetland - Reed/Rush (deeper water, up to approx. 1.5-2 m)	Wetland - Reed/Rush (deeper water, up to approx. 1.5-2 m)	11	Page 155
	Wetland – Grassy (shallow, near shore)	Wetland – Grassy (shallow, near shore)		
Vegetated/Wooded – Upland	—	Vegetated/ Wooded - Upland	12	Page 159
Small and Large Woody Material	Small and Large Woody Material	Small and Large Woody Material	13	Page 162
Organic	Organic, Soil, Peat	Organic, Soil, Peat	14	Page 166
Tundra Cliff	Tundra Cliff	Tundra Cliff	15	Page 169
Inundated Low-Lying Tundra	Inundated Low-Lying Tundra	Inundated Low-Lying Tundra	16	Page 172
Snow-Covered/Ice	Snow-Covered	Snow-Covered	17	Page 175
	Ice	Ice		

Each of the 17 general freshwater shoreline substrates are described using the following sections:

- Definition and Character;
- Oil Behaviour;
- Sensitivity;
- Safety Notes;
- Preferred Treatment Options;
- Response Considerations;
- Best Practices.

Tactics are described in terms of those "preferred" or "possibly applicable for small amounts of oil" and for both surface and subsurface oiling conditions when this is appropriate. Use of the term "preferred" means that those tactics are generally considered appropriate based on net environmental benefit, operational resources, efficiency, safety, and waste generation, and are a practical option in comparison to other tactics.

In practice, two or more substrate types may be present along a segment or section of shoreline. These shorelines with increased complexity due to substrate heterogeneity may pose a challenge to selecting and applying appropriate treatment options. The determination of whether a tactic is appropriate is case-specific and conducted when planners evaluate the operational feasibility of proposed treatment strategies and tactics (Figure 1.2). A general approach is to consider the sensitivity of each substrate type present and choose the more conservative treatment approach, i.e. assess the relative potential effects of applicable treatment tactics and choose the technique(s) that has the lowest potential effect(s) on the substrates present (Table 6.5). Complex shorelines may also be addressed during SCAT surveys by using different zones along-shore and across-shore as appropriate to describe oiling conditions for different substrate types within a segment.

SHORELINE SUBSTRATE
INFORMATION SHEETS

Table 6.5 Relative potential effects of treatment tactics

Technique/ Substrate	Bedrock	Man-made Solid or Ice Covered	Unconsolidated Sediments – Steep	Mud Flat	Mud Bank	Sand Flat	Sand Beach, Bank	Mixed Sediment Flat	Mixed Sediment Beach, Bank	Pebble/Cobble
Natural Recovery	**natural recovery requires no intrusion on the ecological character of the shoreline**									
Flooding	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
Low-pressure ambient	▲	▲	▲	■	■	■	■	■	■	■
Low-pressure warm/hot	■	▲	—	—	—	—	—	—	—	—
High-pressure ambient	▲	▲	—	—	—	—	—	—	—	—
High-pressure warm/hot	■	▲	—	—	—	—	—	—	—	—
Manual removal	▲	▲	▲	●	▲	■	▲	■	▲	▲
Vacuums	▲	▲	▲	■	▲	■	▲	■	▲	▲
Mechanical removal	—	—	■	●	■	■	■	■	■	■
Vegetation cutting	—	—	—	■	—	■	—	—	—	—
Passive sorbents	▲	▲	▲	■	▲	▲	▲	▲	▲	▲
Mixing	—	—	▲	●	■	■	■	■	■	■
Sediment relocation	—	—	▲	●	■	●	■	●	■	■
Burning	▲	▲	—	●	■	●	■	●	■	■
Shoreline cleaner	■	■	▲	—	■	—	■	—	■	■
Bioremediation	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲

▲ Low ■ Moderate ● High — Generally Not Used

Technique/ Substrate	Boulder	Vegetated	Wetland	Vegetated/Wooded – Upland	Small and Large Woody Material	Organic	Tundra Cliff	Inundated Low-Lying Tundra	Snow Covered
Natural Recovery	**natural recovery requires no intrusion on the ecological character of the shoreline**								
Flooding	Low	Low	Low	Low	Low	Low	Low	Low	Moderate
Low-pressure ambient	Low	Low	Low	Low	Low	Low	Low	Low	Moderate
Low-pressure warm/hot	Moderate	—	—	—	—	—	—	—	—
High-pressure ambient	Moderate	—	—	—	—	—	—	—	—
High-pressure warm/hot	Moderate	—	—	—	—	—	—	—	—
Manual removal	Low	Moderate	High	Moderate	Moderate	High	Low	High	Low
Vacuums	Low	Low	Moderate	Low	Low	Low	Low	Low	Low
Mechanical removal	Moderate	Moderate	High	Moderate	Moderate	Moderate	Moderate	High	Low
Vegetation cutting	—	Moderate	Moderate	Moderate	—	—	—	High	—
Passive sorbents	Low	Low	Moderate	Low	Low	Low	Low	Low	Low
Mixing	—	High	High	High	—	High	Low	High	Moderate
Sediment relocation	—	High	High	—	—	High	Low	High	Moderate
Burning	Moderate	Moderate	Moderate	Moderate	Moderate	High	—	High	Moderate
Shoreline cleaner	Moderate	Moderate	Moderate	—	Moderate	—	Low	—	—
Bioremediation	Low	Low	Low	Low	Low	High	Low	Low	Low

Low (▲) Moderate (■) High (●) — Generally Not Used

6.3.1 Freshwater Substrate Information Sheets

Freshwater Substrate – Information 1

Bedrock

Shoreline Substrate Information Sheet 1

BEDROCK

DEFINITION AND CHARACTER

- Bedrock shorelines consist of impermeable outcrops of consolidated native rock, including cliffs (slope face >35°), ramps (inclined slope in the range of 5° to 35°), and platforms (near horizontal with overall slope <5°).
- Resistant bedrock outcrops, such as granites, are stable whereas non-resistant bedrock types, such as the limestone outcrops of eastern Lake Ontario, are easily abraded by ice action and the surface may erode at rates that may be up to several centimetres per year.
- The surface can be irregular, with numerous cracks and crevices, joints and depressions.
- Sediment veneers may overlay bedrock platforms, but the veneers are usually patchy and range from sand to boulders.
- Exposed, high wave-energy and sheltered lower wave-energy bedrock shorelines differ in terms of the character of the shore zone biological communities.

BEDROCK CLIFF

BEDROCK RAMP

Environment and Climate Change Canada / Environnement et Changement climatique Canada

Canada

Freshwater Substrate – Information 1

Bedrock

OIL BEHAVIOUR

– As bedrock is impermeable, stranded oil remains on the surface of the outcrop.
– Oil may pool in depressions on bedrock platforms or ramps.
– Oil that collects in cracks and crevices may not be physically removed by wave and ice action.
– During falling water levels may be deposited as a band, stranding oil above the water line and therefore not in direct contact with running water.
– Oil that comes ashore in sheltered locations is likely to be deposited as a narrow band at or near the water level.
– In sheltered locations, because of the relatively low energy conditions, heavy oils or weathered crude oils may persist for some considerable time (months to years), as there is insufficient energy to naturally remove these oil types.
– Even in sheltered locations, light oils are likely to be washed off a bedrock surface in a short time, i.e. in days to weeks.

STAIN-COAT ON BEDROCK

SENSITIVITY

– On exposed shorelines, plants and animals often inhabit cracks and crevices where they are protected from wave or ice action – these are the same locations where oil might be deposited and persist.
– On sheltered bedrock shorelines, sensitivity to oil can be high due to the combination of potential oil persistence and rich biological communities.
– Overall, ice-scoured bedrock outcrops do not have extensive, diverse, or rich biological communities.

SAFETY NOTES

– On steeper bedrock outcrops, be extremely careful to avoid slips and falls, particularly on exposed shorelines where there is stronger wave action or ice present.

Freshwater Substrate – Information 1

Bedrock

PREFERRED TREATMENT OPTIONS					
Shoreline Treatment Tactic	**Volatile**	**Light**	**Medium**	**Heavy**	**Solid**
Bedrock					
SURFACE					
Natural recovery	●	●	○	○	○
Flooding	●	●	●	–	–
Low-pressure ambient wash	●	●	●	○	–
Low-pressure warm/hot wash	–	–	●	●	●
High-pressure ambient wash	–	–	●	●	●
High-pressure warm/hot wash	–	–	●	●	●
Manual removal	–	○	○	○	○
Vacuum	–	●	●	○	–
Mechanical removal	–	○		–	–
Vegetation cutting	–	○	○	○	○
Passive sorbents	–	○	○	○	–
Shoreline cleaners	–	○	○	–	–
Bioremediation	–	○	○	–	–
SUB-SURFACE					
Natural recovery	–	–	–	–	–
Flooding	–	–	–	–	–
Low-pressure ambient wash	–	–	–	–	–
Low-pressure warm/hot wash	–	–	–	–	–
High-pressure ambient wash	–	–	–	–	–
High-pressure warm/hot wash	–	–	–	–	–
Manual removal	–	–	–	–	–
Vacuum	–	–	–	–	–
Mechanical removal	–	–	–	–	–
Vegetation cutting	–	–	–	–	–
Passive sorbents	–	–	–	–	–
Shoreline cleaners	–	–	–	–	–
Bioremediation	–	–	–	–	–

● Preferred option ○ Possibly applicable for small amounts – Not Applicable

Freshwater Substrate – Information Sheet 1

Bedrock

RESPONSE CONSIDERATIONS
– Natural recovery is less appropriate for medium-heavy or weathered crude oils and in slow moving rivers, backwaters and sheltered shores. – Natural recovery may not be appropriate immediately before freeze-up as the oil would be encapsulated by ice and potentially remobilized during the next thaw. – Natural recovery may be appropriate for volatile oils such as gasoline due to safety concerns caused by fumes, ignition, and flashback. – Oiled material is removed manually, followed by manual removal using hand tools, vacuums, or sorbents on surface oil patches. – Flooding and ambient low-pressure washing are used along with collection and recovery. – Under the appropriate circumstances and with regulatory approval, shoreline cleaners may be used with flooding and/or ambient low-pressure washing, followed by oil collection and recovery.
BEST PRACTICES
– Foot traffic should be controlled to minimize damage to organisms and habitats. – Generally, avoid washing oil from oiled to un-oiled zones. – Avoid excessive vegetation cutting as this may kill the plants and remove the protective cover for other organisms. – The biological effects of high-pressure water washing must be considered, as these tactics can remove healthy organisms.

Shoreline Substrate Information Sheet 2

MAN-MADE SOLID (IMPERMEABLE)

DEFINITION AND CHARACTER

– These shorelines consist of man-made (anthropogenic) structures that are composed of impermeable materials.
– Solid man-made features and structures vary greatly in design, form, and material – includes structures for moorage (docks, wharfs, marinas), protected anchorages (breakwaters), commercial or industrial activities, and backshore or river bank protection (retaining walls).
– Includes historic structures and archaeological or historic sites.
– Stable, impermeable surfaces consisting of a wide range of materials such as concrete, metal, plastic, and wood – the surface of each of these materials is different in texture and roughness.
– The structure may present a vertical face or be sloped.

CONCRETE RETAINING WALL

CONCRETE BOAT RAMP

Environment and Climate Change Canada
Environnement et Changement climatique Canada

Canada

Freshwater Substrate – Information Sheet 2

Man-made Solid (Impermeable)

OIL BEHAVIOUR

- Oil generally behaves in a similar way on solid man-made structures as on bedrock shorelines.
- As man-made solid is impermeable, stranded oil remains on the surface – penetration of a few millimetres may occur in open grain woods or concrete.
- Oil reacts to man-made structures in a variety of ways depending on the material and surface texture: concrete (rough), metal (smooth), and asphalt (rough) – oil is more likely to stick to rougher surfaces.
- Oil is more likely to be deposited in the upper half of the swash/active channel zone. The lower swash/active channel zone usually stays wet and often has a biofilm.
- On exposed shorelines, oil may be splashed above the limit of normal wave action.
- Oil that comes ashore in sheltered locations is likely to be deposited as a band at or near the water level.
- In sheltered locations, because of the relatively low energy conditions, heavy oils or weathered crude oils may persist for some time (months to years), as there is insufficient energy to naturally remove these oil types.
- Even in sheltered locations, light oils are likely to be washed off a man-made solid surface in a short time, i.e. in hours to days.

COAT-COVER ON METAL VESSEL

SENSITIVITY

- Man-made historic, cultural, and archaeological structures typically have a high social value and are assigned a high sensitivity.
- Most other solid man-made structures are relatively low in sensitivity, although their importance and priority will vary with location and human use.
- These shorelines do not have extensive biological communities, as plants are scraped off by ice, though some plants and animals can survive in cracks and crevices.

SAFETY NOTES

- As moorings, docks, and walkways are frequently used by people, there is a high potential that people will come in contact with the oil.
- On steep man-made structures or those with shelves, be extremely careful to avoid falls and slips, particularly on exposed shorelines where there is stronger wave action or ice present.

Freshwater Substrate – Information Sheet 2

Man-made Solid (Impermeable)

PREFERRED TREATMENT OPTIONS

Shoreline Treatment Tactic	Volatile	Light	Medium	Heavy	Solid
Man-Made Solid (Impermeable)					
SURFACE					
Natural recovery	●	●	○	○	○
Low-pressure ambient wash	●	●	●	○	○
Low-pressure warm/hot wash	●	●	●	●	●
High-pressure ambient wash	–	–	●	●	●
High-pressure warm/hot wash	–	–	●	●	●
Manual removal	–	○	○	○	○
Vacuum	–	–	–	○	–
Passive sorbents	○	○	○	○	–
Shoreline cleaners	–	○	○	–	–
SUB-SURFACE					
Natural recovery	–	–	–	–	–
Low-pressure ambient wash	–	–	–	–	–
Low-pressure warm/hot wash	–	–	–	–	–
High-pressure ambient wash	–	–	–	–	–
High-pressure warm/hot wash	–	–	–	–	–
Manual removal	–	–	–	–	–
Vacuum	–	–	–	–	–
Passive sorbents	–	–	–	–	–
Shoreline cleaners	–	–	–	–	–

● Preferred option ○ Possibly applicable for small amounts – Not Applicable

RESPONSE CONSIDERATIONS

- Historic structures, particularly those made of wood or stone, must be treated as a special case to minimize physical damage or degradation.
- Natural recovery is often the preferred option for low human use areas – this option is less appropriate for medium-heavy or weathered crude oils and in slow moving rivers, backwaters and sheltered shores.
- Natural recovery may not be appropriate immediately before freeze-up as the oil would be encapsulated by ice and potentially remobilized during the next thaw.
- Natural recovery may be appropriate for volatile oils such as gasoline due to safety concerns caused by fumes, ignition, and flashback.
- Under the appropriate circumstances and with regulatory approval, shoreline cleaners may be used with ambient low-pressure washing, followed by oil collection and recovery.

Freshwater Substrate – Information Sheet 2

Man-made Solid (Impermeable)

BEST PRACTICES
– Avoid all unnecessary access to oiled man-made historic, cultural, and archaeological structures until there is a special treatment plan. – Control public access on oiled man-made structures to avoid tracking and spreading the oil. – Generally, avoid washing oil from oiled to un-oiled zones – frequently the lower swash/active channel zone is not oiled, and more damage can be caused by treatment if oil is washed downslope. – The biological effects of high-pressure water washing must be considered, as these tactics can remove healthy organisms.

Shoreline Substrate Information Sheet 3

MAN-MADE PERMEABLE

DEFINITION AND CHARACTER

- Man-made (anthropogenic) structures composed of permeable material such as wood and riprap boulders.
- Man-made permeable features and structures include a wide range of designs: such as berms, breakwaters, bulkheads, cribwork, dikes, gabion baskets, piers, retaining walls, riprap and artificial islands. They include shore land extensions, landfill, and areas filled for flood control.
- This shore type includes historic structures and archaeological or historic sites.
- Structures are composed of various sizes of materials with open spaces between pieces leaving them permeable to oil and water penetration.
- Materials include sand, pebbles, boulders, concrete blocks, crushed rock, sand bags, soil, tires, or pre-cast interlocking concrete shapes.
- Common features include riprap, structures for moorage (docks, wharfs and marinas), protected anchorages (breakwaters) or backshore protection (retaining walls).

BANK STABILIZATION WITH RIPRAP

GRANITE SLABS USED FOR A RETAINING WALL

OIL BEHAVIOUR

- In each case, an oiled man-made permeable structure would be treated in the same manner as a natural shoreline type with equivalent characteristics.
- For example:
  - › Riprap, tires, timber posts, bulkhead of sand-filled bags, and wooden dock are on the same size order as boulders.
  - › Gabion mats or baskets would be defined as boulder, cobble or pebble/cobble, depending on the size of the material used.
- The behaviour of oil on made-made permeable structures is similar to natural sediments and a function of the material size.

Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

Freshwater Substrate – Information Sheet 3

Man-made Permeable

OILED GABION BASKETS

SENSITIVITY

- Manmade structures of historic, cultural, and archeological value are highly sensitive.
- Permeable man-made structures are built primarily to stabilize the shoreline or protect docks and marinas.
- Biological productivity is typically higher on permeable man-made shorelines than on solid man-made shorelines as the open pore structure provides additional habitat.

SAFETY NOTES

- Structures in zones of high human use present a high potential for human/oil interaction.
- On steep man-made structures, be extremely careful to avoid falls and slips, particularly on exposed shorelines where there is stronger wave action or ice present.

PREFERRED TREATMENT OPTIONS

- Preferred response options for removing surface and subsurface oil from permeable man-made shorelines are related to the size of the material in the structure and follow the recommendations and guidelines presented in Freshwater Substrate Information Sheets 6 through 9, which address those types of materials.

RESPONSE CONSIDERATIONS

- More aggressive treatment strategies and tactics can be considered for man-made structures than for a natural beach consisting of the same material.
- For smaller, heavily oiled structures, such as a cobble-filled gabion basket, it may be more cost- and time-efficient to remove and rebuild the structure than to attempt to treat it.
- Historic structures are usually made of wood or natural or worked stone – they must be treated as a special case to minimize physical damage or degradation.

BEST PRACTICES

- Avoid large-scale removal of coarse (large-sized) materials as this is not usually practical – removal without replacement will likely lead to shoreline retreat in the form of erosion.
- Generally, avoid washing oil from oiled to un-oiled zones.
- Avoid flushing techniques (e.g. warm or hot water may temporarily mobilize viscous oil) that only move the oil deeper into the shoreline sediments or permeable materials of the structure, unless they also flush the oil out for recovery.

Shoreline Substrate Information Sheet 4

UNCONSOLIDATED SEDIMENTS – STEEP

DEFINITION AND CHARACTER

- Sediment cliffs/bluffs are an erosional steep slope composed of unconsolidated or poorly consolidated fine or mixed sediments (loose material such as clay, sand, and gravel).
- Sediment cliffs are defined as >3 m high and the form is vertical or very steep (>35º).
- A sediment cut bank is the outside bank of a channel that is continually undergoing erosion.
- Cut banks are up to 3 m in height whereas a cliff may be tens of meters high, but in all cases, the form is vertical or very steep, typically >35º.
- Erosion is a result of a range of processes that include groundwater flow, currents, surface wash, waves and boat wakes, wind action and rain wash.
- In addition to direct hydraulic erosion, the cliffs can fail by undercutting, slides, slumping, and rotational slips.

SEDIMENT CLIFF OR BLUFF

SLUMPING SEDIMENT CUT BANK

OIL BEHAVIOUR

- Oil would strand at the base of a cliff or bank but may be splashed onto the cliff face by wave/current action. Penetration would vary with oil viscosity and sediment porosity.
- Oil on the cliff face would remain for a short time only (days to weeks) due to natural erosion; oil at the base of the cliff or that is washed from the cliff face either would be buried by material from above or eroded by wave/current action. Buried oil on this receding shoreline would remain until reworked by wave/current action.
- Persistence is primarily a function of shoreline retreat: where this is rapid, the persistence time would be short; in more stable areas, medium or heavy oil on the cliff or in the beach sediments may remain for as much as a year.

Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

OILED SEDIMENTS AT BASE OF ERODING BANK

SENSITIVITY

– Minimal biological resources can survive on the surface steep unconsolidated sediments because of their unstable nature.

SAFETY NOTES

– Loose, erosional sediments are unstable and provide poor traction for workers on foot.
– Block falls, and slumping are potential safety hazards during any response operations, particularly when the slope is higher than 2 m – these events may occur suddenly and without warning.
– Any techniques that may affect stability of the cliff, such as physical removal of material from the base, should be avoided for safety reasons.

PREFERRED TREATMENT OPTIONS

Shoreline Treatment Tactic	Volatile	Light	Medium	Heavy	Solid
Unconsolidated Sediments – Steep					
SURFACE					
Natural recovery	●	●	○	○	○
Low-pressure ambient wash	●	●	●	●	●
Manual removal	–	○	○	○	○
Mechanical removal	–	○	○	○	○
Dry mixing	–	○	○	○	○
Wet mixing	–	○	○	○	○
Sediment relocation	–	○	○	○	○
SUB-SURFACE					
Natural recovery	–	–	–	–	–
Low-pressure ambient wash	–	–	–	–	–
Manual removal	–	–	–	–	–
Mechanical removal	–	–	–	–	–
Dry mixing	–	–	–	–	–
Wet mixing	–	–	–	–	–
Sediment relocation	–	–	–	–	–

● Preferred option ○ Possibly applicable for small amounts – Not Applicable

Freshwater Substrate – Information Sheet 4

Unconsolidated Sediments - Steep

RESPONSE CONSIDERATIONS
– Natural recovery is often the preferred response option due to the rapid natural erosion of sediment cliffs/bluffs and cut banks – this option may be less appropriate for medium-heavy or weathered crude oils. – As erosion by natural processes is normal, treatment activities such as low-pressure washing that cause additional or accelerated erosion are not necessarily considered to be damaging.
BEST PRACTICES
– Flushing or washing activities may trigger unexpected block falls or slumping. – In many areas, the beaches that front a cliff/bluff or cut bank are very narrow or absent so there may be little working area. – Select treatment techniques that minimize erosion – limit the addition of fine sediment to water and/or mitigate increases in suspended sediments in water adjacent to the treatment area and downstream (e.g. utilize silt fencing in water adjacent to treatment area to limit water movement).

Shoreline Substrate Information Sheet 5

MUD

DEFINITION AND CHARACTER

- A mud flat (slope <5°) or bank/bar (slope typically 5° to 35° but can be >35°) is dominated by very fine sediments (typically muds, silts, and clays) – may be rich in organic detritus and include small amounts of sand.
- This substrate type is used predominantly in association with riverine environments, but flats may be found adjacent to low-lying areas and inlets to lakes.
- These shorelines are often backed by wetland vegetation and most frequently located in sheltered wave-energy lake environments.

MUD FLAT

MUD BANK

OIL BEHAVIOUR

- Oil penetration is limited on mud/clay banks because the clay substrate is impermeable – light oils may mix with waters in the sediments.
- Oil will likely not adhere to the substrate if wet or if a vertical clay surface is present.
- Oil is less likely to stay stranded in the lower swash zones as these remain wet due to wave/current action and groundwater flowing out of the beach.
- All oils except those that are highly viscous or dense could be refloated and carried landward by wave action or rising water levels.
- Burial is possible with heavy viscous oils and as a result of storm activity.
- Oil may enter the subsurface through mud cracks or the holes of burrowing animals (e.g. clams and worms) and may have a long persistence time (years).

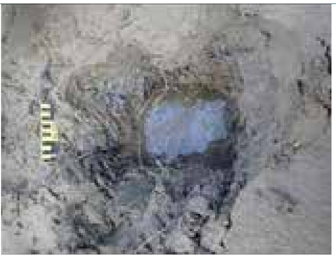
Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

Freshwater Substrate – Information Sheet 5

Mud

OILED DETRITUS AND SEDIMENTS ON MUD BANK



PIT IN LOWER MUD BANK WITH SUBSURFACE OIL IN ORGANIC DETRITUS LAYER AND SHEEN

SENSITIVITY

– Typically, biological utilization is lower in areas where stronger currents are present in the riverine environment but can be high in sheltered areas.
– Sheltered mud flats can be a primary feeding grounds for birds – may be utilized by migratory species.
– Due to their low weight-bearing capacity, muddy habitats are very sensitive to any activities that mix oil deeper into the sediments where it will persist

SAFETY NOTES

– Soft, mud sediments will not support workers on foot without the use of boardwalks (e.g. plywood sheets).
– Sloped, loose, erosional sediments are unstable and provide poor traction for workers on foot.

PREFERRED TREATMENT OPTIONS					
Shoreline Treatment Tactic	**Volatile**	**Light**	**Medium**	**Heavy**	**Solid**
SURFACE					
Mud Flat					
Natural recovery	●	●	○	○	–
Flooding	●	●	–	–	–
Low-pressure ambient wash	●	●	–	–	–
Manual removal	–	–	○	○	○
Vacuum	–	●	–	–	–
Passive sorbents	–	–	○	○	–
Wet mixing	–	●	–	○	–
Bioremediation	–	–	○	–	–
Mud Bank/Bar					
Natural recovery	●	●	○	–	–
Flooding	●	●	●	–	–
Low-pressure ambient wash	○	–	–	–	–
Manual removal	–	○	○	○	○
Vacuum	–	●	●	–	–
Mechanical removal	–	●	●	●	●
Passive sorbents	–	○	○		–
Dry mixing	–	●	●	●	–
Wet mixing	–	●	●	○	–
Bioremediation	–	○	○	–	–

● Preferred option ○ Possibly applicable for small amounts – Not Applicable

Freshwater Substrate – Information Sheet 5

Mud

Shoreline Treatment Tactic	Volatile	Light	Medium	Heavy	Solid
SUB-SURFACE					
Mud Flat					
Natural recovery	–	–	–	–	–
Flooding	–	–	–	–	–
Low-pressure ambient wash	–	–	–	–	–
Manual removal	–	○	○	○	○
Vacuum	–	–	–	–	–
Passive sorbents	–	–	–	–	–
Wet mixing	–	●	●	○	–
Bioremediation	–	○	○	○	–
Mud Bank/Bar					
Natural recovery	–	–	–	–	–
Flooding	●	●	–	–	–
Low-pressure ambient wash	●	●	–	–	–
Manual removal	–	–	○	○	○
Vacuum	–	–	–	–	–
Mechanical removal	–	○	○	○	○
Passive sorbents	–	–	–	–	–
Dry mixing	–	●	●	●	–
Wet mixing	–	●	●	●	–
Bioremediation	–	○	○	○	–

● Preferred option ○ Possibly applicable for small amounts – Not Applicable

RESPONSE CONSIDERATIONS

- In practical terms, there are limited options for removal of oil in this type of shoreline environment.
- To avoid driving oil into the subsurface, less intrusive strategies are preferred – these include herding, flooding or washing, and collection using sorbents or vacuums.
- Natural recovery is the preferred option where this choice exists – this option is less appropriate for medium-heavy or weathered crude oils and in slow moving rivers, backwaters and sheltered shores.
- The weight-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.
- If the mud is soft, foot traffic should be controlled to minimize negative effects.
- Barges or flat-bottomed boats can be used to support operations and personnel.

BEST PRACTICES

- Avoid mixing oil into sediments – subsurface oil could persist for a very long time, i.e. years.
- Disturbing sediment can have an effect even in the absence of oil, so all movement of both personnel and vehicles in oiled and unoiled areas must be carefully controlled.

Shoreline Substrate Information Sheet 6

SAND

DEFINITION AND CHARACTER

- A sand flat (slope <5°), beach or bank/bar (slope 5° to 35°, but typically 5° to 20°) is composed of sand plus any combination (<10%) of granule, pebble, cobble and/or boulder; silt/clay may be present.
- Sand shorelines are sometimes subdivided based on the dominant size of the sand:
  - coarse sand – larger grain size, steeper slopes, poorer bearing capacity;
  - fine sand – smaller grain size, flatter slope, more compacted, provide better traction and higher bearing capacity.
- Flats may be found adjacent to low-lying areas and inlets to lakes.
- Sand beaches have a very dynamic, mobile, unstable surface layer.
- Relatively little current or low levels of wave action (e.g. 0.5 m/s currents or 10 to 30 cm heights) can easily change the surface level by several centimetres over short time periods (hours).
- Changes in water flow and level (including large waves), such as from snow melt and rain storms can rapidly redistribute large volumes of sand. These processes can result in erosion, mixing, or burial of stranded oil. Large waves, as would be expected during storms, can lower or raise a beach surface by as much as 1 m in a few hours.
- Sediment supply to sand beaches is highly dependent on local or upstream source and supply conditions.
- Traction usually is good on sand beaches for most types of vehicles. Traction can be a problem in the lower swash zone, where there are water-saturated sediments, or above the normal swash zone, because of soft wind-blown sands. Reduction of tire pressure can partially compensate for low bearing capacity.

SAND FLAT EXPOSED AT LOWER WATER LEVEL

SAND BEACH

Environment and Climate Change Canada | Environnement et Changement climatique Canada

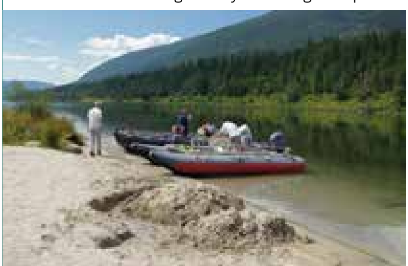
Canada

Freshwater Substrate – Information Sheet 6

Sand

OIL BEHAVIOUR

- Oil penetration is typically limited on sand flats because many sections remain water saturated.
- Sand beaches are permeable for some medium and all light oils – wave action can easily result in mixing, burial or erosion of these lighter stranded oils.
- On a medium- or coarse-grained sand beach, light oils can readily penetrate and mix with groundwater and/or be transported by changing water levels.
- Medium and heavy oils are unlikely to penetrate more than 25 cm because the water table for a sand beach is close to the surface – when wave action occurs, mixing or burial of heavier oils can easily occur due to sand's mobile properties.
- Oil is less likely to stay stranded in the lower swash zones as these remain wet due to wave/current action and groundwater flowing out of the beach.
- All oils except those that are highly viscous or dense could be refloated by wave action, currents or rising water levels.
- Along exposed shorelines, oil persistence will be short (days to weeks) due to higher wave action.
- Sheltered shorelines generally have longer oil persistence (months to years).



SAND BANK WITH TRENCH FOR SUB-SURFACE INVESTIGATION

SURFACE RESIDUE BALL (SAND MIXED WITH OIL)

SENSITIVITY

- Typically, sloped sand shorelines have minimal biological communities due to their higher-energy environments.
- Sheltered sand flats can be feeding grounds for birds – may be utilized by migratory species.
- Sand beaches are common resting or foraging habitats for shorebirds.
- Public and private beaches provide waterfront access to people.
- Seasonal recreational human use significantly increases sensitivity and the potential for people coming into contact with the oil.

SAFETY NOTES

- Coarse sand with a steeper slope typically provides poor traction for vehicles and often for workers on foot.

PREFERRED TREATMENT OPTIONS					
Shoreline Treatment Tactic	**Volatile**	**Light**	**Medium**	**Heavy**	**Solid**
			SURFACE		
Sand Flat					
Natural recovery	●	●	○	–	–
Flooding	●	●	●	–	–
Low-pressure ambient wash	●	●	●	–	–
Manual removal	–	○	○	○	○
Vacuum	–	●	○	○	–
Mechanical removal	–	–	●	●	●
Passive sorbents	–	○	●	○	–
Dry mixing	–	●	○	–	–
Wet mixing	–	●	●	○	–
Sediment relocation	–	●	●	–	–
Bioremediation	–	○	○	–	–
Sand Beach, Bank/Bar					
Natural recovery	●	●	○	–	–
Flooding	●	●	●	–	–
Low-pressure ambient wash	○	–	–	–	–
Manual removal	–	○	○	○	○
Vacuum	–	●	●	–	–
Mechanical removal	–	●	●	●	●
Passive sorbents	–	○	–	–	–
Dry mixing	–	●	●	●	–
Wet mixing	–	●	●	○	–
Sediment relocation	–	●	●	●	–
Bioremediation	–	○	○	–	–
● Preferred option ○ Possibly applicable for small amounts – Not Applicable					

Freshwater Substrate – Information Sheet 6

Sand

Shoreline Treatment Tactic	Volatile	Light	Medium	Heavy	Solid
SUB-SURFACE					
Sand Flat					
Natural recovery	–	–	–	–	–
Flooding	–	–	–	–	–
Low-pressure ambient wash	–	–	–	–	–
Manual removal	–	○	○	○	○
Vacuum	–	–	–	–	–
Mechanical removal	–	–	●	●	●
Passive sorbents	–	–	–	–	–
Dry mixing	–	●	●	–	–
Wet mixing	–	●	●	–	–
Sediment relocation	–	●	●	–	–
Bioremediation	–	○	○	○	–
Sand Beach, Bank/Bar					
Natural recovery	–	–	–	–	–
Flooding	●	●	–	–	–
Low-pressure ambient wash	●	●	–	–	–
Manual removal	–	–	○	○	○
Vacuum	–	–	–	–	–
Mechanical removal	–	○	○	○	○
Passive sorbents	–	–	–	–	–
Dry mixing	–	●	●	●	–
Wet mixing	–	●	●	●	–
Sediment relocation	–	●	●	●	–
Bioremediation	–	○	○	○	–

● Preferred option ○ Possibly applicable for small amounts – Not Applicable

RESPONSE CONSIDERATIONS

- Natural recovery is the preferred option if possible, particularly for small amounts of oil – this option is less appropriate for medium-heavy or weathered crude oils and in slow moving rivers, backwaters and sheltered shores.
- Natural recovery may not be appropriate immediately before freeze-up as the oil would be encapsulated by ice and could remobilize during the next thaw.
- From an operations standpoint, the treatment of oil stranded on sand flats is difficult when the weight-bearing capacity of the sand flat is low.
- Mixing and sediment relocation are more effective on flats with wave or current action.
- Barges or flat-bottomed boats can be used to support operations and personnel.

Freshwater Substrate – Information Sheet 6

Sand

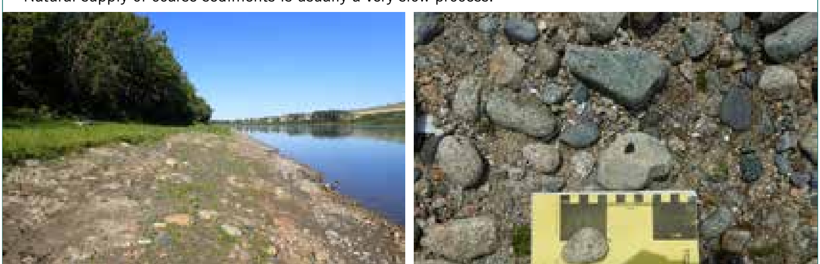
BEST PRACTICES
– Avoid removing too much sediment as natural replacement rates are slow in many areas – excessive removal could lead to erosion. – Activities should avoid mixing unoiled and oiled sediments. Avoid mixing oil into unoiled subsurface sediments except as a planned mixing or sediment relocation strategy. – Concentrations of oil in the sediment are typically low – removing the sediment generates a large volume of lightly oiled waste, which then requires transfer and disposal. – Avoid tracking oil into unoiled areas. Vehicles and personnel always work from an unoiled area towards an oiled area to avoid cross-contamination. – During manual treatment, avoid over-filling collection bags or containers to minimize spillage and to prevent bags or containers from breaking.

Shoreline Substrate Information Sheet 7

MIXED SEDIMENTS

DEFINITION AND CHARACTER

- A mixed sediment flat (slope <5°), beach or bank/bar (slope 5° to 35°) is composed of sand plus any combination (>10%) of granule, pebble, cobble and/or boulder.
- The interstitial spaces (voids) between the coarse pebble/cobble fractions are in-filled with sand or granules.
- Mixed sediment shorelines are sometimes subdivided due to differences in oil penetration and treatment tactics selected. The subtypes are:
  - fine-mixed (sand/granule/pebble);
  - coarse-mixed (includes larger cobble material).
- The surface layer often consists predominantly of coarser sediments (pebble/cobble) with increasing amounts of sand/granule in the subsurface.
- The lower swash zone is often predominantly sand.
- The lower bank and mid-channel bars are often characterized by pebble/cobble from which most of the sand has been washed away, leaving a coarse sediment surface layer overlying mixed sediment – sand/fine sediments tend to accumulate where currents are slow.
- Natural supply of coarse sediments is usually a very slow process.



MIXED SEDIMENT SHORELINE

Environment and Climate Change Canada
Environnement et Changement climatique Canada

Canada

Freshwater Substrate – Information Sheet 7

Mixed Sediments

OIL BEHAVIOUR
– The coarse fractions (pebble/cobble) are in-filled with the finer sands and granules – how the oil behaves is determined more by these finer fractions. – Oil residence time or persistence is primarily a function of the type of oil, the depth of penetration or burial of the oil, and energy (wave, current) levels on the shore. – Depth of oil penetration is primarily a function of the viscosity of the oil. Depth of burial or re-exposure of oiled sediments is primarily a function of physical sediment reworking by water processes. – Light oils can readily penetrate and mix with groundwater and/or be transported by changing water levels. – Heavy oils penetrate through the mixed sediments less readily than on a coarse sediment beach – oil that does penetrate, however, is more likely to persist in the subsurface of a mixed sediment beach. – Oil is less likely to stay stranded in the lower swash zones as these remain wet due to wave/current action and groundwater flowing out of the beach. – All oils except those that are highly viscous or dense would be re-floated by currents or a rising water level.

MIXED SEDIMENTS WITH POOLED OIL

MIXED SEDIMENTS WITH TARBALLS AND PATTIES

SENSITIVITY
– As few animals or plants can survive the continuous reworking of the coarse sediments, exposed or semi-exposed beaches support little life, particularly in the upper swash zone. – Sensitivity is higher in the lower zones of the beach or in sheltered wave environments that tend to be more stable and where organisms are more likely to be present.

SAFETY NOTES
– Mixed sediments typically provide poor traction for vehicles and often for workers on foot.

PREFERRED TREATMENT OPTIONS					
Shoreline Treatment Tactic	**Volatile**	**Light**	**Medium**	**Heavy**	**Solid**
SURFACE					
Mixed Sediment Flat					
Natural recovery	●	●	○	–	–
Flooding	●	●	●	–	–
Low-pressure ambient wash	○	●	●	–	–
Manual removal	–	○	○	○	○
Vacuum	–	●	●	○	–
Mechanical removal	–	●	●	●	●
Passive sorbents	–	○	○	○	–
Dry mixing	–	●	●	●	–
Wet mixing	–	●	●	●	–
Sediment relocation	–	–	–	–	–
Bioremediation	–	○	○	–	–
Mixed Sediment Beach, Bank/Bar					
Natural recovery	●	●	○	–	–
Flooding	●	●	●	–	–
Low-pressure ambient wash	○	●	●	–	○
Manual removal	–	○	○	○	–
Vacuum	–	–	●	●	●
Mechanical removal	–	●	●	●	–
Passive sorbents	–	○	○	–	–
Dry mixing	–	●	●	●	–
Wet mixing	–	●	●	○	–
Sediment relocation	–	●	●	●	–
Bioremediation	–	○	○	–	–

● Preferred option ○ Possibly applicable for small amounts – Not Applicable

Freshwater Substrate – Information Sheet 7

Mixed Sediments

Shoreline Treatment Tactic	Volatile	Light	Medium	Heavy	Solid
SUB-SURFACE					
Mixed Sediment Flat					
Natural recovery	–	–	–	–	–
Flooding	●	●	–	–	–
Low-pressure ambient wash	●	●	–	–	–
Manual removal	–	–	○	○	○
Vacuum	–	–	–	–	–
Mechanical removal	–	●	●	●	●
Passive sorbents	–	–	–	–	–
Dry mixing	–	●	●	●	–
Wet mixing	–	●	●	●	–
Sediment relocation	–	●	●	●	–
Bioremediation	–	○	○	–	–
Mixed Sediment Beach, Bank/Bar					
Natural recovery	–	–	–	–	–
Flooding	●	●	–	–	–
Low-pressure ambient wash	●	●	–	–	–
Manual removal	–	–	○	○	○
Vacuum	–	–	–	–	–
Mechanical removal	–	●	●	●	●
Passive sorbents	–	–	–	–	–
Dry mixing	–	●	●	●	–
Wet mixing	–	●	●	●	–
Sediment relocation	–	●	●	●	–
Bioremediation	–	○	○	○	–

● Preferred option ○ Possibly applicable for small amounts – Not Applicable

RESPONSE CONSIDERATIONS

- Natural recovery may be an acceptable option for small spills, low viscosity oils, or on exposed shoreline, and/or in remote areas – this option is less appropriate for medium-heavy or weathered crude oils and in slow moving rivers, backwaters and sheltered shores.
- When selecting manual and mechanical removal techniques, the following factors must be considered:
  - size of the area to be treated;
  - time available for treatment;
  - amount of oiled sediment that requires handling, transfer, and disposal.
- Manual removal and vacuums can be combined with the use of sorbents on surface oil patches.
- Low-pressure ambient temperature washing with trenches or sumps to collect oil can be combined with vacuum systems to recover the oil.
- Sediment relocation can be followed by mechanical mixing.
- Mixing can be followed by bioremediation as a final polishing tactic.

Freshwater Substrate – Information Sheet 7

Mixed Sediments

BEST PRACTICES
– Excessive removal of sediment can lead to erosion. – Excessive removal of coarse sediments is of concern as natural replacement rates are usually very slow. – As concentrations of oil in sediment are usually very low, manual tactics for removing sediment may generate large volumes of waste that contain relatively small amounts of oil. – If there are attached plants in unoiled lower swash zone and nearshore littoral area, avoid spreading oil into these areas. – Flushing techniques that only move the oil deeper into the sediments, without flushing the oil out of the shore for recovery, are not appropriate.

Shoreline Substrate Information Sheet 8

PEBBLE/COBBLE

DEFINITION AND CHARACTER

- A pebble/cobble beach or bank/bar (slope 5° to 35°) is clearly dominated by either pebbles or cobbles or a combination of both.
- The interstitial spaces (voids) between individual pebbles or cobbles are relatively open and not in-filled with finer material.
- Pebble/cobble beaches have a dynamic, mobile, unstable surface layer.
- The lower bank and mid-channel bars are often characterized by pebble/cobble from which most of the sand has been washed away, leaving a coarse sediment surface layer overlying mixed sediment – sand/fine sediments tend to accumulate where currents are slow.
- Natural supply of coarse sediments is usually a very slow process.

COBBLE BANK/BAR

PEBBLE SUBSTRATE

OIL BEHAVIOUR

- Permeable to all but the semi-solid oils therefore subsurface oiling is typical.
- Oil residence time or persistence is primarily a function of the oil type, depth of penetration, location with respect to the water level, and the wave energy/water flow conditions (current and energy). Typically, only the surface layer of sediments is reworked by normal water movements.
- 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.
- Oil that penetrates below the surface may not be physically reworked except during infrequent, high-energy storms or run-off events
- Oil is less likely to stay stranded in the lower swash zones as these remain wet due to wave/current action and groundwater flowing out of the beach.
- All oils except those that are highly viscous or dense could be refloated and carried up the beach by a rising water level.

Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

Freshwater Substrate – Information Sheet 8

Pebble/Cobble

STAIN-COAT ON PEBBLE

COVER ON COBBLE

SENSITIVITY

- As few animals or plants can survive the continuous reworking of the coarse sediments, exposed or semi-exposed beaches support little life, particularly in the upper swash zone.
- Sensitivity is higher in the lower sections of the beach or in sheltered wave environments that tend to be more stable and where organisms are more likely to be present – habitat and protection are provided within the interstitial spaces of larger materials such as cobbles.

SAFETY NOTES

- Coarse sediments typically provide poor traction for vehicles and often for workers on foot.

Freshwater Substrate – Information Sheet 8

Pebble/Cobble

PREFERRED TREATMENT OPTIONS

Shoreline Treatment Tactic	Volatile	Light	Medium	Heavy	Solid
Pebble/Cobble Beach, Bank/Bar					
SURFACE					
Natural recovery	●	●	○	–	–
Flooding	●	●	●	–	–
Low-pressure ambient wash	○	●	●	–	–
Manual removal	–	○	○	○	○
Vacuum	–	●	●	●	–
Mechanical removal	–	○	○	○	○
Passive sorbents	–	○	○	○	–
Dry mixing	–	○	○	○	–
Wet mixing	–	●	●	○	–
Sediment relocation	–	●	●	●	–
Shoreline cleaners	–	○	○	–	–
Bioremediation	–	○	○	–	–
SUB-SURFACE					
Natural recovery	–	–	–	–	–
Flooding	●	●	–	–	–
Low-pressure ambient wash	●	●	–	–	–
Manual removal	–	–	○	○	○
Vacuum	–	–	–	–	–
Mechanical removal	–	○	○	○	○
Passive sorbents	–	–	–	–	–
Dry mixing	–	○	○	○	–
Wet mixing	–	●	●	●	–
Sediment relocation	–	●	●	●	–
Shoreline cleaners	–	–	–	–	–
Bioremediation	–	○	○	○	–

● Preferred option ○ Possibly applicable for small amounts – Not Applicable

RESPONSE CONSIDERATIONS

- Natural recovery may be an acceptable option for small spills, low viscosity oils, or on exposed shoreline, and/or in remote areas – this option is less appropriate for medium-heavy or weathered crude oils and in slow moving rivers, backwaters and sheltered shores.
- Removal of oiled material can be followed by manual removal, vacuums, or use of sorbents on surface oil patches.
- Flooding and low-pressure washing are a good combination.
- Sediment relocation can be followed by mixing and/or bioremediation.
- Sediment relocation depends on the availability of mechanical wave energy to abrade, redistribute, and replace the sediments.
- Sediment relocation in low wave-energy environments requires mechanical energy or the presence of fines (clays and silts) to remove oil.

Freshwater Substrate – Information Sheet 8

Pebble/Cobble

BEST PRACTICES
– Excessive removal of sediment can lead to erosion. – Excessive removal of coarse sediments is of concern as natural replacement rates are usually very slow. – As concentrations of oil in sediment are usually very low, manual tactics for removing sediment may generate large volumes of waste that contain relatively small amounts of oil. – If there are attached plants in unoiled lower swash zone and nearshore littoral area, avoid spreading oil into these areas. – Flushing techniques that only move the oil deeper into the sediments, without flushing the oil out of the shore for recovery, are not appropriate.

Shoreline Substrate Information Sheet 9

BOULDER

DEFINITION AND CHARACTER

- A boulder beach has an unconsolidated accumulation of boulders in the shore zone.
- A useful rule of thumb to differentiate between boulders and bedrock outcrops is that boulders typically are less than 4 m in size.
- Boulder beaches are highly permeable.
- Boulders provide a stable surface layer that can only be moved by humans and extreme wave/flow conditions.
- Mixed sediment (sand, pebble, cobble) is common at the base of the boulders or in the subsurface.

BOULDER SUBSTRATE

BOULDER SHORELINE

OIL BEHAVIOUR

- Oil stranded on the upper exposed surfaces of the boulders behaves similarly to oil on bedrock.
- Oil has easy access through the large spaces between the individual boulders, thus coating the inner protected faces of the boulder surface and penetrating underlying sediments.
- Oil residence time or persistence is primarily a function of the type of oil, location with respect to the water level, and the wave energy/water flow conditions (current energy).
- Persistence of oil varies greatly between exposed boulder surfaces and protected crevice and subsurface locations.
- Light or non-sticky oils may be easily flushed out of the sediments on the surface or subsurface.

Environment and Climate Change Canada
Environnement et Changement climatique Canada

Canada

Freshwater Substrate – Information Sheet 9

Boulder

COVER ON BOULDER

SENSITIVITY

– This type of beach is stable, and the boulders provide different types of wave/flow exposures and habitats for biological growth.

– Productivity and sensitivity of biological growth can be relatively high, except in areas where boulders are abraded or moved by ice action in winter or by high flow events.

SAFETY NOTES

– Coarse sediments typically provide poor traction for vehicles and often for workers on foot.

PREFERRED TREATMENT OPTIONS

Shoreline Treatment Tactic	Volatile	Light	Medium	Heavy	Solid
Boulder Beach, Bank/Bar					
SURFACE					
Natural recovery	●	●	○	–	–
Flooding	●	●	●	–	–
Low-pressure ambient wash	○	●	●	–	–
Manual removal	–	○	○	○	○
Vacuum	–	●	●	●	–
Mechanical removal	–	○	○	○	○
Passive sorbents	–	○	○	○	–
Shoreline cleaners	–	○	○	–	–
Bioremediation	–	○	○	–	–
SUB-SURFACE					
Natural recovery	●	●	○	–	–
Flooding	●	●	●	–	–
Low-pressure ambient wash	●	●	●	–	–
Manual removal	–	–	–	–	–
Vacuum	–	–	–	–	–
Mechanical removal	–	○	○	○	○
Passive sorbents	–	–	–	–	–
Shoreline cleaners	–	–	–	–	–
Bioremediation	–	○	○	○	–

● Preferred option ○ Possibly applicable for small amounts – Not Applicable

Freshwater Substrate – Information Sheet 9

Boulder

RESPONSE CONSIDERATIONS
– The outer exposed surfaces of boulders are similar in some ways to a bedrock outcrop and can be treated using similar techniques. – The inner protected surfaces of the interstitial spaces are very difficult to access and the options for oil removal are limited. – In most cases, all but surface oil would be difficult to recover. – Natural recovery may be an acceptable option for small spills, low viscosity oils, or on exposed shoreline, and/or in remote areas – this option is less appropriate for medium-heavy or weathered crude oils and in slow moving rivers, backwaters and sheltered shores. – Removal of oiled material is followed by manual removal of surface oil. – If oil can be removed from the difficult-to-access inner surfaces by washing, this should be done before the oil weathers and decreases the effectiveness of removal. – Under the appropriate circumstances and with regulatory approval, shoreline cleaners may be combined with flooding and/or ambient low-pressure washing and oil collection and recovery. – If oil leaching is a concern, the boulders could be lifted out mechanically, either from the land side or from a barge, the subsurface oil removed or treated, and the boulders replaced.
BEST PRACTICES
– It is not practical or effective to remove boulders from this type of shoreline. – Boulders form a strong armour layer and would not be replaced naturally. Removal without replacement, therefore, could lead to erosion. – If there are attached plants in unoiled lower swash zone and nearshore littoral area, avoid spreading oil into these areas. – Flushing techniques that only move the oil deeper into the sediments, without flushing the oil out of the shore for recovery, are not appropriate.

Shoreline Substrate Information Sheet 10

VEGETATED

DEFINITION AND CHARACTER

– Vegetated shorelines or channel margins are stable and consist of cohesive terrestrial or water tolerant vegetation alongside swash zone or bed of a river, creek or stream.
– More common in prairie, muskeg, and tundra regions – regions of flat topography where water flow for most of the year is slow.
– The vegetation can consist of any type (herbaceous, shrub, willow, and/or tree) with >25% ground cover.
– Includes tree branches overhanging the shore zone and exposed roots.
– Occasionally these shorelines are flooded by wind-induced surges or high water.

VEGETATED SHORELINE

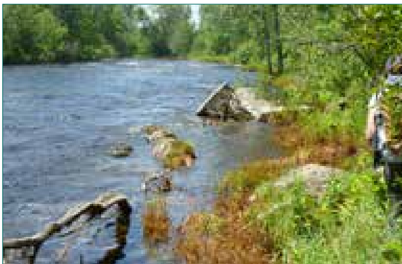
VEGETATED CHANNEL MARGIN

OIL BEHAVIOUR

– When the water level is high, oil readily adheres to vegetation and will coat the surface.
– If the vegetation is thick, it will help restrict oil from penetrating the vegetation – oiling will be heaviest on the outer fringe of vegetation.
– When the water level is low, there is typically less oiling of the vegetation, and oil will only coat a narrow band of sediment at the high-water mark.
– Natural removal rates can be very slow due to low energy environments and dense vegetation.

Environment and Climate Change Canada
Environnement et Changement climatique Canada
Canada

Vegetated



OILED VEGETATION ALONG CHANNEL MARGIN

OIL BAND ON VEGETATION STEMS

SENSITIVITY

– These shores are biologically rich habitats.

– Vegetation roots contribute to shoreline/channel margin stability – stems slow the velocity of flood waters and winds, reducing erosion.

SAFETY NOTES

– Shoreline/channel margin stability may be affected by treatment activities.

PREFERRED TREATMENT OPTIONS

Shoreline Treatment Tactic	Volatile	Light	Medium	Heavy	Solid
Vegetated Shoreline, Channel Margin					
SURFACE					
Natural recovery	●	●	○	○	–
Flooding	●	●	●	–	–
Low-pressure ambient wash	●	●	●	–	–
Manual removal	–	○	○	○	○
Vacuum	–	●	●	●	–
Vegetation cutting	–	○	○	○	○
Passive sorbents	–	○	○	–	–
Dry mixing	–	–	–	–	–
Bioremediation	–	–	–	–	–
SUB-SURFACE					
Natural recovery	○	○	○	○	–
Flooding	●	●	–	–	–
Low-pressure ambient wash	●	●	–	–	–
Manual removal	–	–	○	○	○
Vacuum	–	–	–	–	–
Vegetation cutting	–	–	–	–	–
Passive sorbents	–	–	–	–	–
Dry mixing	–	○	○	○	–
Bioremediation	–	○	○	○	–

● Preferred option ○ Possibly applicable for small amounts – Not Applicable

Freshwater Substrate – Information Sheet 10

Vegetated

RESPONSE CONSIDERATIONS
– Natural recovery is often the least damaging alternative for treating light and moderate oiling, particularly where access is limited or difficult. – Manual tactics using shovels or rakes could be used in small, heavily oiled areas. – Oiled vegetation could be cut and collected. – Sorbents are effective for fresh crude oil and petroleum products – loose organic sorbents (e.g. sphagnum peat moss – Sphag Sorb®) can be spread on the surface and lightly raked into areas of sticky or liquid oil then removed for proper disposal. – Loose organic sorbents can be applied by hand or a small sprayer to provide a barrier to reduce the risk of oil exposure by wildlife (e.g. waterfowl, aquatic furbearers). – Exposed tree/shrub stems and roots may be wiped with sorbent pads, brushes, or other manual methods to remove gross oiling – if gross oiling cannot be removed using these methods, affected roots may be cut-out if bank stability will not be affected.
BEST PRACTICES
– Avoid trampling vegetation and using heavy machinery as this is likely to incorporate oil more deeply into sediments – walking boards may be used to access areas by foot for treatment. – Minimize substrate removal and vegetation cropping unless they are very heavily oiled – if vegetation and sediment are removed, only the top 2 to 5 cm of oiled surface should be picked up if possible, to avoid root damage. – Avoid raking and trampling oil on to living plants. – Minimize intrusive physical damage by using only low-pressure washing techniques. – Excessive removal of vegetation (including roots) and/or substrate may contribute to erosion.

Shoreline Substrate Information Sheet 11

WETLAND

DEFINITION AND CHARACTER

- Shallow-water vegetation near/at water-land interface (e.g. cattails, sedges, grasses) and deeper-water emergent vegetation (e.g. broad beds of emergent aquatic vegetation such as bulrush and reeds found in water depths up to 1.5-2 m).
- Common in sheltered wave-energy environments.
- Support a stable cover of surface vegetation and root system, the leafy portion of which dies back during winter months.
- Dominated by herbaceous vegetation that provides >25% ground cover.
- Wetland types vary significantly in species assemblages, in substrate character and in size.
- Characterized by a surface accumulation of organic matter deposited in water, although inorganic (i.e. mineral) sediments dominate the substratum.
- Extremely productive for plant and animal life and provide habitat to many migratory birds.

CATTAILS IN SHALLOW WATER NEAR WATER-LAND INTERFACE

EMERGENT AQUATIC VEGETATION IN DEEPER WATER

Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

Wetland

OIL BEHAVIOUR

- Many factors influence how oil affects wetlands: oil type, extent of vegetation contamination, degree of sediment contamination, exposure to natural removal processes, time of year of the spill and species types.
- Most types of oil readily adhere to and are retained on the stems and leaves of vegetation.
- An oiled band forms when floating oil comes in contact with the stems of plants – the width, i.e. vertical height, of this oiled band depends on changes in water levels while the oil is mobile on the water surface.
- If the vegetation is thick, it will help restrict oil from penetrating the vegetation – oiling will be heaviest on the outer fringe of vegetation.
- In some cases, oil trapped in vegetation may be a source of remobilized oil that can be subsequently released to oil or reoil other sites.
- Light oils may penetrate sediments through cracks or holes of burrowing animals and persist in the subsurface sediments for long periods (years).
- Medium and heavy oils will remain on the surface and may smother plants and animals.
- Vegetation dies back seasonally and returns to the aquatic system, either sinking to the waterbody bed or forming decaying vegetation mats on shorelines and banks/bars.
- Natural recovery rates vary depending on the oil type, total area affected, oil thickness, plant type, growth rates, and the season during which the oiling occurred. For example, a reed bed may recover in less than a year or one growth cycle following light oiling.

BAND OF OILING ALONG THICKER INTERIOR VEGETATION

OILED PLANT STEMS NEAR WATER SURFACE

SENSITIVITY

- Wetlands are the most sensitive habitats because of their high biological use and value, difficulty of treatment, and potential for long-term effects to many organisms.
- Vegetation roots contribute to shoreline/channel margin stability – stems slow the velocity of flood waters and winds, thereby reducing erosion.

SAFETY NOTES

- Shoreline/channel margin stability may be affected by treatment activities.
- Caution should be exercised if wading in water as footing may be unstable and water depth may change unexpectedly.

PREFERRED TREATMENT OPTIONS

Shoreline Treatment Tactic	Volatile	Light	Medium	Heavy	Solid
Wetland					
SURFACE					
Natural recovery	●	●	○	○	–
Flooding	●	●	●	–	–
Low-pressure ambient wash	●	●	●	–	–
Manual removal	–	○	○	○	○
Vacuum	–	○	○	–	–
Vegetation cutting	–	○	○	○	○
Passive sorbents	–	○	○	○	–
Burning	○	○	○	○	–
SUB-SURFACE					
Natural recovery	●	●	○	–	–
Flooding	●	●	–	–	–
Low-pressure ambient wash	●	●	–	–	–
Manual removal	–	○	○	○	○
Vacuum	–	–	–	–	–
Vegetation cutting	–	–	–	–	–
Passive sorbents	–	–	–	–	–
Burning	–	–	–	–	–

● Preferred option ○ Possibly applicable for small amounts – Not Applicable

RESPONSE CONSIDERATIONS

– Each wetland area should have an individualized treatment plan based on its physical and biological character, and on circumstances of the spill, such as oiling conditions, time of year, size of spill, type of oil, location, and usage of area.

– Due to multiple sensitivity issues, it is often essential to evaluate the net environmental benefit in order to select appropriate tactics and determine how they are used – a specialist may be required to provide judgement calls in this regard.

– Natural recovery is often the least damaging alternative for treating light and moderate oiling, particularly where access is limited or difficult.

– Factors influencing the selection of options include: the rate of natural recovery; the possible benefits of a response to accelerate recovery; and any possible damage or delays in recovery that response activities may cause.

– Natural recovery may not be appropriate near the time of freeze-up as the oil would be encapsulated by ice and potentially remobilized during the next thaw.

– Response activities are best carried out from a boat or using boardwalks or mats to minimize the trampling of plants.

– Flooding and washing techniques that herd oil into collection areas without extensively disturbing the vegetation cover are preferred treatment techniques.

– Loose organic sorbents (e.g. sphagnum peat moss – Sphag Sorb®) can be applied by hand or a small sprayer to provide a barrier to reduce the risk of oil exposure by wildlife (e.g. waterfowl, aquatic furbearers).

– Generally, treatment activities are less likely to damage plants and root systems in late fall during the die-back phase or in winter when the substrate is frozen.

BEST PRACTICES
– Avoid trampling vegetation as this is likely to incorporate oil more deeply into sediments. – Trampling of vegetation without oil also directly effects the vegetation – offset these effects by using boardwalks, limiting the number of people and their access, and designating pathways that can be restored after treatment. – Minimize substrate removal and vegetation cropping unless they are very heavily oiled – if vegetation and sediment are removed, only the top 2 to 5 cm of oiled surface should be picked up if possible, to avoid root damage. – Minimize intrusive physical damage by using only low-pressure washing techniques. – Cutting of oiled plant stems during the early or active growing season could affect the plants and should only be considered if leaving the oil would threaten other resources, such as migratory or nesting birds. – Avoid burning if the lower stems and roots of a plant are dry and therefore not insulated from the heat. – Excessive removal of vegetation (including roots) and/or substrate may contribute to erosion and delay recovery.

Shoreline Substrate Information Sheet 12

VEGETATED/WOODED – UPLAND

DEFINITION AND CHARACTER

- The active flood plain between the bankfull level and the backshore with continuous terrestrial vegetation that is periodically inundated during high discharge events (seasonal or flood events) in a flowing-water environment.
- The vegetation can consist of any type (herbaceous, shrub, and/or tree) with >25% ground cover.
- May include man-made features, such as residential properties and maintained parks.

FLOODED AGRICULTURAL AREA ADJACENT TO WATERCOURSE

UPLAND FLOODED AREA ADJACENT TO WATERCOURSE – NOTE 'MUDDY' WATER

OIL BEHAVIOUR

- Oil on water can enter an upland during a flood event caused by high seasonal water levels, spring melt, rainstorms, diversions or damming. These events raise water levels above the normal channel confines onto the floodplain or backshore uplands.
- When the water level is high, oil readily adheres to vegetation and will coat the surface.
- If the vegetation is thick, it will help restrict oil from penetrating the vegetation – oiling will be heaviest on the outer fringe of vegetation.
- Floating oil may coat or stain trunks, stems and leaves resulting in an oiled band – the width of an oil band would depend on water level changes at the time the oil is still mobile on the water surface.
- Oil would contact the soils along the fringes of the flooded area and as the water recedes to more normal levels.
- Thin sporadic coating of oil could be expected on the soil surface – higher surface concentrations would be created in depressions that trap and hold small oil-on-water pools.
- Stranded oil may be partially buried/buried with silt/clay deposited by receding flood waters.
- Natural removal rates can be very slow due to low energy environments and dense vegetation.

Environment and Climate Change Canada   Environnement et Changement climatique Canada

Canada

Freshwater Substrate – Information Sheet 12

Vegetated/Wooded – Upland

BAND OF OILING ALONG THICKER INTERIOR VEGETATION

OILED TREE TRUNKS (THIN BLACK BAND) ABOVE WATER SURFACE

SENSITIVITY

– Important for terrestrial mammals, birds, and reptiles – can be important recreational areas.
– Vegetation roots contribute to shoreline/channel margin stability – stems slow the velocity of flood waters and winds, thereby reducing erosion.

SAFETY NOTES

– Shoreline/channel margin stability may be affected by treatment activities.

PREFERRED TREATMENT OPTIONS

Shoreline Treatment Tactic	Volatile	Light	Medium	Heavy	Solid
Vegetated/Wooded – Upland					
SURFACE					
Natural recovery	●	●	○	○	○
Flooding	●	●	●	–	–
Low-pressure ambient wash	●	●	●	○	–
Manual removal	–	○	○	○	○
Vacuum	–	●	●	–	–
Vegetation cutting	–	○	○	○	○
Passive sorbents	–	–	○	○	–
Dry mixing	–	–	–	–	–
Bioremediation	–	–	–	–	–
SUB-SURFACE					
Natural recovery	○	○	○	○	–
Flooding	●	●	–	–	–
Low-pressure ambient wash	●	●	–	–	–
Manual removal	–	–	○	○	○
Vacuum	–	–	–	–	–
Vegetation cutting	–	–	–	–	–
Passive sorbents	–	–	–	–	–
Dry mixing	–	○	○	○	–
Bioremediation	–	○	○	○	–

● Preferred option ○ Possibly applicable for small amounts – Not Applicable

Vegetated/Wooded – Upland

RESPONSE CONSIDERATIONS

- Natural recovery is often the least damaging alternative for treating light and moderate oiling, particularly where access is limited or difficult.
- Manual tactics using shovels or rakes may be used in small, heavily oiled areas.
- Oiled vegetation may be cut and collected.
- Sorbents are effective for fresh crude oil and petroleum products – loose organic sorbents (e.g. sphagnum peat moss – Sphag Sorb®) can be spread on the surface and lightly raked into areas of sticky or liquid oil then removed for proper disposal.
- Loose organic sorbents can be applied by hand or a small sprayer to provide a barrier to reduce the risk of oil exposure by wildlife (e.g. waterfowl, aquatic furbearers).
- Exposed tree/shrub stems and roots may be wiped with sorbent pads, brushes, or other manual methods to remove gross oiling – if gross oiling cannot be removed using these methods, affected roots may be cut-out if bank stability will not be affected.

BEST PRACTICES

- Avoid trampling vegetation and using heavy machinery as this is likely to incorporate oil more deeply into sediments – walking boards may be used to access areas by foot for treatment.
- Minimize substrate removal and vegetation cropping unless they are very heavily oiled – if vegetation and sediment are removed, only the top 2 to 5 cm of oiled surface should be picked up if possible, to avoid root damage.
- Avoid raking and trampling oil on to living plants.
- Minimize intrusive physical damage by using only low-pressure washing techniques.
- Excessive removal of vegetation (including roots) and/or substrate may contribute to erosion.

Shoreline Substrate Information Sheet 13

SMALL AND LARGE WOODY MATERIAL

DEFINITION AND CHARACTER

- Shoreline or bank is dominated (>75% cover of underlying substrate) by wood and logs that have been deposited on the shore by wave action or currents.
- An unconsolidated accumulation dominated by floating or stranded branches and logs [<10 cm diameter referred to as Small Woody Material (SWM); >10 cm diameter as Large Woody Material (LWM)] diameter that have collected or been deposited on the shoreline, channel margin or floodplain.
- Large woody material deposits provide a stable surface layer. They are moved by ice, human activities, or natural events as might occur during high runoff periods.
- Small and large woody materials can occur along river banks, above or below the water-line or mid-stream, at different levels of submergence.
- Low-lying areas are susceptible to flooding and the inland extent of these incursions is commonly marked by log lines.
- Includes active beaver lodges – the interior of a lodge may have two levels with one or two passageways that may be too small to access for treatment.

ACCUMULATION OF WOODY MATERIAL AT THE HEAD OF MID-CHANNEL ISLAND

ACCUMULATION OF WOODY MATERIAL IN SMALL EMBAYMENT

Environment and Climate Change Canada
Environnement et Changement climatique Canada
Canada

OIL BEHAVIOUR

– An oiled woody material shoreline would be treated in the same manner as a shoreline type with equivalent characteristics.
– Large woody material is on the same size order as boulders and creates a similar gap size and thus should be treated as a boulder beach.
– Large woody material is permeable and has a stable surface layer – oil will adhere to the dry surface.
– Large woody material frequently overlays sand or mixed sediment beaches.
– The large spaces between the individual pieces of trees/logs allow all types of oil to be carried into the underlying sediments.
– Oil stranded on SWM accumulations may bind the materials to create Oiled Debris Mats (ODMs).
– Oil residence time or persistence is primarily a function of the oil type, location with respect to the water level, and wave-energy levels on the shoreline or water flow conditions (current energy).
– Light or non-sticky oils can easily be flushed out of surface sediments due to the large gaps between driftwood pieces.
– High-energy shorelines will generally have short oil persistence (days to weeks) and sheltered shorelines will generally have longer oil residence times (months to years).

DISCRETE AREA OF OILED LARGE WOODY MATERIAL

WOODY MATERIAL LINE WITH OILING

SENSITIVITY

– Minimal biological communities exist on shorelines dominated by large woody material, though plants and animals can be found on or between logs.

SAFETY NOTES

– Large woody material may provide an unstable substrate for vehicles and workers on foot.

Small and Large Woody Material

PREFERRED TREATMENT OPTIONS

Shoreline Treatment Tactic	Volatile	Light	Medium	Heavy	Solid
Small and Large Woody Material					
SURFACE					
Natural recovery	●	●	○	○	○
Flooding	●	●	●	–	–
Low-pressure ambient wash	●	●	●	○	–
Low-pressure warm/hot wash	–	–	●	●	●
High-pressure ambient wash	–	–	○	○	○
Manual removal	–	○	○	○	○
Mechanical removal	–	○	○	○	○
Passive sorbents	–	○	○	○	–
Burning	–	○	○	○	–
Bioremediation	–	–	–	–	–
SUB-SURFACE					
Natural recovery	○	○	○	○	○
Flooding	●	●	●	–	–
Low-pressure ambient wash	●	●	●	–	–
Low-pressure warm/hot wash	–	–	–	–	–
High-pressure ambient wash	–	–	–	–	–
Manual removal	–	–	○	○	○
Mechanical removal	–	○	○	○	○
Passive sorbents	–	–	–	–	–
Burning	–	–	–	–	–
Bioremediation	–	○	○	○	–

● Preferred option ○ Possibly applicable for small amounts – Not Applicable

Freshwater Substrate – Information Sheet 13

Small and Large Woody Material

RESPONSE CONSIDERATIONS
– The inner protected surfaces of the interstitial spaces are very difficult to access and the options for oil removal are limited. – In most cases, all but surface oil would be difficult to recover. – Natural recovery may be an acceptable option for small spills, low viscosity oils, or on exposed shoreline, and/or in remote areas – this option is less appropriate for medium-heavy or weathered crude oils and in slow moving rivers, backwaters and sheltered shores. – Removal of small oiled material is followed by manual removal of surface oil from large material – use chainsaws to cut-out only the oiled parts of branches or logs. – If oil can be removed from the difficult-to-access inner surfaces by washing, this should be done before the oil weathers and decreases the effectiveness of removal. – If oil leaching is a concern, the large trees/logs could be lifted out mechanically, either from the land side or from a barge, the subsurface oil removed or treated, and the large woody material replaced – as logs form a strong amour layer, removal without replacement may lead to erosion. – Disturbance of an active beaver lodge for oil recovery should be conducted in consultation with wildlife agencies to ensure that personnel are not exposed to beaver aggression.
BEST PRACTICES
– It is not practical or effective to remove large trees/logs from this type of shoreline – If there are attached plants in unoiled lower swash zone and nearshore littoral area, avoid spreading oil into these areas. – Flushing techniques (e.g. warm or hot water may temporarily mobilize viscous oil) that only move the oil deeper into the sediments, without flushing the oil out of the shore for recovery, are not appropriate.

Shoreline Substrate Information Sheet 14

ORGANIC

DEFINITION AND CHARACTER

– An accumulation of decaying wood, vegetation, organic matter, or peat.
– Deposits may occur as a mat on a beach or bank/bar or a mobile slurry – tend to accumulate primarily in low-energy, sheltered areas, which is where oil is also likely to accumulate.
– Mats are either wet or dry ("dewatered"), erode easily, and are redistributed by wave or current action.
– May form a slurry at the edge of the beach or shore that resembles "coffee grounds".
– Channel banks of organic composition are common for streams and rivers flowing through prairie, muskeg and tundra regions.
– Peat shorelines are common along low-lying or sheltered Arctic shorelines – peat is eroded from tundra cliffs.
– If not contained and recovered properly, areas with accumulation may result from the use of sorbents (e.g. sphagnum peat moss – Sphag Sorb®) during the response – these will typically contain oil.

ACCUMULATION OF DECAYING ORGANIC MATTER ON SHORE

PEAT RELEASED FROM ERODING TUNDRA OUTCROP

OIL BEHAVIOUR

– Organic matter has a tendency to absorb and hold oil.
– Heavy oils do not penetrate far into a mat, even if the mat is dry or dewatered, but may be buried or become mixed with organic detritus where it is reworked by wave action.
– Volatile and light oils penetrate organic detritus more easily than heavier oils – if oil penetrates the mat, relatively little recoverable oil may remain on the surface.
– Oils that contact organic slurry are likely to be mixed and remain so, especially in the low wave-energy areas where these slurries typically accumulate – the slurry has a similar effect to that of a loose granular sorbent and partially contains the oil and prevents it from spreading.
– Stranded oil may have a low residence time due to high erosion rates along peat shorelines.

Environment and Climate Change Canada Environnement et Changement climatique Canada

Canada

Organic

ACCUMULATION OF DECAYING ORGANIC MATTER WITH PARTIALLY BURIED SORBENT

DECAYING ORGANIC MATTER WITH VISIBLE SHEEN ADJACENT TO WETLAND

SENSITIVITY

– Although not typically an important biological habitat, organic shorelines are potential bird-feeding areas.

SAFETY NOTES

– Very poor weight-bearing capacity due to low cohesion of decaying organic materials.

PREFERRED TREATMENT OPTIONS

Shoreline Treatment Tactic	Volatile	Light	Medium	Heavy	Solid
Organic Shoreline, Channel Margin					
SURFACE					
Natural recovery	●	●	○	–	–
Flooding	●	●	●	–	–
Low-pressure ambient wash	●	●	●	–	–
Manual removal	–	○	○	○	○
Vacuum	–	●	●	–	–
Passive sorbents	–	○	○	○	–
Dry mixing	–	○	○	–	–
Wet mixing	–	○	○	–	–
SUB-SURFACE					
Natural recovery	–	–	–	–	–
Flooding	●	●	●	–	–
Low-pressure ambient wash	●	●	●	–	–
Manual removal	–	○	○	○	–
Vacuum	–	–	–	–	–
Passive sorbents	–	–	–	–	–
Dry mixing	–	–	–	–	–
Wet mixing	–	–	–	–	–

● Preferred option ○ Possibly applicable for small amounts – Not Applicable

Freshwater Substrate – Information Sheet 14

Organic

RESPONSE CONSIDERATIONS
– Natural recovery is often the least damaging alternative for treating light and moderate oiling, particularly where access is limited or difficult. – Natural recovery may not be appropriate near the time of freeze-up as the oil would be encapsulated by ice and potentially remobilized during the next thaw. – Manual tactics using shovels or rakes could be used in small, heavily oiled areas – then apply mixing to any remaining materials to accelerate physical and biological processes.

BEST PRACTICES
– Avoid trampling vegetation and using heavy machinery as this is likely to incorporate oil more deeply into sediments – walking boards may be used to access areas by foot for treatment. – When peat is found in association with tundra (which is a living plant community), minimize substrate removal and vegetation cropping unless they are very heavily oiled – if vegetation and sediment are removed, only the top 2 to 5 cm of oiled surface should be picked up if possible. – Avoid raking and trampling oil on to living plants. – Minimize intrusive physical damage by using only low-pressure washing techniques. – Avoid burning peat or oiled material near living plant communities.

Shoreline Substrate Information Sheet 15

TUNDRA CLIFF

DEFINITION AND CHARACTER

– Tundra cliffs are an erosional feature on Arctic shorelines – they are composed of a tundra (vegetation) mat that usually overlies peat and exposed ground ice with varying degrees of mixed sediment layers.
  › Ice-rich tundra cliffs are primarily composed of a tundra mat, peat and ice, with relatively little sediment – these are generally fronted by sand or mixed sediment beaches.
  › Ice-poor tundra cliffs are unconsolidated sediment cliffs with an overlying surface layer of tundra vegetation and peat and may have minor interstitial ice in the cliff face.
– As the ice-rich cliff face retreats due to wave action or as thermal erosion melts the ground ice, the tundra and peat materials fall to the base of the cliff - initially this material falls as fragmented and irregular blocks until it is reworked by wave action.
– Despite rapid erosion rates, relatively little beach-forming material is supplied to the shore zone so that beaches usually are either narrow or absent in many areas – eroded peat commonly accumulates at the base of a tundra cliff or may be transported alongshore.
– Cliffs range from less than 1 m to as much as 5 or 10 m high in some cases.

ICE-RICH TUNDRA CLIFF

ICE-POOR TUNDRA CLIFF

Freshwater Substrate – Information Sheet 15

Tundra Cliff

OIL BEHAVIOUR
– Oil that is washed up on exposed ground ice is unlikely to stick and would flow back down onto the beach unless air temperatures are below freezing. – If there are fragmented or slumped blocks at the base of the cliff, oil may pool in the spaces between the blocks. – Oil may be splashed on to the top of a low cliff surface where it would be untouched by normal wave action. – If there is a sand or mixed sediment beach at the base of the cliff, oils may penetrate – if these substrates become oiled, they would be treated as sand or mixed sediment depending upon their character. – Oil persistence is usually short due to natural erosion – oil persistence may be longer if the oil is buried byblock falls, incorporated into peat slurries, or absorbed into a beach. – If oil is on the cliff surface or on slumped tundra blocks, it will likely be reworked and remobilized by wave/water action. – Exposed (high-energy) shorelines will generally have short oil persistence (days to weeks), and sheltered, low-energy shorelines will generally have longer oil residence times (months to years).
SENSITIVITY
– Minimal biological resources can survive on the surface of tundra cliffs because of their unstable nature, though the vegetation on the tundra is sensitive to disturbance, and migratory birds use these shorelines during the summer months
SAFETY NOTES
– As tundra cliffs are often undercut and are naturally unstable, safety is a primary concern during operations. – Loose, erosional sediments are unstable and provide poor traction for workers on foot. – Block falls, and slumping are potential safety hazards during any response operations, particularly when the slope is higher than 2 m – these events may occur suddenly and without warning.

Freshwater Substrate – Information Sheet 15

Tundra Cliff

PREFERRED TREATMENT OPTIONS

Shoreline Treatment Tactic	Volatile	Light	Medium	Heavy	Solid
Tundra Cliff					
SURFACE					
Natural recovery	●	●	○	–	–
Flooding	–	●	●	●	–
Low-pressure ambient wash	●	●	●	–	–
Manual removal	–	–	○	○	○
Mechanical removal	–	●	●	●	●
Passive sorbents	–	○	○	○	–
Dry mixing	–	●	●	●	–
Sediment relocation	–	○	○	○	–
SUB-SURFACE					
Natural recovery	–	–	–	–	–
Flooding	–	–	–	–	–
Low-pressure ambient wash	–	–	–	–	–
Manual removal	–	–	–	–	–
Mechanical removal	–	–	–	–	–
Passive sorbents	–	–	–	–	–
Dry mixing	–	–	–	–	–
Sediment relocation	–	–	–	–	–

● Preferred option ○ Possibly applicable for small amounts – Not Applicable

RESPONSE CONSIDERATIONS

- Natural recovery is the preferred response option due to the rapid natural erosion, particularly of ice-rich tundra cliffs – oil on the cliff face, at the top edge of a cliff , or in the tundra and peat deposits at the base of a cliff will probably be naturally removed within weeks provided that the oil is not stranded at the onset of freeze-up.
- Natural recovery may not be appropriate immediately before freeze-up as the oil would be encapsulated by ice and potentially remobilized during the next thaw.
- As erosion by natural processes is normal, treatment activities such as low-pressure washing that cause additional erosion are not necessarily considered to be damaging – any erosion caused by treatment should be minimized, however, as the vegetation on the tundra is a living community.
- Mixing and sediment relocation are more effective on shores with wave action.

BEST PRACTICES

- Flushing or washing activities may trigger unexpected block falls or slumping.
- In many areas, the beaches that front a cliff/bluff or cut bank are very narrow or absent so there may be little working area.
- Select treatment techniques that minimize erosion – limit the addition of fine sediment to water and/or mitigate increases in suspended sediments in water adjacent to the treatment area (e.g. utilize silt fencing in water adjacent to treatment area to limit water movement).

Shoreline Substrate Information Sheet 16

INUNDATED LOW-LYING TUNDRA

DEFINITION AND CHARACTER

- The shorelines of these low-lying areas are often complex and convoluted, consisting predominantly of a combination of vegetated flats, peat mats, lagoons, and small streams.
- These areas can include subsiding tundra, ponds or lakes. Areas of flooded tundra polygons have a complex configuration of interconnected ridges with pools that contain decomposing vegetation.
- This type of shoreline is dominated by vegetation.
- Occasionally these shorelines are flooded or inundated by wind-induced surges or high water.
- The landward limits of past surge events are usually marked by lines of woody material.

INUNDATED LOW-LYING TUNDRA

OIL BEHAVIOUR

- During the summer, the sediments and/or peat deposits are often water-saturated so that oil would be restricted to surface areas only.
- Vegetation is often water-saturated, which limits oil penetration.
- The tundra has a vegetated soil or peat surface that resists penetration by heavy oil – heavy oils can persist, however, when buried by sediments or peat deposits.
- Light oil and light refined products can penetrate the soil, especially when the soil is dry – when this occurs, there may be relatively little recoverable oil on the surface.
- Residence times for oil on untreated tundra may increase as both the viscosity of the oil and the water content of the tundra decrease.
- Complete removal of the oil by natural processes may be delayed until a storm surge.
- Other substrates may be present with inundated low-lying tundra – wave action may push sand, gravel and driftwood on to the vegetation or peat mat. If these substrates become oiled, they would be treated as sand, pebble, cobble or boulder beaches or bank/bars depending upon their character.
- Natural recovery rates vary, and recovery may take as little as a few years following light oiling but may take decades in extensive, thick deposits of viscous oil.

Environment and Climate Change Canada | Environnement et Changement climatique Canada
Canada

Freshwater Substrate – Information Sheet 16

Inundated Low-Lying Tundra

SENSITIVITY

– These shorelines are sensitive to trampling and vehicle traffic during the open-water season.
– These shorelines are important for animal life and provide habitat to many migratory birds during the summer.

SAFETY NOTES

– Shallow nearshore water may limit access to the site by water and make it necessary to access the site by land – however, the complicated character of the shoreline and the presence of many water saturated sections may make it difficult to access and move on the land.

PREFERRED TREATMENT OPTIONS

Shoreline Treatment Tactic	Volatile	Light	Medium	Heavy	Solid
Inundated Low-Lying Tundra					
SURFACE					
Natural recovery	●	●	○	–	–
Flooding	●	●	●	–	–
Low-pressure ambient wash	●	●	●	●	–
Manual removal	–	○	○	○	○
Vacuum	–	●	●	●	–
Vegetation cutting	–	○	○	○	○
Passive sorbents	–	○	○	○	–
SUB-SURFACE					
Natural recovery	–	–	–	–	–
Flooding	–	–	–	–	–
Low-pressure ambient wash	–	–	–	–	–
Manual removal	–	–	–	–	–
Vacuum	–	–	–	–	–
Vegetation cutting	–	–	–	–	–
Passive sorbents	–	–	–	–	–

● Preferred option ○ Possibly applicable for small amounts – Not Applicable

RESPONSE CONSIDERATIONS

– Natural recovery is often the least damaging alternative for treating light and moderate oiling, particularly where access is limited or difficult.
– Natural recovery may not be appropriate immediately before freeze-up as the oil would be encapsulated by ice and potentially remobilized during the next thaw.
– Manual tactics using shovels or rakes could be used in small, heavily oiled areas.
– Oiled vegetation could be cut and collected, preferably only on dry surfaces.
– Sorbents are effective for fresh crude oil and petroleum products – the most effective technique in a peat-rich environment might be to use natural peat as a sorbent and remove the most heavily oiled fraction.

Freshwater Substrate – Information Sheet 16

Inundated Low-Lying Tundra

BEST PRACTICES
– Surface disturbance is minimized if treatment is done during winter months when the surface material is frozen. – Avoid trampling vegetation and using heavy machinery as this is likely to incorporate oil more deeply into sediments. The weight-bearing capacity of these low-lying areas is usually low during the open-water season but increases after freeze-up. In summer, treatment crews could use walking boards or snowshoes to minimize damage and trampling. – Where the tundra (which is a living plant community) has been oiled, minimize substrate removal and vegetation cropping unless they are very heavily oiled– if vegetation and sediment are removed, only the top 2 to 5 cm of oiled surface should be picked up if possible, to avoid root damage. – Avoid raking and trampling oil on to living plants. – Minimize intrusive physical damage by using only low-pressure washing techniques. – Avoid burning close to living plant communities.

Shoreline Substrate Information Sheet 17

SNOW-COVERED/ICE

DEFINITION AND CHARACTER

- Under winter conditions or in a cold climate, the shore (underlying substrate) may be covered by snow and/or ice – these conditions are typically temporary but may exist year-round in high latitudes.
- Snow and ice components are combined with the character of the underlying geological substrate of the shoreline to determine response options – oil behaviour and the selection of treatment strategies also consider whether the underlying sediments are frozen or not frozen.
- Shorefast ice (or an "ice foot") forms on most lake shores and river banks throughout Canada each winter.
- Frozen splash or spray can form a coat of ice on the surface of the substrate.
- Fresh water flowing down slope from the backshore can freeze and may mix with the ice foot or frozen splash and spray.
- Ice floes originating from the break of the lake or upstream sources can be stranded on a shoreline, bank or bar.
- Ice can form by the freezing of water in the interstitial spaces of sediments.
- The character of an ice surface can range from a thin sheet of frozen spray, to a solid ice foot, individual stranded floes, or a wet surface of melting ice.
- The form of shore-zone ice can range from a vertical face to a level or low-angle slope.
- Snow surface character is highly variable, ranging from fresh powder/drifting snow with a soft surface, loose granular, hard/dry/crusty, to wet slush.
- Snow is typically permeable, while ice is impermeable.

LAKE SHORELINE IN SPRING WITH PARTIAL SNOW-COVER/ ICE REMAINING

BOULDER SUBSTRATE WITH ICE

Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

Freshwater Substrate – Information Sheet 17

Snow-Covered/Ice

OIL BEHAVIOUR
– Since snow is permeable, stranded oil will be absorbed into the snow and be partially contained by the snow (natural sorbent) – the freeze-thaw process forms ice lenses within the snow that can limit penetration of oil into snow. – Oil-in-snow content is dependent on oil type and snow character and is lowest on firm compacted snow surfaces in below-freezing temperatures and highest for fresh snow conditions. – Light oils can migrate laterally hundreds of metres within snow so that detection can be challenging – detection dogs have been used successfully to locate subsurface oil in snow. – Oil causes snow to melt – for example, crude oils will melt snow but do not spread over a wide surface area. – The presence of ice in the shore zone helps prevent oil on surface water from contacting shore substrates. – Ice is impermeable, so stranded oil remains on the surface – oil will not adhere to the ice surface unless air, water and oil surface temperatures are below 0°C. – Ice in sediments (frozen interstitial or groundwater) can prevent the penetration of stranded oil. – Where there is broken ice present, without a landfast ice cover, oil may reach the shore and become stranded on the substrate in between the ice pieces. – Oil persistence on ice and snow is highly variable. – Oil may freeze onto the ice surfaces and remain stranded until the ice melts – once the ice and snow melt, the oil may then penetrate the underlying substrate and could persist for long periods of time, depending on the substrate and exposure.

OIL IN GROUNDED ICE FLOES

OIL PARTIALLY ENCAPSULATED IN ICE

SENSITIVITY
– The snow or ice layer itself is not considered to be a sensitive environment. – When selecting oil removal tactics, the nature and sensitivity of the underlying sediment or bedrock substrates must be considered.

SAFETY NOTES
– If operations are to be completed on ice, an Ice Safety Plan must be prepared and implemented.

Freshwater Substrate – Information Sheet 17

Snow-Covered/Ice

PREFERRED TREATMENT OPTIONS

Shoreline Treatment Tactic	Volatile	Light	Medium	Heavy	Solid
SURFACE					
Snow-Covered					
Natural recovery	●	●	○	–	–
Flooding	●	●	●	–	–
Low-pressure ambient wash	●	●	●	–	–
Manual removal	–	○	○	○	○
Vacuum	–	●	●	–	–
Mechanical removal	–	○	●	●	●
Passive sorbents	○	○	○	–	–
Dry mixing	–	–	–	–	–
Wet mixing	–	●	●	○	–
Sediment relocation	–	●	●	○	–
Burning	●	●	●	○	–
Ice					
Natural recovery	●	●	○	–	–
Flooding	●	●	○	–	–
Low-pressure ambient wash	●	●	●	○	–
Low-pressure warm/hot wash	–	–	●	●	–
High-pressure ambient wash	–	–	–	○	○
Manual removal	–	○	○	○	○
Vacuum	–	●	●	○	–
Mechanical removal*	–	●	●	●	●
Passive sorbents	○	○	○	–	–
Burning	●	●	●	○	–

● Preferred option ○ Possibly applicable for small amounts – Not Applicable

* Oil may be encapsulated on an ice surface by freezing wave spray (i.e. subsurface) – the oil/ice can be removed as blocks using chain saws or mechanical cutters.

Freshwater Substrate – Information Sheet 17

Snow-Covered/Ice

Shoreline Treatment Tactic	Volatile	Light	Medium	Heavy	Solid
SUB-SURFACE					
Snow-Covered					
Natural recovery	●	●	○	–	–
Flooding	●	●	–	–	–
Low-pressure ambient wash	●	●	–	–	–
Manual removal	–	○	○	○	○
Vacuum	–	○	○	–	–
Mechanical removal	–	○	●	●	●
Passive sorbents	○	○	○	–	–
Dry mixing	–	●	●	○	–
Wet mixing	–	●	●	–	–
Sediment relocation	–	●	●	○	–
Burning	–	–	–	–	–
Ice					
Natural recovery	–	–	–	–	–
Flooding	–	–	–	–	–
Low-pressure ambient wash	–	–	–	–	–
Low-pressure warm/hot wash	–	–	–	–	–
High-pressure ambient wash	–	–	–	–	–
Manual removal	–	–	–	–	–
Vacuum	–	○	○	–	–
Mechanical removal*	–	○	○	○	○
Passive sorbents	–	–	–	–	–
Burning	–	–	–	–	–

● Preferred option ○ Possibly applicable for small amounts – Not Applicable

* Oil may be encapsulated on an ice surface by freezing wave spray (i.e. subsurface) – the oil/ice can be removed as blocks using chain saws or mechanical cutters.

Freshwater Substrate – Information Sheet 17

Snow-Covered/Ice

RESPONSE CONSIDERATIONS
– Natural recovery may be preferred for volatile and light oils that will evaporate during thaw periods unless the oil spill is close to sensitive habitats or populated areas. – Natural recovery is less appropriate for medium-heavy or weathered crude oils and in slow moving rivers, backwaters and sheltered shores. – When there is no physical energy to remove the oil, natural recovery does not take place until spring melt and breakup. – If the adjacent watercourse is ice-free and air temperatures are above freezing, flooding or low pressure ambient-water washing may be practical to flush the oiled snow onto the water surface for containment and recovery. – Pooled oil on the snow or ice surface, oil that is contained by berms, or oiled snow and that is collected and piled in a suitable location can be removed by burning – this may be suitable in remote areas where minimizing waste is an important consideration.
BEST PRACTICES
– Implement best practices according to the underlying sediment or bedrock substrates.

6.4 Shoreline Treatment Tactics

This section of the field guide describes the different types of techniques used to treat oiled freshwater shorelines. Shoreline treatment operations are generally conducted to accelerate the removal of oil and the subsequent recovery of the oiled shoreline or to prevent stranded oil from remobilizing. Remobilized oil may oil or re-oil adjacent sections of shoreline.

As a first step, the key objective for shoreline treatment should be established by selecting one of the following options:

- Allow the oiled shore zone to recover naturally;
- Accelerate the natural recovery of the oiled shoreline; or
- Restore the oiled shore zone to its pre-spill condition.

The following universal best management practices apply to all response operations:

- Use available resources in a safe, efficient, and effective manner;
- Avoid causing more damage to the shoreline than the oil itself would;
- Minimize the generation and handling of waste materials.

Making decisions involves evaluating questions and considering them against the key objective:

- What is the type and amount of oil on a segment of shoreline?
- Is the oil on the surface or has it penetrated sediments?
- What is the likely residence time or persistence of the oil?
- What are the resources at risk during that residence period?
- What is the sensitivity and vulnerability of those resources?
- What are the logistics and access to the affected area or sites?
- What is the likely effectiveness of treatment to reduce environmental effects or risks?
- What are the safety considerations for working in the area?

Treating an oiled shoreline usually involves a phased approach with separate response objectives and shoreline treatment criteria for each phase. A typical sequence involves:

1. Initial removal of bulk oil, oil that can be removed easily and/or oil that would easily be remobilized;

2. Removal of the residual coat or stain if this residue poses an environmental threat or concern;

3. A completion phase in which sediment is replaced or staging areas, roads and other access points, fences, etc. are restored or repaired.

It is important to note that natural recovery is often the preferred response, particularly when:

- Oiling has occurred on high-energy shorelines where wave action will remove most of the oil in a relatively short time.
- The oil is volatile or non-persistent.
- The degree of oiling is low (e.g. very light, light or even moderate oiling as determined by the SCAT process).
- Shorelines are remote or inaccessible.
- Available treatment tactics may cause more damage than leaving the shore to recover naturally.
- Available treatment techniques either cannot accelerate natural recovery or are not practical, i.e. the oiling is As Low As Reasonably Practicable (ALARP).
- Treatment would be unsafe for response personnel.

The net environmental benefit of treatment versus natural recovery should consider on a case-by-case basis the following:

- The expected fate and persistence of the residual oil.
- The estimated rate of natural recovery.
- The possible benefits of treatment in terms of accelerating recovery.
- The risks associated with the presence of the oil as it weathers (e.g. toxicity and smothering effects).
- The possible delays to recovery that may be caused by response activities.

Natural recovery often has greater potential in the marine (tidal) environment as water levels can change substantially (i.e. up to several metres) over short time frames (i.e. hours to days). However, natural recovery is an option in freshwater locations of higher energy, where turbulent water flow and wind or current generated waves and swash accelerate oil removal by water-washing processes. Natural recovery is less appropriate for medium-heavy or weathered crude oils and in slow moving rivers, backwaters and sheltered shores where the oil is likely to persist due to low energy conditions or in slow small streams where the dispersion potential is low.

Shoreline treatment techniques appropriate for freshwater environments are shown in Table 6.6 and are detailed in the following **Shoreline Treatment Information Sheets (Section 6.4.1).** These tactics are grouped into five (5) categories that reflect the general treatment approach.

Table 6.6 Shoreline treatment tactics

Shoreline Treatment Techniques	Shoreline Treatment Information	
	Sheet #	Page #
Natural Recovery	**1**	**Page 196**
Natural recovery allows the oiled shoreline to recover without intervention – the stranded oil is left to natural weathering and oil removal processes.		
Physical Methods – Washing		
When using washing techniques, the water stream usually moves the oil to a location downslope (onto the adjacent water or a collection area) for containment, recovery, and collection for disposal. Washing techniques are distinguished from each other by the amount of pressure used and the temperature of the water. The trade-off between the effectiveness of oil removal and biological effects often must be assessed. Equipment used to carry out the different types of washing techniques is usually available commercially.		
Flooding	2	Page 198
Low-pressure: (1) ambient water wash; (2) warm/hot water wash	3	Page 201
High-pressure: (1) ambient water wash; (2) warm/hot water wash	4	Page 205
Physical Methods – Removal		
Involves physically removing oil or oiled materials, such as sediments, debris, and vegetation, from the shore zone for disposal. The size of the area, the type and amount of oil, the type of shoreline, and accessibility to the site are important factors to consider when selecting one of these tactics. Mechanical removal tactics primarily use equipment designed for earth-moving or construction projects.		
Manual removal	5	Page 209
Vacuum – onshore pooled oil	6	Page 212
Vacuum – nearshore submerged/sunken oil	7	Page 215
Mechanical removal	8	Page 217
Vegetation cutting	9	Page 220
Passive sorbents	10	Page 223

Shoreline Treatment Techniques	Shoreline Treatment Information	
	Sheet #	Page #
Physical Methods – In-situ Treatment		
These treatment tactics are conducted on site and in situ, which minimizes the generation or recovery of oiled materials requiring transfer and disposal. When evaluating the appropriateness of in-situ treatment, the consequences of not removing the oil must be considered. In particular, the anticipated change in oil weathering or natural removal rates that would be caused by the treatment should be evaluated.		
Dry mixing	11	Page 226
Wet mixing	12	Page 229
Sediment relocation	13	Page 232
Burning	14	Page 235
Chemical and Biological Treatment		
Chemical or biological agents are added to the stranded oil or oiled sediments to help remove oil from the shoreline or accelerate natural recovery. Because the addition of a substance to the shoreline could negatively affect the environment, the use of chemical and biological agents must comply with all relevant federal and provincial/territorial laws and regulations.		
Shoreline cleaners	15	Page 238
Bioremediation: nutrient addition; microbe seeding (inoculation); biostimulants (e.g. enzymes); phytoremediation	16	Page 241
Dispersants: Dispersants are chemical agents that enhance the formation of fine oil droplets, which are subsequently dispersed into the adjacent water to biodegrade. The dispersion of oil into freshwater is not recommended in most circumstances because there is insufficient water volume in rivers and often in lakes to allow dilution of dispersed oil to low concentrations. Furthermore, moving oil from the shoreline into the water column could negatively affect freshwater intakes (e.g. municipal drinking water intakes).		
Herders and Solidifiers: Herders are chemical agents that herd oil spilled on a water surface into thickened slicks to facilitate collection/recovery or in-situ burning. Solidifiers are chemical agents that congeal when added to oil to form a cohesive mass and thereby facilitate collection/recovery. These tactics are not applicable to shoreline response and are not discussed further in this guide.		

Each of the 16 shoreline treatment techniques are described using the following sections:

- Objective;
- Description;
- Safety Notes;
- Applications;
- Overview of Tactic Consideration(s) for Specific Conditions;
- Operational Limiting Factors and Potential Solutions.

The following **Shoreline Treatment Decision Guides** provide a quick reference for selecting shoreline treatment tactics based on substrate type and degree of oiling (Figures 6.4, 6.5 and 6.6). In all cases, safety must be assessed at each step within a **Shoreline Treatment Decision Guide** – safety is always the highest priority.

SHORELINE TREATMENT

INFORMATION SHEETS

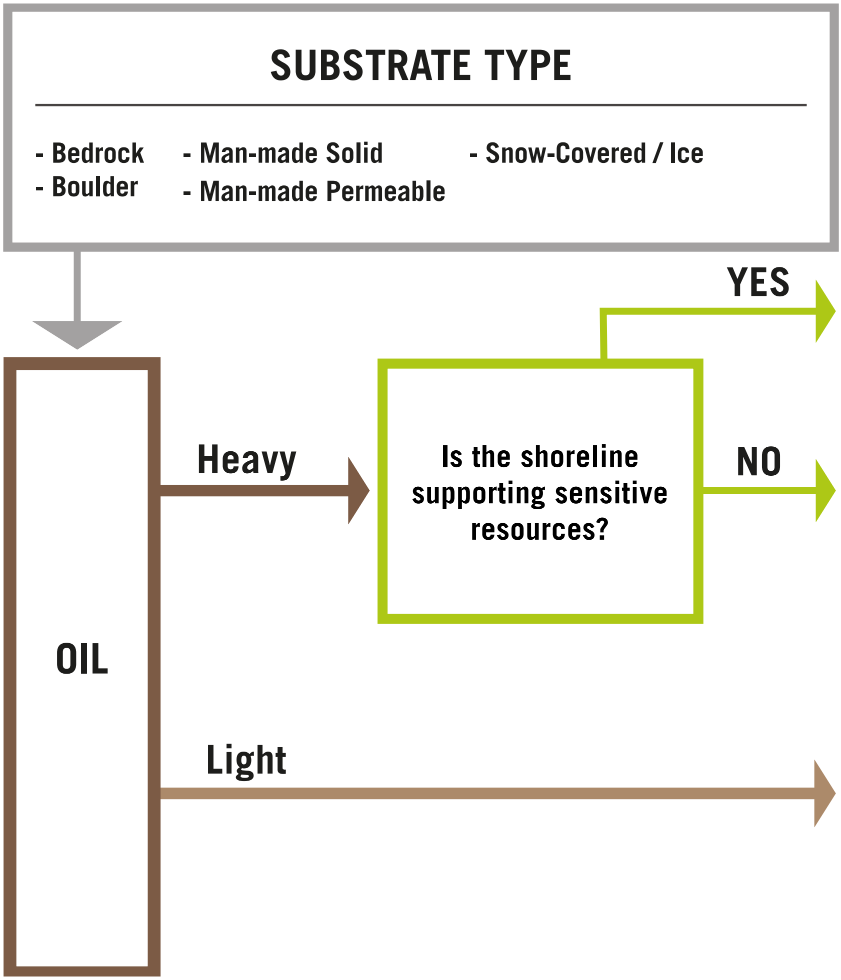


Figure 6.4 Shoreline Treatment Decision Guide: bedrock, boulder, man-made and snow-covered/ice substrate types

	Shoreline Treatment Techniques	Shoreline Treatment Information	
		Sheet #	Page #
YES	Low-pressure wash	3	Page 201
	Manual removal	5	Page 209
NO	Low-pressure wash	3	Page 201
	High-pressure wash	4	Page 205
	Manual removal	5	Page 209
	Passive sorbents	10	Page 223
YES	Natural Recovery	1	Page 196
	Flooding	2	Page 198
	Low-pressure wash	3	Page 201
	Manual removal	5	Page 209
	Passive sorbents	10	Page 223
	Shoreline cleaners	15	Page 238

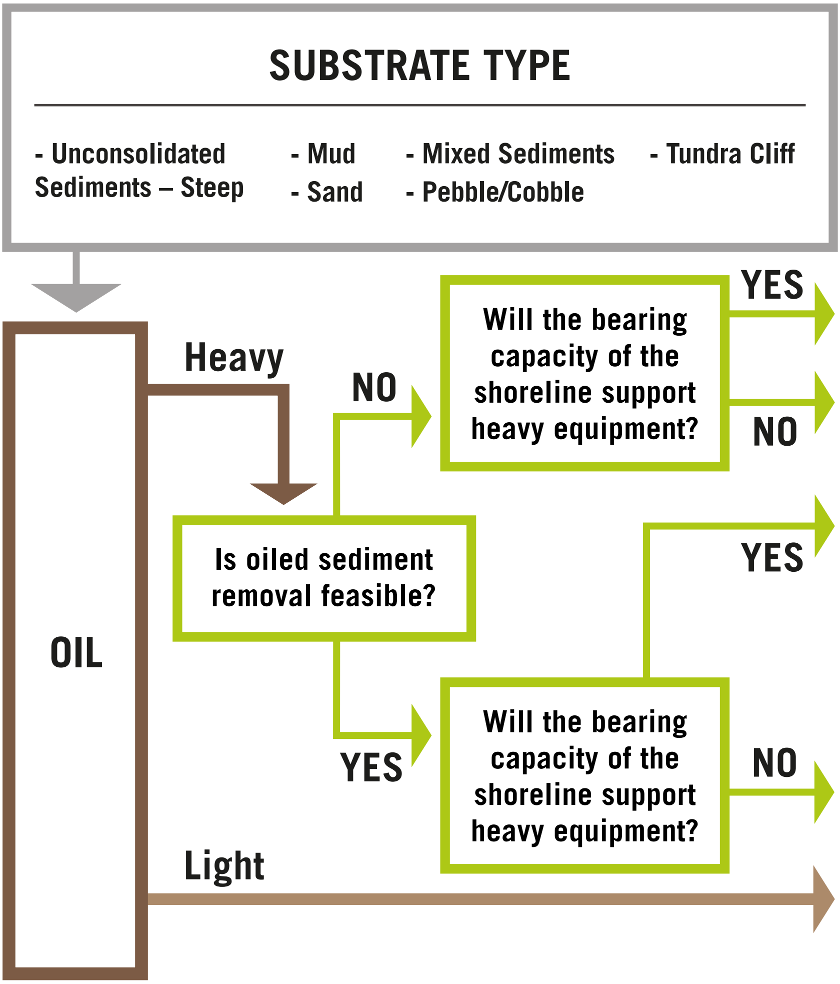


Figure 6.5 Shoreline Treatment Decision Guide: unconsolidated substrate types

	Shoreline Treatment Techniques	Shoreline Treatment Information	
		Sheet #	Page #
YES	Vacuum - onshore pooled oil	6	Page 212
	Mechanical removal	8	Page 217
NO	Manual removal	5	Page 209
YES	Dry mixing	11	Page 226
	Wet mixing	12	Page 229
	Sediment relocation	13	Page 232
YES	Natural Recovery	1	Page 196
	Flooding	2	Page 198
	Low-pressure wash	3	Page 201
	Manual removal	5	Page 209
	Passive sorbents	10	Page 223
	Bioremediation	16	Page 241

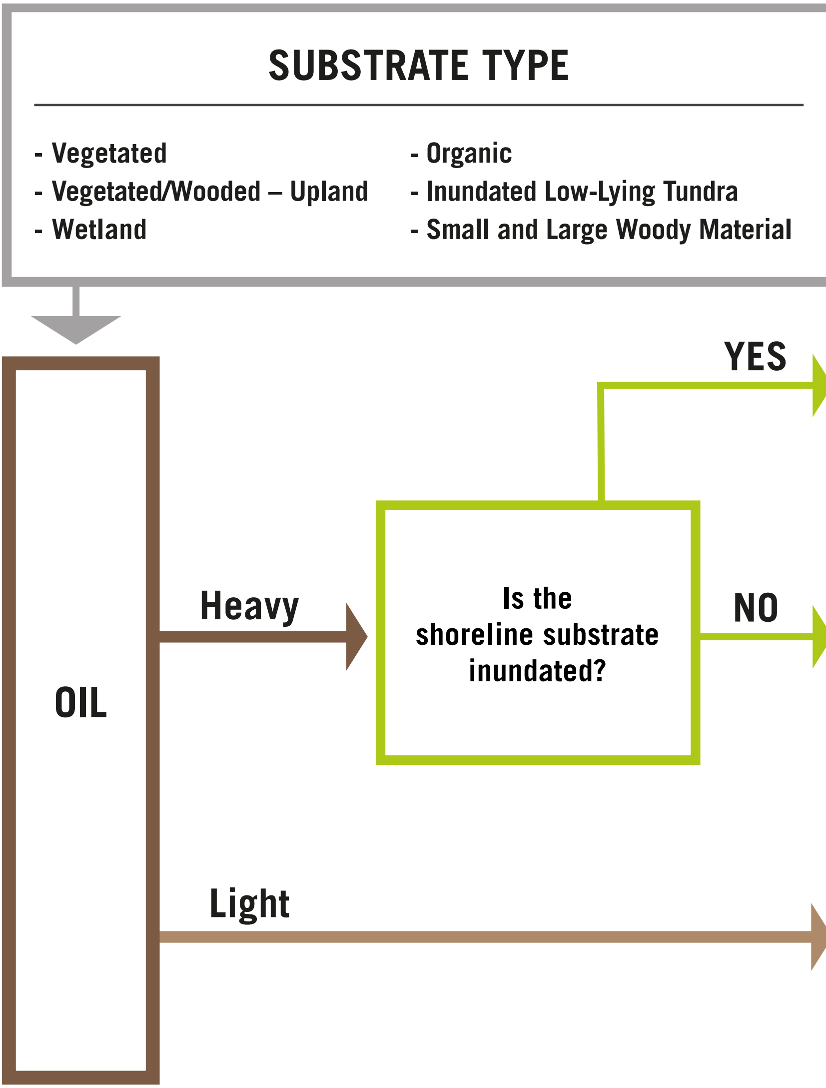


Figure 6.6 Shoreline Treatment Decision Guide: vegetated, organic and woody material substrate types

	Shoreline Treatment Techniques	Shoreline Treatment Information	
		Sheet #	Page #
YES	Vacuum – nearshore submerged/ sunken oil	7	Page 215
	Mechanical removal	8	Page 217
	Vegetation cutting	9	Page 220
NO	Flooding	2	Page 198
	Low-pressure wash	3	Page 201
	Manual removal	5	Page 209
	Mechanical removal	8	Page 217
	Burning	14	Page 235
YES	Natural Recovery	1	Page 196
	Flooding	2	Page 198
	Manual removal	5	Page 209
	Passive sorbents	10	Page 223
	Bioremediation	16	Page 241

The selection of shoreline treatment tactics can also be supported by a dedicated SCAT data management and decision support software that will identify the preferred shoreline treatment tactic(s) based on substrate type, and oiling type and condition.

All options except natural recovery require some form of intrusion on the ecological character of the shoreline that is being treated. The relative consequence of each option on the various types of shorelines is summarized in Table 6.5. Keep in mind that in practice, two or more shoreline treatment techniques are usually combined to achieve the operational objectives. Treatment techniques are recommended to be compatible with the character of the shore zone and with the oiling conditions (type and volume of oil) as documented by the SCAT process and considering a range of operational parameters (Table 6.7). The optimal treatment technique would:

- have a minimal effect;
- involve minimal labour and logistical requirements;
- provide rapid treatment rates;
- generate no/minimal oiled waste.

Most rivers and streams undergo relatively large seasonal variations in water level and flow, and these should be considered in the selection of shoreline treatment tactics and timing of application. For example, over the course of a season, the zone of oiling may be completely submerged or exposed.

Oil spill countermeasures decisions must align with current legislative and regulatory regimes and be subjected to a net environmental benefit assessment that confirms the benefits outweigh the effects of the response technique. At the time of writing, spill treating agents (STAs), such as shoreline cleaning agents, may only be used in Canada in the context of an oil spill from offshore oil exploration and production facilities and cannot be applied without authorisation from the appropriate regulator; there is one shoreline cleaning agent listed in Canada that may be considered for approval during a spill response – Corexit® EC9580A (shoreline cleaning agent).

Table 6.7 Operational parameters to consider when recommending treatment techniques

Treatment Techniques	Logistics Support and Labour Effort	Relative Operational Rate	Waste Volumes and Types
Natural Recovery	**VERY LOW** Monitoring teams	**Not Applicable**	**NONE**
Wash and Recover	**VERY HIGH** – Pumps, hoses, sorbents, boom, skimmers, storage – Labour intensive	**SLOW**	**HIGH** Liquids
Removal (Manual)	**VERY HIGH** – Shovels, rakes, sorbents, vacuums – Labour intensive	**SLOW**	**MODERATE** Solids or liquids
Removal (Vacuum)	**LOW** Vacuum trucks, portable vacuum units	**RAPID**	**HIGH** Liquids
Removal (Mechanical)	**LOW** Earth-moving or agricultural equipment	**RAPID**	**HIGH** Solids
In Situ	**VERY LOW** Mechanical support, earth-moving or agricultural equipment	**RAPID**	**VERY LOW** Some solid logistics wastes, possible burn residues
Shoreline Cleaner	**HIGH** – Pumps, hoses, sorbents, boom, skimmers, storage – Labour intensive	**SLOW**	**HIGH** Liquids
Bioremediation	**LOW** Possible mechanical support for mixing	**RAPID** (but very slow treatment rate)	**VERY LOW** Some solids logistics waste

6.4.1 Shoreline Treatment Information Sheets

Shoreline Treatment – Information Sheet 1

Natural Recovery

Shoreline Treatment Information Sheet 1

NATURAL RECOVERY

OBJECTIVE
– To allow the oiled shoreline to recover without intervention – the stranded oil is left to natural weathering and oil removal processes.
DESCRIPTION
– Information on the oiling conditions, the freshwater processes and physical character of the shoreline, and the resources at risk must be assessed in order to evaluate the probable consequences of allowing the oil to be naturally removed or to degrade naturally. – In many circumstances, the site should be monitored over a period to ensure that the assessment is correct or that the rate of weathering and natural oil removal is proceeding as anticipated. – Natural recovery is the preferred option if possible, particularly for small amounts of oil – this option is less appropriate for medium-heavy or weathered crude oils and in slow moving rivers, backwaters and sheltered shores. – Natural recovery may not be appropriate immediately before freeze-up as the oil would be encapsulated by ice and could remobilize during the next thaw.
SAFETY NOTES
– Care should be exercised as oiled surfaces may be very slippery leading to slips and falls.

Environment and Climate Change Canada
Environnement et Changement climatique Canada
Canada

Shoreline Treatment – Information Sheet 1

Natural Recovery

APPLICATIONS FOR SURFACE OILING					
Substrate Category	**Volatile**	**Light**	**Medium**	**Heavy**	**Solid**
Bedrock	●	●	○	○	○
Man-made Solid (Impermeable)	●	●	○	○	○
Man-made Permeable	*see natural substrate with equivalent characteristics*				
Unconsolidated Sediments – Steep	●	●	○	○	○
Mud Flat	●	●	○	○	–
Mud Bank/Bar	●	●	○	–	–
Sand Flat or Beach, Bank/Bar	●	●	○	–	–
Mixed Sediment Flat or Beach, Bank/Bar	●	●	○	–	–
Pebble/Cobble	●	●	○	–	–
Boulder	●	●	○	–	–
Vegetated	●	●	○	○	–
Wetland	●	●	○	○	–
Vegetated/Wooded – Upland	●	●	○	○	○
Small and Large Woody Material	●	●	○	○	○
Organic	●	●	○	–	–
Tundra Cliff	●	●	○	–	–
Inundated Low-Lying Tundra	●	●	○	–	–
Snow -Covered/Ice	●	●	○	–	–

● Preferred option ○ Possibly applicable for small amounts – Not Applicable

OVERVIEW OF TACTIC CONSIDERATION(S) FOR SPECIFIC CONDITIONS

Flowing Water:
– Monitoring of sites over the long-term may be more challenging due to logistics and access.

Winter:
– Appropriate for winter use.
– If operations are to be completed on ice, an Ice Safety Plan must be prepared and implemented.

Remote Areas:
– Useful for remote or inaccessible areas, or areas where it is unsafe for field workers to operate.

OPERATIONAL LIMITING FACTORS AND POTENTIAL SOLUTIONS

Limitation:	**Solution:**
Natural recovery may not be appropriate if the oil spill is threatening important ecological resources or human activities or resources	Resources at risk must be assessed in order to evaluate the probable consequences of allowing the oil to be naturally removed or to degrade naturally
The potential for stranded oil to be remobilized and oil or re-oil adjacent resources or previously unoiled sections of shore must be considered – this threat to adjacent resources or areas may rule out the option to rely on natural recovery	Explore all the alternatives and review trade-offs for treatment approach

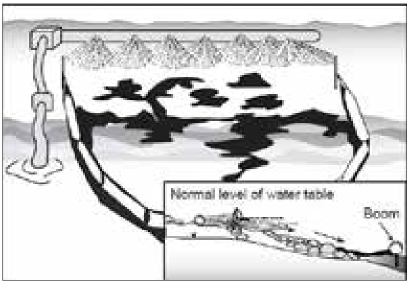
Shoreline Treatment Information Sheet 2
FLOODING

OBJECTIVE

– To flood a site with a large volume of ambient-temperature freshwater so that mobile or remobilized oil is lifted and carried downslope to a collection area.
– To flood a site with a large volume of ambient-temperature freshwater in advance of shoreline oiling to prevent oil from penetrating a porous shoreline (e.g. Pebble/Cobble Beach).

DESCRIPTION

– A large amount of freshwater is used to flood the surface area of impermeable bedrock or solid manmade shoreline or to raise the water table to the surface of the beach in the case of sediment shorelines.
– Mobile or non-sticky oil is transported with the water as it flows downslope due to gravity. The oil is contained with boom and removed from the surface with skimmers other means of collection.
– The high-volume (200 to 1000 L/minute), low-pressure (<20 psi or <1.5 bars) supply of freshwater at ambient temperatures is pumped using large diameter pipes (10 to 20 cm) and/or hoses onto the upper section of the oiled shoreline.
– Water is pumped onto the shoreline either directly from a hose without a nozzle or through a pipe or hose (“header”) that is perforated at intervals with 0.25 to 0.5 cm holes and placed along the upper shoreline parallel to the water line. A flexible hose is better for the latter application, as it conforms to the actual surface of the shoreline being flooded.



FLOODING OR ‘DELUGE’ WITH AMBIENT FRESHWATER MOVES OIL DOWNSLOPE TO A COLLECTION AREA

SAFETY NOTES

– Make sure all personnel are properly trained to use the equipment and are wearing the right PPE.
– Care should be exercised as oiled surfaces may be very slippery leading to slips and falls.

Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

Shoreline Treatment – Information Sheet 2

Flooding

APPLICATIONS FOR SURFACE OILING					
Substrate Category	**Volatile**	**Light**	**Medium**	**Heavy**	**Solid**
Bedrock	●	●	●	–	–
Man-made Solid (Impermeable)	–	–	–	–	–
Man-made Permeable	*see natural substrate with equivalent characteristics*				
Unconsolidated Sediments - Steep	–	–	–	–	–
Mud Flat or Bank/Bar	●	●	●	–	–
Sand Flat or Beach, Bank/Bar	●	●	●	–	–
Mixed Sediment Flat or Beach, Bank/Bar	●	●	●	–	–
Pebble/Cobble	●	●	●	–	–
Boulder	●	●	●	–	–
Vegetated	●	●	●	–	–
Wetland	●	●	●	–	–
Vegetated/Wooded - Upland	●	●	●	–	–
Small and Large Wood Material	●	●	●	–	–
Organic	●	●	●	–	–
Tundra Cliff	–	●	●	●	–
Inundated Low-Lying Tundra	–	●	●	–	–
Snow-Covered	●	●	●	–	–
Ice	●	●	○	–	–

● Preferred option ○ Possibly applicable for small amounts – Not Applicable

FLOODING SHORELINE WITH PERFORATED HEADER HOSE

OVERVIEW OF TACTIC CONSIDERATION(S) FOR SPECIFIC CONDITIONS

Flowing Water:
– Appropriate for containment/recovery areas with minimal to no flow.

Winter:
– Appropriate for winter use, if conditions allow.
– If operations are to be completed on ice, an Ice Safety Plan must be prepared and implemented.

Remote Areas:
– Consider logistics and waste management/disposal requirements – may be less appropriate as technique requires very high logistics support and labour.

Shoreline Treatment – Information Sheet 2

Flooding

OPERATIONAL LIMITING FACTORS AND POTENTIAL SOLUTIONS	
Limitation: Avoid washing oil and/or sediments downslope into areas with attached plant or animal communities, particularly if these areas were not initially oiled	**Solution:** Wash oil into areas with minimal or no vegetation so effects on the biological communities will be lower
The mobilized or flushed oil and oiled sediment should be contained and collected for disposal	Ensure shoreline treatment plan includes effective site-specific containment and recovery approach

Shoreline Treatment Information Sheet 3

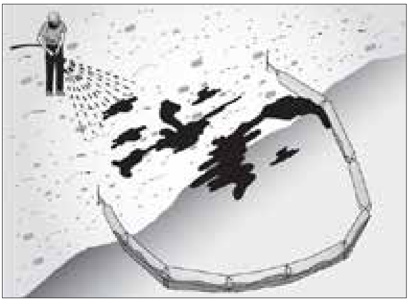
LOW-PRESSURE WASH

OBJECTIVE

– To wash and flush oils at low-pressure, using freshwater at either ambient or warm/hot temperatures, towards a collection area.

DESCRIPTION

– With hand-operated or remote-controlled hoses, freshwater is used to wash, flush, and herd oil to a collection point for recovery and removal.
– Output pressures from the hose are usually controlled by a nozzle and are low (<3 bars or 50 psi) – water is either ambient temperature or heated between 30°C (warm) and 100°C (hot).
– Oil that is flushed or dislodged by the low-pressure hoses is readily carried downslope by the high-volume flow of water.
– Mobile or dislodged oil is transported with the water as it flows downslope, which prevents the oil from being redeposited elsewhere – may be combined with flooding.
– Warm water dislodges and flushes oil that cannot be removed using low-pressure, ambient temperature water.
– Booms or other containment tactics collect the oil for removal.



LOW-PRESSURE AMBIENT WASHING FLUSHES OIL DOWNSLOPE TO A COLLECTION AREA

SAFETY NOTES

– Tactic is labour-intensive and equipment must be moved frequently.
– Make sure all personnel are properly trained to use the equipment and are wearing the right PPE.
– Care should be exercised as oiled surfaces may be very slippery leading to slips and falls.

Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

Low-pressure wash

APPLICATIONS FOR SURFACE OILING					
Low-Pressure	Ambient Water Wash				
Substrate Category	Volatile	Light	Medium	Heavy	Solid
Bedrock	●	●	●	○	–
Man-made Solid (Impermeable)	●	●	●	○	○
Man-made Permeable	*see natural substrate with equivalent characteristics*				
Unconsolidated Sediments - Steep	●	●	●	●	●
Mud Flat	●	●	●	–	–
Mud Flat or Bank/Bar	○	–	–	–	–
Sand Flat	●	●	●	–	–
Sand Beach, Bank/Bar	○	–	–	–	–
Mixed Sediment Flat or Beach, Bank/Bar	○	●	●	–	–
Pebble/Cobble	○	●	●	–	–
Boulder	○	●	●	–	–
Vegetated	●	●	●	–	–
Wetland	●	●	●	–	–
Vegetated/Wooded - Upland	●	●	●	○	–
Small and Large Wood Material	●	●	●	○	–
Organic	●	●	●	–	–
Tundra Cliff	●	●	●	–	–
Inundated Low-Lying Tundra	●	●	●	●	–
Snow-Covered	●	●	●	–	–
Ice	●	●	○	○	–

● Preferred option ○ Possibly applicable for small amounts – Not Applicable

Shoreline Treatment – Information Sheet 3

Low-pressure wash

Low-Pressure	Warm/Hot Water Wash				
Substrate Category	Volatile	Light	Medium	Heavy	Solid
Bedrock	–	–	●	●	●
Man-made Solid (Impermeable)	●	●	●	●	●
Man-made Permeable	*see natural substrate with equivalent characteristics*				
Unconsolidated Sediments - Steep	–	–	–	–	–
Mud Flat	–	–	–	–	–
Mud Flat or Bank/Bar	–	–	–	–	–
Sand Flat	–	–	–	–	–
Sand Beach, Bank/Bar	–	–	–	–	–
Mixed Sediment Flat or Beach, Bank/Bar	–	–	–	–	–
Pebble/Cobble	–	–	–	–	–
Boulder	–	–	–	–	–
Vegetated	–	–	–	–	–
Wetland	–	–	–	–	–
Vegetated/Wooded - Upland	–	–	–	–	–
Small and Large Wood Material	–	–	●	●	●
Organic	–	–	–	–	–
Tundra Cliff	–	–	–	–	–
Inundated Low-Lying Tundra	–	–	–	–	–
Snow-Covered	–	–	–	–	–
Ice	–	–	●	●	–

● Preferred option ○ Possibly applicable for small amounts – Not Applicable

Shoreline Treatment – Information Sheet 3

Low-pressure wash

HERDING OIL USING AMBIENT WATER

FLUSHING RIVER BANK USING AMBIENT WATER

OVERVIEW OF TACTIC CONSIDERATION(S) FOR SPECIFIC CONDITIONS

Flowing Water:
– Appropriate for containment/recovery areas with minimal to no flow.

Winter:
– Appropriate for winter use, if ice conditions allow.
– If operations are to be completed on ice, an Ice Safety Plan must be prepared and implemented.

Remote Areas:
– Consider logistics and waste management/disposal requirements – may be less appropriate as technique requires very high logistics support and labour and generates high waste volumes (liquids).

OPERATIONAL LIMITING FACTORS AND POTENTIAL SOLUTIONS

Limitation:	Solution:
Avoid washing oil and/or sediments downslope into areas with attached plant or animal communities, particularly if these areas were not initially oiled	Wash oil into areas with minimal or no vegetation so effects on the biological communities will be lower
The mobilized or flushed oil and oiled sediment should be contained and collected for disposal	Ensure shoreline treatment plan includes effective site-specific containment and recovery approach

Shoreline Treatment Information Sheet 4

HIGH-PRESSURE WASH

OBJECTIVE
– To wash and flush oils at high-pressure, using freshwater at either ambient or warm/hot temperatures, towards a collection area. – Typically used to remove oil that has adhered to hard substrates or man-made structures.
DESCRIPTION
– With hand-operated or remote-controlled hoses with jets, freshwater is used to wash, flush, and herd oil to a collection point for recovery and removal. – The higher water pressure provides the increased physical force required to dislodge and flush oil that cannot be removed using lower pressure. – Output pressures from the hose are usually controlled by a nozzle and exceed 4 bars or 60 psi. – If pressures higher than 70 bars (1000 psi) are used, this technique is commonly referred to as pressure washing – commercial units are available that produce up to 275 bars (approximately 4000 psi) of pressure. – Water is either ambient temperature or heated between 30° (warm) and 100°C (hot). – Oil that is flushed or dislodged by the high-pressure hoses is readily carried downslope by the high-volume flow of water. – Mobile or dislodged oil is transported with the water as it flows downslope, which prevents the oil from being redeposited elsewhere – may be combined with flooding. – Warm water dislodges and washes tenacious oil that cannot be dislodged by ambient temperature water. – Booms or other containment tactics collect the oil for removal.
SAFETY NOTES
– Tactic is labour-intensive and equipment must be moved frequently. – Make sure all personnel are properly trained to use the equipment and are wearing the right PPE. – Care should be exercised as oiled surfaces may be very slippery leading to slips and falls.

Environment and Climate Change Canada
Environnement et Changement climatique Canada

Canada

Shoreline Treatment – Information Sheet 4

High-pressure wash

APPLICATIONS FOR SURFACE OILING					
High-Pressure	**Ambient Water Wash**				
Substrate Category	**Volatile**	**Light**	**Medium**	**Heavy**	**Solid**
Bedrock	–	–	●	●	●
Man-made Solid (Impermeable)	–	–	●	●	●
Man-made Permeable	*see natural substrate with equivalent characteristics*				
Unconsolidated Sediments - Steep	–	–	–	–	–
Mud Flat	–	–	–	–	–
Mud Bank/Bar	–	–	–	–	–
Sand Flat or Beach, Bank/Bar	–	–	–	–	–
Mixed Sediment Flat or Beach, Bank/Bar	–	–	–	–	–
Pebble/Cobble	–	–	–	–	–
Boulder	–	–	–	–	–
Vegetated	–	–	–	–	–
Wetland	–	–	–	–	–
Vegetated/Wooded - Upland	–	–	–	–	–
Small and Large Wood Material	–	–	○	○	○
Organic	–	–	–	–	–
Tundra Cliff	–	–	–	–	–
Inundated Low-Lying Tundra	–	–	–	–	–
Snow-Covered	–	–	–	–	–
Ice	–	–	–	○	○

● Preferred option ○ Possibly applicable for small amounts – Not Applicable

Shoreline Treatment –Information Sheet 4

High-pressure wash

High-Pressure	Warm/Hot Water Wash				
Substrate Category	Volatile	Light	Medium	Heavy	Solid
Bedrock	–	–	●	●	●
Man-made Solid (Impermeable)	–	–	●	●	●
Man-made Permeable	*see natural substrate with equivalent characteristics*				
Unconsolidated Sediments - Steep	–	–	–	–	–
Mud Flat	–	–	–	–	–
Mud Flat or Bank/Bar	–	–	–	–	–
Sand Flat or Beach, Bank/Bar	–	–	–	–	–
Mixed Sediment Flat or Beach, Bank/Bar	–	–	–	–	–
Pebble/Cobble	–	–	–	–	–
Boulder	–	–	–	–	–
Vegetated	–	–	–	–	–
Wetland	–	–	–	–	–
Vegetated/Wooded - Upland	–	–	–	–	–
Small and Large Wood Material	–	–	–	–	–
Organic	–	–	–	–	–
Tundra Cliff	–	–	–	–	–
Inundated Low-Lying Tundra	–	–	–	–	–
Snow-Covered	–	–	–	–	–
Ice	–	–	–	–	–

● Preferred option ○ Possibly applicable for small amounts – Not Applicable

HIGH-PRESSURE WASHING

OVERVIEW OF TACTIC CONSIDERATION(S) FOR SPECIFIC CONDITIONS

Flowing Water:
– Appropriate for containment/recovery areas with minimal to no flow.

Winter:
– Appropriate for winter use, if ice conditions allow.
– If operations are to be completed on ice, an Ice Safety Plan must be prepared and implemented.

Remote Areas:
– Consider logistics and waste management/disposal requirements – may be less appropriate as technique requires very high logistics support and labour and generates high waste volumes (liquids).

Shoreline Treatment – Information Sheet 4

High-pressure wash

OPERATIONAL LIMITING FACTORS AND POTENTIAL SOLUTIONS	
Limitation: High-pressure water can dislodge, or damage attached healthy organisms	**Solution:** Avoid using on areas with attached healthy plants and animals
Avoid washing oil and/or sediments downslope into areas with attached plant or animal communities, particularly if these areas were not initially oiled	Wash oil into areas with minimal or no vegetation so effects on the biological communities will be less
High-pressure action could emulsify the oil if this has not occurred already	The trade-off between the effectiveness of oil removal and other effects must be considered
The mobilized or flushed oil and oiled sediment should be contained and collected for disposal	Ensure shoreline treatment plan includes effective site-specific containment and recovery approach

Shoreline Treatment Information Sheet 5

MANUAL REMOVAL

OBJECTIVE

– To remove oil or oiled materials, including oiled sediments, using manual labour and hand tools (e.g. rakes, shovels, sieves).

DESCRIPTION

– Shoreline teams pick up oil, oiled sediments, or oily material with rakes, forks, trowels, shovels, sorbent materials, or buckets.
– This may include scraping or wiping with sorbent materials or sieving if the oil has come ashore as tar balls.
– Collected material is placed directly in plastic bags, drums, or other containers for transfer – if the containers are to be carried to a temporary storage area, they should not weigh more than what one person can easily and safely carry.
– To avoid spilling, containers should not be overfilled or dragged along the ground – collected material can be placed directly into the bucket of a front-end loader.
– This technique can be used practically and effectively in any location, for small amounts of oil on most types of shoreline.

OILED SEDIMENTS ARE SHOVELED INTO BAGS OR DIRECTLY INTO A FRONT-END LOADER

SAFETY NOTES

– Tactic is labour-intensive and personnel may be exposed to a variety of weather conditions, such as heat, cold, and rain, and must have the appropriate PPE.
– Personnel safety must also be considered in areas with rapidly changing water levels and when volatile oils are present.
– Care should be exercised as oiled or wet bedrock and pebbles/cobbles can be very slippery leading to slips and falls.

Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

APPLICATIONS FOR SURFACE OILING					
Substrate Category	**Volatile**	**Light**	**Medium**	**Heavy**	**Solid**
Bedrock	–	○	○	○	○
Man-made Solid (Impermeable)	–	○	○	○	○
Man-made Permeable	*see natural substrate with equivalent characteristics*				
Unconsolidated Sediments - Steep	–	○	○	○	○
Mud Flat	–	○	○	○	○
Mud Bank/Bar	–	○	○	○	○
Sand Flat or Beach, Bank/Bar	–	○	○	○	○
Mixed Sediment Flat or Beach, Bank/Bar	–	○	○	○	○
Pebble/Cobble	–	○	○	○	○
Boulder	–	○	○	○	○
Vegetated	–	○	○	○	○
Wetland	–	○	○	○	○
Vegetated/Wooded - Upland	–	○	○	○	○
Small and Large Wood Material	–	○	○	○	○
Organic	–	○	○	○	○
Tundra Cliff	–	○	○	○	○
Inundated Low-Lying Tundra	–	○	○	○	○
Snow-Covered/Ice	–	○	○	○	○

● Preferred option ○ Possibly applicable for small amounts – Not Applicable

MANUAL REMOVAL OF OIL INTO BAGS FOR COLLECTION

MANUAL REMOVAL OF SUNKEN TARBALLS IN SHALLOW, NEARSHORE ENVIRONMENT

Shoreline Treatment – Information Sheet 5

Manual removal

OVERVIEW OF TACTIC CONSIDERATION(S) FOR SPECIFIC CONDITIONS
Flowing Water: – Appropriate for use on applicable substrates. **Winter:** – Appropriate for winter use, but efficiency may be less due to unfavourable weather conditions. – If operations are to be completed on ice, an Ice Safety Plan must be prepared and implemented. **Remote Areas:** – Consider logistics and waste management/disposal requirements – may be less appropriate as technique requires very high logistics support and labour and generates moderate waste volumes (solids or liquids).

OPERATIONAL LIMITING FACTORS AND POTENTIAL SOLUTIONS	
Limitation:	**Solution:**
When large numbers of personnel are required to meet the treatment criteria, excessive foot traffic can damage vegetated areas or disturb adjacent resources such as nesting birds	Regulate foot traffic via access corridors and optimize treatment approach to help limit the amount of back and forth to a site
Walking in the oiled zone will carry oil into areas that have already been treated and trample oil into subsurface sediments	Regulate foot traffic via access corridors and decontaminate equipment and PPE as needed
Labour intensive	Ensure adequate resources available (workers, equipment)

Shoreline Treatment Information Sheet 6

VACUUM – ONSHORE POOLED OIL

OBJECTIVE

– To remove oil by suction using vacuums from areas where it has pooled or collected in sumps or depressions.

DESCRIPTION

– Commercially available vacuum equipment is used, which includes small hand-carried or larger truck-mounted vacuum systems – the suction end of these units is usually deployed manually to collect oil and/or oily water.
– These units are not the same as mobile vacuum systems that have a fixed slot or similar suction system mounted below a mobile platform (usually a tank truck) and are not labour intensive.
– Several types of commercially available vacuum units have been designed specifically for shoreline treatment – these involve a pump and small, detachable storage drums (0.2 m^3/45 gallons); some feature a dual-head system with water jets to mobilize oil mounted next to a suction head that lifts and recovers the oil/water mixture.
– Vacuums are primarily used when oil is pooled in natural depressions and hollows or has been herded into collection areas, such as lined pits or trenches (Shoreline Protection Information Sheet 6).
– This technique can be combined with flooding or deluge techniques to float and collect oil (Shoreline Treatment Information Sheet 2).
– The dual head wash vacuum system is used in places that are hard to access, such as between boulders.
– Varying quantities of waste are generated depending on the system used and the location.

SAFETY NOTES

– Tactic is labour-intensive, and equipment must be moved frequently, and the suction arm must be handled or operated manually.
– It is not safe to use vacuums with volatile oils or oils that cannot be pumped.
– Care should be exercised as oiled or wet bedrock and pebbles/cobbles can be very slippery leading to slips and falls.
– Bearing capacity of shoreline or bridge is adequate

Environment and Climate Change Canada
Environnement et Changement climatique Canada
Canada

Shoreline Treatment – Information Sheet 6

Vacuum – onshore pooled oil

APPLICATIONS FOR SURFACE OILING					
Substrate Category	**Volatile**	**Light**	**Medium**	**Heavy**	**Solid**
Bedrock	–	●	●	○	–
Man-made Solid (Impermeable)	–	–	–	○	–
Man-made Permeable	*see natural substrate with equivalent characteristics*				
Unconsolidated Sediments - Steep	–	–	–	–	–
Mud Flat or Bank/Bar	–	●	●	–	–
Sand Flat	–	●	●	○	–
Sand Beach, Bank/Bar	–	●	●	–	–
Mixed Sediment Flat	–	●	●	○	–
Mixed Sediment Beach, Bank/Bar	–	–	●	●	–
Pebble/Cobble	–	●	●	●	–
Boulder	–	●	●	●	–
Vegetated	–	●	●	●	–
Wetland	–	○	○	–	–
Vegetated/Wooded - Upland	–	●	●	–	–
Small and Large Wood Material	–	–	–	–	–
Organic	–	●	●	–	–
Tundra Cliff	–	–	–	–	–
Inundated Low-Lying Tundra		●	●	●	
Snow-Covered		●	●	–	
Ice	–	●	●	○	–

● Preferred option ○ Possibly applicable for small amounts – Not Applicable


OIL REMOVAL USING VACUUM SYSTEM


VACUUM HOSE NOZZLE

Shoreline Treatment – Information Sheet 6

Vacuum – onshore pooled oil

OVERVIEW OF TACTIC CONSIDERATION(S) FOR SPECIFIC CONDITIONS	
Flowing Water: – Appropriate for areas with minimal or no flow (i.e. natural collection areas). **Winter:** – Appropriate for winter use, if conditions allow. – If operations are to be completed on ice, an Ice Safety Plan must be prepared and implemented. **Remote Areas:** – Portable vacuum units may be appropriate for remote areas or areas with difficult access for heavy equipment. – Consider logistics and waste management/disposal requirements – may be less appropriate as technique may generate high waste volumes (liquids).	
OPERATIONAL LIMITING FACTORS AND POTENTIAL SOLUTIONS	
Limitation: Generation of large volumes of liquid wastes	**Solution:** Use better nozzles and appropriate skimmers, and field guides to reduce co-collected water (encourage collection of oil vs large volumes of 'oily' liquids)
Requires vehicle access to containment/recovery area	Improvements to access points with fill (gravel) and rig mats
Labour intensive	Ensure adequate resources available (workers, equipment)

Shoreline Treatment Information Sheet 7

VACUUM – NEARSHORE SUBMERGED/SUNKEN OIL

OBJECTIVE

– To remove oil by suction using vacuums from areas with shallow water (less than 2 m deep) immediately adjacent to the shoreline.

DESCRIPTION

– Commercially available vacuum equipment is manually deployed from the shore or mounted on a floating platform.
– For large amounts of mobile oil, a decanting process is required to separate oil and water.
– For sunken solid particles, such as tar balls, the oil can be collected in a filter or mesh.
– Large concentrate fields/areas of tar balls or tar patties should be contained where required by first installing silt fencing.
– Varying quantities of waste are generated depending on the system used and the location.

1. Floating mesh “trap”
2. Vaccuum manifold and 3 inch (8 cm) trash pump
3. Long handled dip net to collect tar balls / patties
4. 3-4 inch (8-10 cm) rigid hose
5. Pole powered 4-5 m boat

POTENTIAL SET-UP FOR SHALLOW, NEARSHORE SUNKEN OIL RECOVERY USING A VACUUM SYSTEM

SAFETY NOTES

– Tactic is labour-intensive, and equipment must be moved frequently, and the suction arm must be handled or operated manually.
– It is not safe to use vacuums with oils that cannot be pumped.
– Care should be exercised as oiled or wet bedrock and pebbles/cobbles can be very slippery leading to trips, slips, and falls.

Environment and Climate Change Canada | Environnement et Changement climatique Canada

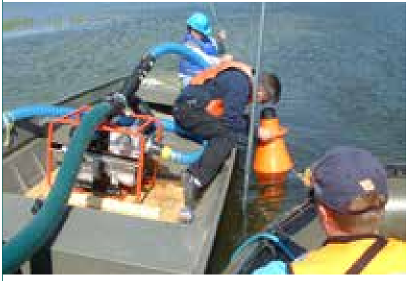
Canada

Shoreline Treatment – Information Sheet 7

Vacuum – nearshore submerged/sunken oil

APPLICATIONS FOR SURFACE OILING

– Vacuums are one of the few practical options, along with manual recovery, for removing nearshore sunken oil in shallow waters less than 2 m deep.



USING A VIEWING TUBE TO DIRECT VACUUMING OF SUNKEN OIL IN NEARSHORE, SHALLOW WATER

MESH USED TO COLLECT RECOVERED TAR BALLS

OVERVIEW OF TACTIC CONSIDERATION(S) FOR SPECIFIC CONDITIONS

Flowing Water:
– Appropriate for areas with minimal to no flow (i.e. natural collection areas).

Winter:
– Appropriate for winter use, if conditions allow.

Remote Areas:
– Portable vacuum units may be appropriate for remote areas or areas with difficult access for heavy equipment.
– Consider logistics and waste management/disposal requirements – may be less appropriate as technique may generate high waste volumes (organic detritus).

OPERATIONAL LIMITING FACTORS AND POTENTIAL SOLUTIONS

Limitation:	Solution:
Generation of large volumes of organic detritus (e.g. decaying vegetation)	Use appropriate filters and field guides to reduce co-collected organic detritus (encourage collection of oil vs large volumes of decaying vegetation)
Requires vehicle access to containment/recovery area	Improvements to access points with fill (gravel) and rig mats
Labour intensive	Ensure adequate resources available (workers, equipment)
Poor visibility due primarily to suspended sediments may limit efficiency and effectiveness in locating and removing sunken oil	Delineation/segregation of areas with silt fence to reduce water movement may reduce turbidity and improve efficiency and effectiveness of treatment approach

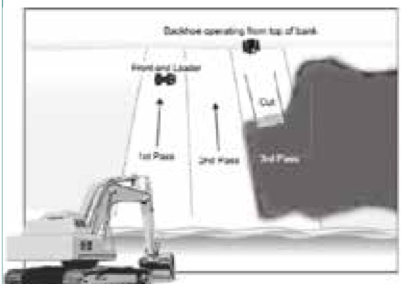
Shoreline Treatment Information Sheet 8
MECHANICAL REMOVAL

OBJECTIVE

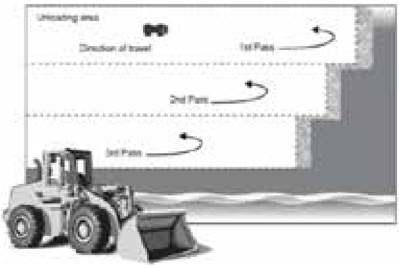
– To remove oil and oiled materials using mechanical equipment.

DESCRIPTION

– Oil and oiled surface and subsurface materials are removed from shorelines using a range of mechanical devices – mechanical removal is faster than manual removal but generates more waste.
– The method of operation varies considerably depending on the type of equipment available and its ability to operate on a section of shoreline.
– Elevating scrapers, front-end loaders, backhoes, or vacuum trucks can remove and transfer material directly to a truck or temporary storage area in a single step – other equipment, such as graders, sidecast material that must then be picked up by scrapers, loaders, or backhoes for transfer.
– Several mobile beach cleaners have been developed specifically for oil spill shoreline treatment.
– Off-site beach-cleaning machines that treat or wash oiled materials are included with this technique – these involve a waste management program of transfer and temporary storage and treatment, even if sediments are replaced on the shore.
– The suitability of different types of machines for treating oil on shorelines is determined by the weight-bearing capacity of the sediments and the slope of the shore zone, as well as the performance characteristics of the individual equipment.
– Mechanical removal options are different from mechanical in-situ treatment options that do not generate waste materials.



DIRECT MECHANICAL REMOVAL USING A BACKHOE



DIRECT MECHANICAL REMOVAL USING A FRONT-END LOADER

Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

Shoreline Treatment – Information Sheet 8

Mechanical removal

SAFETY NOTES
– During operation of heavy equipment, a spotter should be present to ensure safe operations. – Traction of heavy equipment is typically reduced as sediment size increases.

APPLICATIONS FOR SURFACE OILING

Substrate Category	Volatile	Light	Medium	Heavy	Solid
Bedrock	–	○	–	–	–
Man-made Solid (Impermeable)	–	–	–	–	–
Man-made Permeable	*see natural substrate with equivalent characteristics*				
Unconsolidated Sediments - Steep	–	○	○	○	○
Mud Flat	–	–	–	–	–
Mud Bank/Bar	–	●	●	●	●
Sand Flat	–	–	●	●	●
Sand Beach, Bank/Bar	–	●	●	●	●
Mixed Sediment Flat or Beach, Bank Bar	–	●	●	●	●
Pebble/Cobble	–	○	○	○	○
Boulder	–	○	○	○	○
Vegetated	–	–	–	–	–
Wetland	–	–	–	–	–
Vegetated/Wooded - Upland	–	–	–	–	–
Small and Large Wood Material	–	○	○	○	○
Organic	–	–	–	–	–
Tundra Cliff	–	●	●	●	●
Inundated Low-Lying Tundra	–	–	–	–	–
Snow-Covered	–	○	●	●	●
Ice	–	●	●	●	●

● Preferred option ○ Possibly applicable for small amounts – Not Applicable

BACKHOE REMOVING UNOILED OVERBURDEN TO REVEAL SUBSURFACE OILING

SKID STEER REMOVING OILED SEDIMENTS

Shoreline Treatment – Information Sheet 8

Mechanical removal

OVERVIEW OF TACTIC CONSIDERATION(S) FOR SPECIFIC CONDITIONS
Flowing Water: – Appropriate for use on applicable substrates. **Winter:** – Appropriate for winter use, but efficiency may be less due to unfavourable weather conditions. – If operations are to be completed on ice, an Ice Safety Plan must be prepared and implemented. **Remote Areas:** – Consider logistics and waste management/disposal requirements – may be less appropriate as technique requires access for earth-moving equipment and generates high waste volumes (solids).

OPERATIONAL LIMITING FACTORS AND POTENTIAL SOLUTIONS	
Limitation: If used on mud flats, wetlands, or tundra surfaces, mechanical techniques can cause significant adverse effects, either by mixing oil with the unoiled surface or subsurface sediments or by damaging plant stems and root systems	**Solution:** Limit the use of heavy equipment on these types of substrate
Avoid repeated handling or transfer of oiled sediments as much as possible as this increases the potential for spillage and decreases efficiency	Optimize shoreline treatment approach to help minimize the handling and transfer of oiled sediments

Shoreline Treatment Information Sheet 9

VEGETATION CUTTING

OBJECTIVE

– To remove parts of oiled plants in order to prevent the oil from remobilizing or to protect animals and birds from contact with the oil.

DESCRIPTION

– Vegetation cutting is usually a manual operation whereby scythes, knives, powered weed cutters, and/or rakes are used to cut and collect the oiled vegetation.
– Mechanical cutters can also be used, depending on the conditions at the site (i.e. weight-bearing capacity, access to the site, and the types of plants).
– Floating weed cutters can be used to work close to the shoreline if the water is not too deep.
– Vegetation cutting is primarily used to remove small amounts of oiled vegetation from bedrock shorelines, wetlands, vegetated/wooded uplands, and inundated low-lying tundra – it is suitable for use on a variety of different plants.
– Oil readily adheres to and is retained on the stems and leaves of dry vegetation – if there is extensive oiled vegetation, significant amounts of oil can be recovered by cutting and removing this vegetation.

SAFETY NOTES

– Make sure all personnel are properly trained to use the equipment and are wearing the proper PPE.
– Care should be exercised as oiled surfaces may be very slippery leading to slips and falls.
– Some vegetation can cause skin irritation (e.g. Poison Ivy).

Environment and Climate Change Canada
Environnement et Changement climatique Canada
Canada

APPLICATIONS FOR SURFACE OILING

Substrate Category	Volatile	Light	Medium	Heavy	Solid
Bedrock	–	○	○	○	○
Man-made Solid (Impermeable)	–	–	–	–	–
Man-made Permeable	*see natural substrate with equivalent characteristics*				
Unconsolidated Sediments - Steep	–	–	–	–	–
Mud Flat or Bank/Bar	–	–	–	–	–
Sand Flat or Beach, Bank/Bar	–	–	–	–	–
Mixed Sediment Flat or Beach, Bank/Bar	–	–	–	–	–
Pebble/Cobble	–	–	–	–	–
Boulder	–	–	–	–	–
Vegetated	–	○	○	○	○
Wetland	–	○	○	○	○
Vegetated/Wooded - Upland	–	–	○	○	○
Small and Large Wood Material	–	–	–	–	–
Organic	–	–	–	–	–
Tundra Cliff	–	–	–	–	–
Inundated Low-Lying Tundra	–	○	○	○	○
Snow-Covered/Ice	–	–	–	–	–

● Preferred option ○ Possibly applicable for small amounts – Not Applicable

MANUAL CUTTING OF VEGETATION

ON-WATER VEGETATION CUTTING AND REMOVAL USING A 'REED HARVESTER'

OVERVIEW OF TACTIC CONSIDERATION(S) FOR SPECIFIC CONDITIONS
Flowing Water: – Appropriate for use on applicable substrates or in areas with minimal or no flow. **Winter:** – Appropriate for winter use, but efficiency may be less due to unfavourable weather conditions. **Remote Areas:** – Consider logistics and waste management/disposal requirements – may be less appropriate as technique requires very high logistics support and labour and generates moderate waste volumes (oiled vegetation).

OPERATIONAL LIMITING FACTORS AND POTENTIAL SOLUTIONS	
Limitation:	**Solution:**
Cutting oiled vegetation during the active growing season may adversely affect the plant and should only be considered if the risk of leaving the oil threatens other resources (e.g. migratory or nesting birds) as the loss of plants or stems removes habitat for some species	Where the option exists, cut vegetation late in the growing season or during the winter die-back season to minimize risk to the plants and other resources
Excessive removal of vegetation is ecologically intrusive and generates a high volume of waste	When cutting, remove only the oiled parts of the plant and leave the lower unoiled parts of the stem and roots systems intact
Foot traffic can damage plants and trample oil into the sediments	Cut vegetation from a boat or using boardwalks/mats

Shoreline Treatment Information Sheet 10

PASSIVE SORBENTS

OBJECTIVE

– Sorbent materials are deployed to recover oil on the surface of the water or ground.

DESCRIPTION

– Sorbent materials can be used in both protection and treatment mode – they are placed in the shore zone to collect floating oil as it comes ashore or to collect remobilized stranded oil as it leaches off the shoreline and out of the shoreline sediments.
– Commercially available sorbents are supplied as sausage boom, rolls, sweeps, pads, and snare.
– Sorbents can be installed in filter fences in streams (Shoreline Protection Information Sheet 8).
– Includes loose organic sorbents (e.g. sphagnum peat moss – Sphag Sorb®) applied to riverbanks or shorelines/land surfaces to sorb oil or act as a contact barrier (Shoreline Protection Information Sheet 7).
– Loose organic sorbents can be applied by hand or a small sprayer to provide a barrier to reduce the risk of oil exposure by wildlife (e.g. waterfowl, aquatic furbearers).
– Sorbent booms or sweeps are usually fixed in place with stakes and/or anchors in a line or parallel lines to form a floating barrier that moves with the changing water level at the water's edge.
– In both the protection and treatment modes, the sorbent material is left to collect oil on contact for subsequent removal and disposal.
– Sorbents are often used as a follow-up technique after bulk oil has been removed or in areas where access is difficult.
– In a peat-rich environment, natural peat can be used as a sorbent on fresh crude oil and products.

SAFETY NOTES

– Tactic is labour-intensive and personnel may be exposed to a variety of weather conditions, such as heat, cold, and rain, and must have the appropriate PPE.
– Personnel safety must also be considered in areas with rapidly changing water levels and when volatile oils are present.
– Care should be exercised as oiled or wet bedrock and pebbles/cobbles can be very slippery leading to slips and falls.
– Sorbents can become very heavy when saturated – ensure proper lifting procedures and limits are followed.

Environment and Climate Change Canada
Environnement et Changement climatique Canada

Canada

Passive sorbents

APPLICATIONS FOR SURFACE OILING					
Substrate Category	**Volatile**	**Light**	**Medium**	**Heavy**	**Solid**
Bedrock	–	○	○	○	–
Man-made Solid (Impermeable)	○	○	○	○	–
Man-made Permeable	*see natural substrate with equivalent characteristics*				
Unconsolidated Sediments - Steep	–	–	–	–	–
Mud Flat	–	○	○	○	–
Mud Bank/Bar	–	○	○	–	–
Sand Flat	–	○	○	○	–
Sand Beach, Bank/Bar	–	○	○	–	–
Mixed Sediment Flat	–	○	○	○	–
Mixed Sediment Beach, Bank/Bar	–	○	○	–	–
Pebble/Cobble	–	○	○	○	–
Boulder	–	○	○	○	–
Vegetated	–	○	○	–	–
Wetland	–	○	○	○	–
Vegetated/Wooded - Upland	–	○	○	○	–
Small and Large Wood Material	–	○	○	○	–
Organic	–	○	○	○	–
Tundra Cliff	–	○	○	○	–
Inundated Low-Lying Tundra	–	○	○	○	–
Snow-Covered/Ice	○	○	○	–	–

● Preferred option ○ Possibly applicable for small amounts – Not Applicable

LINE OF SNARE ALONG VEGETATED SHORELINE

SORBENTS IN CHANNEL DOWNSTREAM OF TREATMENT AREA

OVERVIEW OF TACTIC CONSIDERATION(S) FOR SPECIFIC CONDITIONS	
Flowing Water: – Appropriate for use on applicable substrate types. – More difficult to keep in place along shorelines exposed to currents. **Winter:** – Appropriate for winter use, if conditions allow. – If operations are to be completed on ice, an Ice Safety Plan must be prepared and implemented. **Remote Areas:** – Consider logistics and waste management/disposal requirements – may be less appropriate as technique requires very high logistics support and labour and generates high waste volumes (oiled sorbents).	
OPERATIONAL LIMITING FACTORS AND POTENTIAL SOLUTIONS	
Limitation:	**Solution:**
Sorbents quickly reach their capacity when in contact with large amounts of oil – they must be replaced frequently even when dealing with relatively small amounts of oil	Ensure adequate resources available (workers, equipment, waste storage)
Lines of sorbents on ropes become tangled quickly – cutting the entangled sorbents for bagging and removal is time-consuming and difficult	Ensure lines of sorbents are properly secured
Loose sorbents, such as cork, peat moss, wood chips, and sawdust, are difficult to contain and may sink or migrate into non-oiled areas. Pads and snare may also become loose and cause secondary contamination	Avoid use of loose sorbents unless migration is unlikely or can be effectively contained. Ensure there is containment and control of all sorbents

Shoreline Treatment Information Sheet 11

DRY MIXING

OBJECTIVE
– Dry mixing of oiled sediments on land to break up and oxygenate oil residues to accelerate natural weathering and removal processes without removing sediment.
DESCRIPTION
– Oiled sediments are agitated by tilling, raking, digging, or ploughing actions that physically turn over or displace sediments on the surface and subsurface. – Rotary garden tillers or rakes are used to manually mix the sediments. – For larger applications, heavier machinery is used including agricultural equipment (e.g. disc systems, harrows, ploughs, rakes or tines) or earth-moving equipment (e.g. rippers/tines, front-end loaders, backhoes, graders, or bulldozers). – The weight-bearing capacity of the sediments will determine which types of equipment to use. – Agricultural “rippers” or “scarifiers” usually break up sediments to a depth of 50 cm whereas backhoes dig to significantly greater depths, i.e. on the order of 1 m or more. – There is no removal of oiled sediments associated with dry mixing.
SAFETY NOTES
– During operation of heavy equipment, a spotter should be present to ensure safe operations. – Traction of heavy equipment is typically reduced as sediment size increases. – Safety evaluations are crucial to ensure that volatile fractions are not present in the oil.

Environment and Climate Change Canada   Environnement et Changement climatique Canada

Canada

Shoreline Treatment – Information Sheet 11

Dry mixing

APPLICATIONS FOR SURFACE OILING					
Substrate Category	**Volatile**	**Light**	**Medium**	**Heavy**	**Solid**
Bedrock	–	–	–	–	–
Man-made Solid (Impermeable)	–	–	–	–	–
Man-made Permeable	*see natural substrate with equivalent characteristics*				
Unconsolidated Sediments - Steep	–	○	○	○	○
Mud Flat	–	–	–	–	–
Mud Bank/Bar	–	●	●	●	–
Sand Flat	–	●	○	–	–
Sand Beach, Bank/Bar	–	●	●	●	–
Mixed Sediment Flat or Beach, Bank/Bar	–	●	●	●	–
Pebble/Cobble	–	○	○	○	–
Boulder	–	–	–	–	–
Vegetated	–	–	–	–	–
Wetland	–	–	–	–	–
Vegetated/Wooded - Upland	–	–	–	–	–
Small and Large Wood Material	–	–	–	–	–
Organic	–	○	○	–	–
Tundra Cliff	–	●	●	●	–
Inundated Low-Lying Tundra	–	–	–	–	–
Snow-Covered	–	●	●	–	–
Ice	–	–	–	–	–

● Preferred option ○ Possibly applicable for small amounts – Not Applicable


SKID STEER WITH TILLER ATTACHMENT FOR DRY MIXING


AREA THAT HAS BEEN DRY MIXED

Shoreline Treatment – Information Sheet 11

Dry mixing

OVERVIEW OF TACTIC CONSIDERATION(S) FOR SPECIFIC CONDITIONS
Flowing Water: – Appropriate for use on applicable substrates. **Winter:** – Appropriate for winter use, if conditions allow. – If operations are to be completed on ice, an Ice Safety Plan must be prepared and implemented. **Remote Areas:** – Consider logistics and waste management/disposal requirements – may be less appropriate as technique requires access for earth-moving equipment.

OPERATIONAL LIMITING FACTORS AND POTENTIAL SOLUTIONS	
Limitation: Burying oil would delay its physical breakdown or weathering	**Solution:** Monitor mixing operations to limit burial of oil
Technique is not appropriate if it causes the release of large amounts of oil that could threaten to re-oil the shoreline or adjacent locations	Ensure shoreline treatment plan includes effective site-specific containment and recovery approach
Be careful not to alter the shoreline in a way that would cause erosion or accretion where these processes are an issue	Site restoration/remediation is an important component of the shoreline treatment plan

Shoreline Treatment Information Sheet 12

WET MIXING

OBJECTIVE

– Wet mixing is used to release and recover surface or subsurface oil by physically agitating sediments in shallow water (less than 1 m deep) on site.

DESCRIPTION

– Wet mixing is used in shallow water (less than 1 m deep).
– The sediments are agitated in situ to release the oil by physical abrasion.
– The released oil is recovered within the containment area by skimmers or sorbents.
– Oiled sediments can be mixed using agricultural equipment (e.g. disc systems, harrows, ploughs, rakes or tines) or earth-moving equipment (e.g. rippers/tines, front-end loaders, or backhoes/excavators).
– Water jets, either high-volume + low-pressure or low-volume + high-pressure, can also be used to agitate the underwater sediments within a boomed containment area.
– Custom-designed machines that combine mechanical mixing with water jets have proven very effective.
– The weight-bearing capacity of the sediments will determine which types of equipment to use.

SAFETY NOTES

– During operation of heavy equipment, a spotter should be present to ensure safe operations.
– Traction of heavy equipment is typically reduced as sediment size increases.
– Operations in flowing water environments may require fast water rescue support personnel.

Environment and Climate Change Canada
Environnement et Changement climatique Canada
Canada

Wet mixing

APPLICATIONS FOR SURFACE OILING					
Substrate Category	**Volatile**	**Light**	**Medium**	**Heavy**	**Solid**
Bedrock	–	–	–	–	–
Man-made Solid (Impermeable)	–	–	–	–	–
Man-made Permeable	*see natural substrate with equivalent characteristics*				
Unconsolidated Sediments - Steep	–	○	○	○	○
Mud Flat or Bank/Bar	–	●	●	○	–
Sand Flat or Beach, Bank/Bar	–	●	●	○	–
Mixed Sediment Flat	–	●	●	●	–
Mixed Sediment Beach, Bank/Bar	–	●	●	○	–
Pebble/Cobble	–	●	●	○	–
Boulder	–	–	–	–	–
Vegetated	–	–	–	–	–
Wetland	–	–	–	–	–
Vegetated/Wooded - Upland	–	–	–	–	–
Small and Large Wood Material	–	–	–	–	–
Organic	–	○	○	–	–
Tundra Cliff	–	–	–	–	–
Inundated Low-Lying Tundra	–	–	–	–	–
Snow-Covered	–	●	●	○	–
Ice	–	–	–	–	–

● Preferred option ○ Possibly applicable for small amounts – Not Applicable

SET-UP OF WET MIXING EQUIPMENT FOR LAKE ENVIRONMENT

AGITATING COARSE-MIXED SEDIMENTS WITH A WALKING EXCAVATOR

USING WATER JETS TO AGITATE COARSE-MIXED SEDIMENTS

Shoreline Treatment – Information Sheet 12

Wet mixing

OVERVIEW OF TACTIC CONSIDERATION(S) FOR SPECIFIC CONDITIONS
Flowing Water: – Appropriate for containment/recovery areas with minimal to no flow. **Winter:** – Appropriate for winter use, if ice conditions allow. – If operations are to be completed on ice, an Ice Safety Plan must be prepared and implemented. **Remote Areas:** – Consider logistics and waste management/disposal requirements – may be less appropriate as technique requires access for earth-moving equipment.

OPERATIONAL LIMITING FACTORS AND POTENTIAL SOLUTIONS	
Limitation:	**Solution:**
Most types of equipment will not operate in water deeper than 1 m	Review site-specific conditions prior to tactic implementation to delineate any areas where equipment cannot operate
Suitable access for earth-moving equipment	Utilize a 4x4 walking excavator to access along steep shorelines
Tactic may adversely affect the biota living in or on the surface of the sediments	Site restoration/remediation is an important component of the shoreline treatment plan

Shoreline Treatment Information Sheet 13

SEDIMENT RELOCATION

OBJECTIVE
– To move oiled materials from one location to another location where there is a higher level of water movement, typically wave energy, that is available to accelerate natural oil removal processes.
DESCRIPTION
– Earth-moving equipment (e.g. front-end loaders, graders, or bulldozers) is used to move the oil or oiled sediments from the surface or subsurface areas where they are protected from natural physical abrasion and weathering processes to locations where these processes are more active, such as the swash zone or active channel margin. – Sediment relocation differs from mixing techniques as the oiled sediments are physically moved from one location to another as opposed to being agitated in place. – Oil released from the substrate enters the water column as particulate oil, dispersed oil, or oil-mineral aggregates – the bulk of the oil dissipates in the water column and is not collected. – Sediment relocation can be combined with manual removal techniques to recover small patches of high-concentration oil uncovered during excavation.
SAFETY NOTES
– During operation of heavy equipment, a spotter should be present to ensure safe operations. – Traction of heavy equipment is typically reduced as sediment size increases.

Environment and Climate Change Canada   Environnement et Changement climatique Canada

Canada

Sediment relocation

APPLICATIONS FOR SURFACE OILING					
Substrate Category	**Volatile**	**Light**	**Medium**	**Heavy**	**Solid**
Bedrock	–	–	–	–	–
Man-made Solid (Impermeable)	–	–	–	–	–
Man-made Permeable	*see natural substrate with equivalent characteristics*				
Unconsolidated Sediments - Steep	–	○	○	○	○
Mud Flat or Bank/Bar	–	–	–	–	–
Sand Flat	–	●	●	–	–
Sand Beach, Bank/Bar	–	●	●	●	–
Mixed Sediment Flat	–	–	–	–	–
Mixed Sediment Beach, Bank/Bar	–	●	●	●	–
Pebble/Cobble	–	●	●	●	–
Boulder	–	–	–	–	–
Vegetated	–	–	–	–	–
Wetland	–	–	–	–	–
Vegetated/Wooded - Upland	–	–	–	–	–
Small and Large Wood Material	–	–	–	–	–
Organic	–	–	–	–	–
Tundra Cliff	–	–	–	–	–
Inundated Low-Lying Tundra	–	○	○	○	–
Snow-Covered	–	●	●	○	–
Ice	–	–	–	–	–

● Preferred option ○ Possibly applicable for small amounts – Not Applicable

OILED SEDIMENTS ARE RELOCATED TO THE LOWER SWASH ZONE

OVERVIEW OF TACTIC CONSIDERATION(S) FOR SPECIFIC CONDITIONS

Flowing Water:
– Appropriate for use, if conditions allow.

Winter:
– Appropriate for winter use, if conditions allow.

Remote Areas:
– Consider logistics and waste management/disposal requirements – may be less appropriate as technique requires access for earth-moving equipment.

OPERATIONAL LIMITING FACTORS AND POTENTIAL SOLUTIONS	
Limitation: Burying oil would delay its physical breakdown or weathering	**Solution:** Monitor mixing operations to limit burial of oil
Technique is not appropriate if it causes the release of large amounts of oil that could threaten to re-oil the shoreline or adjacent locations	Ensure shoreline treatment plan includes effective site-specific containment and recovery approach
Avoid moving oiled materials into areas with attached plant or animal communities, particularly if these areas were not initially oiled	Move oiled materials into areas with minimal or no vegetation so effects on the biological communities will be less
It may be difficult for some stakeholders to accept this tactic due to the perception that oil is being re-introduced to aquatic environment	Educate stakeholders on this science-based process

Shoreline Treatment Information Sheet 14
BURNING

OBJECTIVE
– To burn oil, oiled material, or oiled vegetation at the site to remove or reduce the amount of oil on the shoreline.
DESCRIPTION
– Burning is primarily used for oiled combustible materials, such as small and large woody material, that can be collected and piled to facilitate burning – it can also be used when vegetation has been oiled, such as in a wetland. – In limited circumstances, direct burning of oil on a beach can be carried out if the oil is pooled or concentrated in sumps, trenches, or other types of containers. – Burning efficiency can be improved by using air blowers to provide wind on piles to be burned. – Torches can be used to burn oil from hard substrates, but it is labour-intensive and uses large amounts of energy to remove small amounts of oil. – In most cases, heavy or solid burned oil residues remain which must be recovered manually. – Under the appropriate circumstances and with regulatory approval(s).
SAFETY NOTES
– Might necessitate construction of fire breaks on land and fire-resistant containment boom on water. – Even with a controlled burn changeable weather can produce safety-related hazards. – Air quality issues for public and responders must be addressed.

Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

Burning

APPLICATIONS FOR SURFACE OILING					
Substrate Category	**Volatile**	**Light**	**Medium**	**Heavy**	**Solid**
Bedrock	–	–	–	–	–
Man-made Solid (Impermeable)	–	–	–	–	–
Man-made Permeable	*see natural substrate with equivalent characteristics*				
Unconsolidated Sediments - Steep	–	–	–	–	–
Mud Flat or Bank/Bar	–	–	–	–	–
Sand Flat or Beach, Bank/Bar	–	–	–	–	–
Mixed Sediment Flat or Beach, Bank/Bar	–	–	–	–	–
Pebble/Cobble	–	–	–	–	–
Boulder	–	–	–	–	–
Vegetated	–	–	–	–	–
Wetland	○	○	○	○	–
Vegetated/Wooded - Upland	–	–	–	–	–
Small and Large Woody Material	–	○	○	○	–
Organic	–	–	–	–	–
Tundra Cliff	–	–	–	–	–
Inundated Low-Lying Tundra	–	–	–	–	–
Snow-Covered/Ice	●	●	●	○	–

● Preferred option ○ Possibly applicable for small amounts – Not Applicable

REMOVAL OF OILED LOGS BY BURNING

Shoreline Treatment – Information Sheet 14

Burning

OVERVIEW OF TACTIC CONSIDERATION(S) FOR SPECIFIC CONDITIONS
Flowing Water: – Appropriate for use on applicable substrates. **Winter:** – Appropriate for winter use, if conditions allow. – If operations are to be completed on ice, an Ice Safety Plan must be prepared and implemented. **Remote Areas:** – Consider logistics and waste management/disposal requirements – heavy or solid burned residues may need to be recovered manually.

OPERATIONAL LIMITING FACTORS AND POTENTIAL SOLUTIONS	
Limitation: Burning heavily oiled marsh vegetation when soils are dry can destroy the root systems and have a major effect on the ecosystem	**Solution:** Review site-specific conditions prior to tactic implementation to determine if approach is appropriate
Generation of smoke may be an undesirable side effect, although this is not a health or safety issue if standard safety precautions are observed	Ensure you have notified government agencies and obtained approval(s) for burn plan

Shoreline Treatment Information Sheet 15

SHORELINE CLEANERS

OBJECTIVE

– To remove or lift oil from shoreline substrates by adding a chemical agent so that the oil can be contained and recovered on the adjacent waters.

DESCRIPTION

– Shoreline cleaners, also known as surface washing agents or beach cleaners, contain a surfactant or solvent to facilitate or increase the efficiency of removal of stranded oil by washing.
– Whereas hydrocarbon solvents alter the viscosity of the oil, surfactants alter the surface tension of the oil by a mechanism often referred to as detergency so that the oil does not stick to substrate materials.
– The oil is lifted by wave action or current and may drift away from the shore unless it is contained and recovered.
– Can be applied directly to an oiled area with a hand spray or hose system – it can be used directly or as a pre-soak that is left for some time before flooding or washing is carried out. Manufacturer's recommended soak time should be followed.
– Under the appropriate circumstances and with regulatory approval, shoreline cleaning agents can also be used in a protection mode to pre-treat shorelines and prevent oil from becoming stranded on the substrate.
– Requires regulatory approval(s).
– Be prepared to conduct field tests to demonstrate efficacy.
– At the time of writing, spill treating agents (STAs), such as shoreline cleaning agents, may only be used in Canada in the context of an oil spill from offshore oil exploration and production facilities and cannot be applied without authorisation from the appropriate regulator; there is one shoreline cleaning agent listed in Canada that may be considered for approval during a spill response – Corexit®EC9580A (shoreline cleaning agent).

SAFETY NOTES

– Tactic is labour-intensive and equipment must be moved frequently.
– Make sure all personal are properly trained to use the equipment and are wearing the right PPE.
– Care should be exercised as oiled surfaces may be very slippery leading to slips and falls.

Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

Shoreline Treatment – Information Sheet 15

Shoreline Cleaners

APPLICATIONS FOR SURFACE OILING					
Substrate Category	**Volatile**	**Light**	**Medium**	**Heavy**	**Solid**
Bedrock	–	○	○	–	–
Man-made Solid (Impermeable)	–	○	○	–	–
Man-made Permeable	*see natural substrate with equivalent characteristics*				
Unconsolidated Sediments - Steep	–	–	–	–	–
Mud Flat or Bank/Bar	–	–	–	–	–
Sand Flat or Beach, Bank/Bar	–	–	–	–	–
Mixed Sediment Flat or Beach, Bank/Bar	–	–	–	–	–
Pebble/Cobble	–	○	○	–	–
Boulder	–	○	○	–	–
Vegetated	–	–	–	–	–
Wetland	–	–	–	–	–
Vegetated/Wooded - Upland	–	–	–	–	–
Small and Large Wood Material	–	–	–	–	–
Organic	–	–	–	–	–
Tundra Cliff	–	–	–	–	–
Inundated Low-Lying Tundra	–	–	–	–	–
Snow-Covered/Ice	–	–	–	–	–

● Preferred option ○ Possibly applicable for small amounts – Not Applicable

TEST APPLICATION OF SHORELINE CLEANER PRIOR TO LOW-PRESSURE WASH

OVERVIEW OF TACTIC CONSIDERATION(S) FOR SPECIFIC CONDITIONS

Flowing Water:
– Appropriate for containment/recovery areas with minimal or no flow.

Winter:
– Appropriate for winter use, if conditions allow.

Remote Areas:
– Consider logistics and waste management/disposal requirements – may be less appropriate as technique requires high logistics support and labour and generates high waste volumes (liquids).

Shoreline Treatment – Information Sheet 15

Shoreline Cleaners

OPERATIONAL LIMITING FACTORS AND POTENTIAL SOLUTIONS	
Limitation: Shoreline cleaners expose biota to a chemical that may have toxic side effects and adds a chemical to the environment, which may have other effects The mobilized oil should be contained and collected for disposal	**Solution:** Shoreline cleaners are regulated by the federal government and the appropriate approvals and compliance are required for their use Ensure shoreline treatment plan includes effective site-specific containment and recovery approach

Shoreline Treatment Information Sheet 16

BIOREMEDIATION

OBJECTIVE
– To enhance or increase the rate of biodegradation of oil in the shore zone by adding oil spill bioremediation agents – includes nutrient addition, microbe seeding (inoculation), biostimulants (e.g. enzymes), and phytoremediation.

DESCRIPTION
– Historically, microbe seeding, biostimulants, and phytoremediation techniques have had limited use and application for the remediation of oil on shorelines – this information sheet focuses on the nutrient addition approach. – Naturally occurring micro-organisms (bacteria) use oxygen to convert hydrocarbons into water and carbon dioxide – this process usually occurs at the oil/water interface and is limited primarily by the availability of oxygen and nutrients and the exposed surface area of the oil. – Nutrients can be added in solid (e.g. pellets) or liquid forms – water-soluble nutrients are released over time. – Although fertilizers can be used alone on a shore to degrade residual surface and/or subsurface oil, the process is more effective if combined with mixing or other tactics for breaking the oil down into smaller particles. – Off-site treatment of oiled sediments is similar to land farming technology and could involve microbe seeding and/or phytoremediation as well as adding nutrients.

SAFETY NOTES
– Make sure all personnel are properly trained to use the equipment and are wearing the right PPE. – Care should be exercised as oiled surfaces may be very slippery leading to slips and falls.

Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

Shoreline Treatment – Information Sheet 16

Bioremediation

APPLICATIONS FOR SURFACE OILING					
Substrate Category	**Volatile**	**Light**	**Medium**	**Heavy**	**Solid**
Bedrock	–	○	○	–	–
Man-made Solid (Impermeable)	–	–	–	–	–
Man-made Permeable	*see natural substrate with equivalent characteristics*				
Unconsolidated Sediments - Steep	–	–	–	–	–
Mud Flat, Bank/Bar	–	○	○	–	–
Sand Flat, Beach, Bank/Bar	–	○	○	–	–
Mixed Sediment Flat, Beach, Bank/Bar	–	○	○	–	–
Pebble/Cobble	–	○	○	–	–
Boulder	–	○	○	–	–
Vegetated	–	–	–	–	–
Wetland	–	–	–	–	–
Vegetated/Wooded - Upland	–	–	–	–	–
Small and Large Wood Material	–	–	–	–	–
Organic	–	–	–	–	–
Tundra Cliff	–	–	–	–	–
Inundated Low-Lying Tundra	–	–	–	–	–
Snow-Covered	–	–	–	–	–

● Preferred option ○ Possibly applicable for small amounts – Not Applicable

OVERVIEW OF TACTIC CONSIDERATION(S) FOR SPECIFIC CONDITIONS

Flowing Water:
– Appropriate for use on applicable substrates.

Winter:
– Nutrient enrichment is less effective at colder temperatures.

Remote Areas:
– Consider logistics and waste management/disposal requirements – technique is appropriate as it has low logistics support and labour and generates very low waste volumes.

OPERATIONAL LIMITING FACTORS AND POTENTIAL SOLUTIONS

Limitation:	**Solution:**
This is an effective but relatively slow process compared to other options	Nutrient enrichment is more effective during warmer seasons, as the rate of biodegradation increases with higher temperatures
Bioremediation can be used without affecting plants or animals. Nutrients should not be over-used, however, as this action can alter the normal balance of processes	Make sure that a remediation plan is operational for the affected resources
Bioremediation agents may be subject to federal and/or provincial approvals and regulations, particularly those that include viable organisms	Appropriate approvals and compliance are required for their use

6.5 Waste Considerations

Waste management poses a significant challenge for any oil spill response. Significant volumes of waste of various types such as liquid oil, oily debris, and PPE can be generated by response operations (Table 6.8). Past incidents have shown that the amount of waste generated during response can significantly exceed the original volume of spilled oil. The volume of waste generated is largely influenced by:

- The volume of oil spilled;
- The oil type and weathering stage;
- The type of shoreline substrate;
- Treatment techniques;
- Treatment criteria.

Table 6.8 Oily waste types (percentages are indicative: revised from IPIECA 2014)

Category	Characteristics	Examples	Comments
Oily liquids	Generally, oil and water with the water content ranging from 0 to ≥ 90%, usually towards the top end of that range. Minor amounts of mineral or organic matter may be present.	– Liquid recovered from sediments or equipment washing activities – Accumulated water from storage areas – Liquids recovered from skimming operations	Remove as much water as possible before managing the remaining liquid.
Pastes and solids	1. Dominated by oil 2. Dominated by fine mineral matter Both may contain relatively low amounts (< 10%) of water and/or organic matter.	– Tar balls – Waxy deposits – Oily sand/silt	Materials recovered from flowing water environments may contain substantial quantities of organic matter and/or free water.

Category	Characteristics	Examples	Comments
Coarse sediments	Generally low in free water (1%) and organic content (< 10%). The oil content varies depending on the size of the sediments and degree of oiling (often > 10%).	– Pebbles/cobbles on higher energy beaches – Mixed sediment areas	
Sorbent material	Natural and synthetic materials used to absorb oil. The bulk of the waste consists of the sorbent material itself. Oil content is often > 5% but variable. Water, mineral matter is low (< 10%) and organic matter very low (< 5%).	– Bulk – Pillows – Sheets – Natural materials (e.g. straw)	The oil content is highly variable. Sorbents with a high surface area to volume ratio, used in heavily oiled areas may contain substantially more than 5% oil.
Organic matter	Typically consists of more than 80% vegetative material, ≥ 5% oil with the remainder water and mineral matter.	– Aquatic vegetation – Riparian zone vegetation	Biodegradable substances. Smell and toxicity hazards associated with decomposition.

Category	Characteristics	Examples	Comments
Solid waste	Solid material of various sorts that has become oiled. Oil content variable (> 5%), water and mineral matter low (< 10%), organic matter variable and high if the waste is itself organic.	– Debris lying on the oil affected area (e.g. plastics, wood) – PPE (e.g. gloves, boots, coveralls, etc.) – Used equipment (e.g. rakes, shovels, scrapers, etc.	For PPE and equipment, consider washing/ decontamination and re-use.
Oiled fauna	Fauna that has become oiled. The animal is organic (> 70%), with the oil content variable (>5 %), free water (< 15%) and mineral matter (< 10%) being low.	– Mainly birds – Also, fish, mammals (e.g. aquatic furbearers), reptiles	Live fauna should be sent to specialist treatment facilities. All corpses should be counted before disposal. Some may be kept for necropsies and scientific studies.

In Canada, all provinces and territories have regulations in place that provide a framework and guidance on how oily wastes should be handled and managed. Typically, oily wastes generated by response operations are considered as hazardous wastes and strict procedures must be implemented for the storage, transport and disposal of these waste. A specific waste management plan must be developed for each incident as site-specific information is essential to identify potential temporary storage locations, transportation, and disposal options. The development of this plan is highly dependent on the identification of response strategies and these activities must be closely coordinated – these should be based on the following principles:

– **Avoid generating waste.** Response strategies and techniques that avoid creating waste should be considered as a priority.
  › Prioritize manual recovery and treatment.
  › Remove debris on shorelines before they are affected by oil.
  › Prevent secondary contamination.

- **Reduce the volume of waste generated.** Ensure that response strategies and techniques will reduce the amount of contaminated material.
  - › Provide training to treatment crews.
  - › Minimize the use of sorbents.
  - › Segregate waste at the source according to waste type.
  - › Minimize removal of sediments or excavation.

- **Reuse response materials and equipment** as much as possible instead of disposing of it.
  - › Decontaminate and reuse response equipment.

- **Recycle waste** as much as possible.
  - › Bring liquid oil to a refinery or cement plant for re-valorization.

Oil spill waste management requires the implementation of a logistical chain that will ensure that recovered wastes are stored, transported, and disposed of in a safe manner in accordance with local regulations. The failure to implement an efficient waste stream can result in stopping all treatment operations. It is therefore of extreme importance that careful considerations be given to waste management when identifying and implementing response strategies, especially when a spill occurs in a remote area.

Typically, an efficient waste stream will consist of these steps (Figure 6.7):

1. Waste collected during treatment operations (either on water or on shorelines) are segregated (liquid, solids, PPE, absorbents, ancillary, etc.) on-site and temporarily stored near the collection site. Adapted containers for each waste type are used in accordance with local regulations. The type of container must be carefully selected as these will eventually have to be transported to another storage location. Access and transportation mode must be carefully considered especially when operating in remote locations or in wintertime. Secondary containment, such as membranes, will be installed to prevent any secondary contamination during operations.

2. Full containers are then transported (or their content transferred) to either an intermediate storage or directly to final disposal. Intermediate storage is typically located in an easily accessible and secure area such as a parking lot or warehouse. Intermediate storage can be used to consolidate smaller containers used at the spill site into larger containers/tanks. Intermediate storage sites

are also designed with secondary containment to avoid secondary contamination especially as they are often located outside of the contaminated spill area.

3. Eventually, all waste will be transported to a final disposal site or recycled. Final disposal must comply with provincial and territorial regulations for hazardous waste.

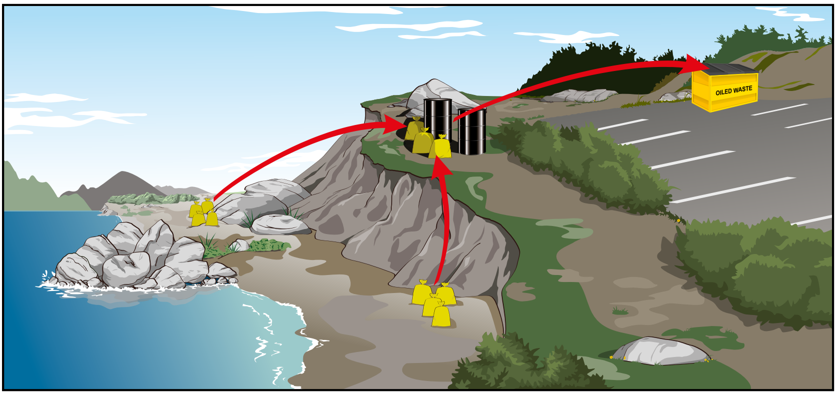


Figure 6.7 Typical waste management logistics models

7 | Response – Special Topics

7.1 Rivers

7.1.1 Water Levels and Oil

River, stream, and creek water levels vary constantly in response to changing inputs to the drainage system from precipitation, storm runoff, groundwater and snow/ice melt (Section 3.2.4). These variations may be small and ephemeral, only changing the water level by some tens of centimetres for a few hours to overbank flooding of several metres that may persist for days to weeks. Oil stranded on a falling water level may coat the river bank (Figure 7.1). Oil stranded during a flood event may be deposited on a flood plain above the active channel (Figure 7.1) and effectively become a land spill unaffected by water action for some months thereafter (Figure 7.2).

Figure 7.1 Oil (weathered crude – left panel; unweathered heavy crude – right panel) stranded during a falling water level

Figure 7.2 Oil deposited on a flood plain during a flood event

The effect on oil already stranded on the river bank is a function of whether the water level rises or falls and can result in either removal or burial of the previously stranded oil. Stranded oil that is removed may be transported and redeposited downstream.

7.1.2 Response in Fast Water

The term “Fast Water” or “Fast Current” when describing spill response refers generally to oil spills in water moving at one knot (0.5 m/s) or greater.

Responding to spills in fast water environments imposes additional hazards due to the extreme loads placed on equipment and the danger of personnel being swept away in fast currents. Safety of responders must always be assessed before attempting to deploy equipment in fast water. The use of boom as a floating barrier is subject to failure for a variety of reasons (Figure 7.3). Boom failure tends to occur when the current speed exceeds 0.75 knots (0.4 m/s). Depending on the issue, boom failure may be corrected by changing the boom angle, boom length, boom size (e.g. skirt length) or anchor weight. It is also possible that booming operations are not feasible in certain locations and a new spill management location must be used. Booming strategies are generally well understood by field responders; however, in fast water or in ice, there are additional considerations.

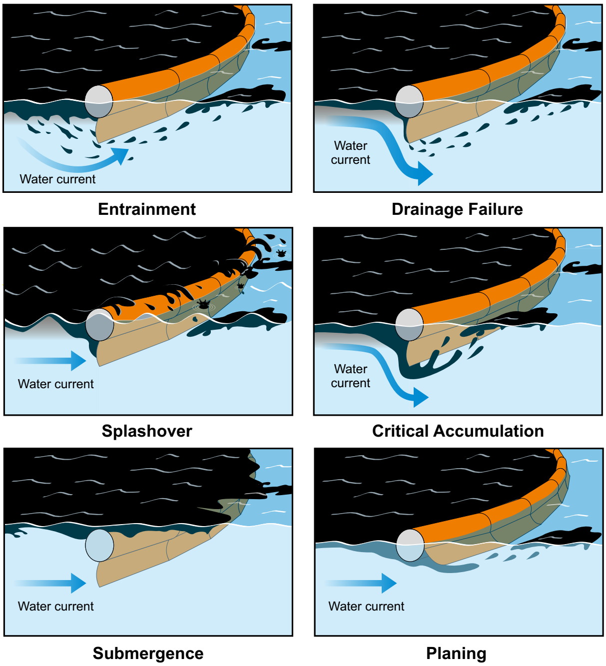


Figure 7.3 Typical boom failures often caused by fast current speed

As the current speed increases, the force on the boom and its components also increases. It is possible to reduce these forces by using boom with a shorter skirt, changing the boom angle in relation to the shoreline, and/or by reducing the length of the boom sections. If current speed is less than 2 knots, a boom skirt length of 12 inches (approx. 30 cm) is appropriate; however, as current speed increases to greater than 2 knots, a skirt length of 6 inches (approx. 15 cm) or shorter is recommended. Table 7.1 depicts the river speed and the recommended boom angle and length for river boom. These are approximations and adjustments in the field would be required. The reduction in boom length and boom angle may necessitate the use of cascade booming in order to cover the area required for deflection booming operations. Shorter sections of boom are used and anchored in an overlapping pattern to direct oil towards a collection area. Chevron booming configurations may also be used in fast water (Section 6.2.1) The use of BoomVanes™ or specialized sweep/buster systems may also be considered for larger rivers or bodies of water. These units can operate effectively in much faster currents (i.e. 3 knots for smaller systems and up to 5 knots for larger systems) but require a minimum depth of water.

Table 7.1 River speed and recommended boom angle and length

River Speed		Approximate Boom Angle	Boom Length Required
Knots	m/s	degrees	m
1	0.5	70	50
2	1.0	45	70
3	1.5	30	100
4	2.1	20	120
5	2.6	15	200
6	3.1	10	> 200

In fast water where shorter boom sections are necessary, there is a requirement for additional anchor systems. Multiple anchors, lines and buoys add to the complexity of the deployment and increase the chances of lines fouling or becoming entangled in propellers. Responders need to review the plan for anchoring and approach it systematically to avoid these issues. The use of trip lines will help when removing anchors, especially in fast water where the additional force may cause anchors to be set deeply and are therefore difficult to pull out of the bottom sediments. The use of shoreline anchors and cable ferry systems require good, secure anchor points. Shoreline anchor plates help to spread the load over several anchor points. Lines under tension are a safety issue and responders must be aware of the risk and avoid positioning themselves in the 'snap-back zone' (i.e. the direct path of a parting line).

When planning response strategies in fast water environments it is critical to understand and characterize the operating environment, including such factors as currents and flow patterns, natural collection sites, and then translating the information into estimating current and deflection angles, and potential forces on boom and rigging (Figure 7.4). For example, the selection of a booming strategy and technique should involve an understanding of the nature of current flow and the variations in speed between the faster-flowing cut-bank areas and the generally slower-moving, more quiescent areas along the inner bends in a river or stream (Figure 7.5). Current speeds increase as channels narrow and turbulence or eddies are common in the lee of shoals or islands and at a confluence.

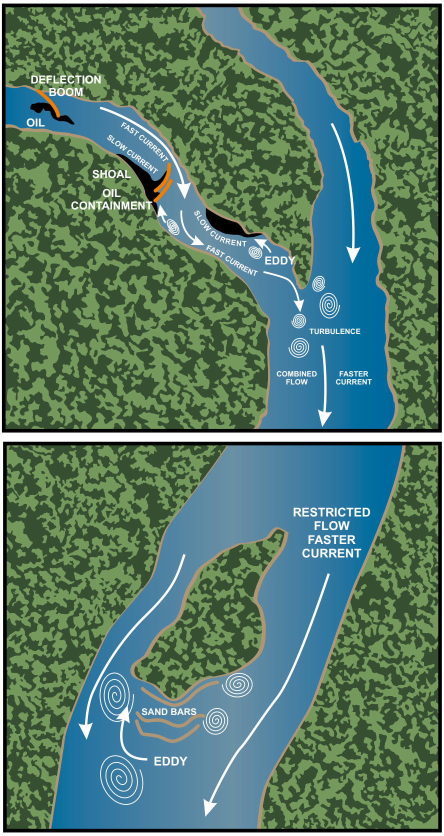


Figure 7.4 Typical river flow patterns and boom deployments

Figure 7.5 Example of booming strategy in a channel

7.1.3 Small and Large Woody Material

Woody material is a common feature of rivers and streams in Canada. The origin of the material may be natural river bank erosion, upstream transport or beaver cutting and the woody deposits may occur as lines of debris at a former or current water level, log jams and beaver lodges or dams (Figure 7.6). Large woody material (LWM) is defined as an unconsolidated accumulation of material larger than 10 cm in diameter and small woody material (SWM) as similar accumulations less than 10 cm in diameter.

Figure 7.6 Line of woody material stranded at former high-water level

Debris lines or log jams typically are ephemeral features that are created by and reconfigured or removed by high water level events associated with period of high discharge, such as a spring freshet. Beaver activity sites with LWM may be defined as active or inactive lodges, feed piles, embankment dens, or dams (Figure 7.7).

Figure 7.7 Beaver activity site: feed pile

Treatment approaches for small and large woody material are described in Section 6.3.1, Freshwater Substrate Information Sheet #13.

7.2 Subsurface Oil on Sediment Beaches, Banks or Bars

7.2.1 Introduction

Stranded oil can penetrate sediments or be buried by wave and current action (Figure 7.8).

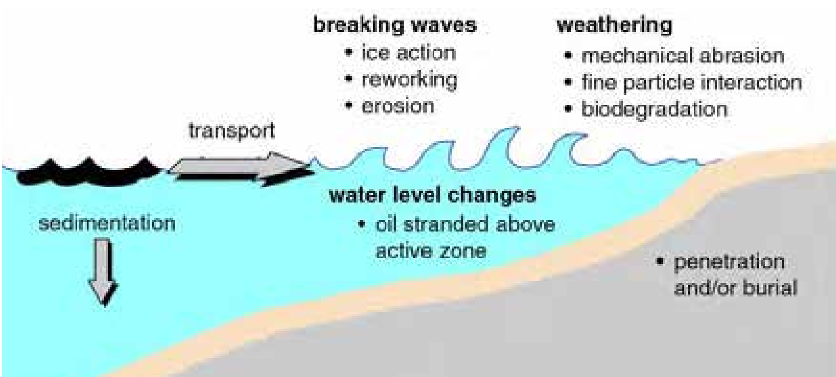


Figure 7.8 Oil stranding on shoreline

Penetration is controlled by the oil character and the sediment size – the potential for penetration decreases with viscosity and sediment grain size (Figure 7.9). Burial is the result of sediment transport and deposition by water flowing over the stranded oil (Figure 7.10).

Figure 7.9 Cobble beach on which emulsified oil has penetrated > 1 m before reaching an impermeable hard sand layer

Figure 7.10 Oiled debris and sediments located approx. 5-10 cm below the sediment surface

7.2.2 Detection and Delineation

The current practice for detection and delineation of subsurface oil in sediment shorelines relies primarily on the use of manually or mechanically excavated pits and trenches to allow visual examination and documentation of subsurface conditions and/or sampling for offsite analysis. Table 7.2 summarizes existing accepted practices in terms of horizontal detection and delineation, vertical delineation, survey speed, oil character and relative cost.

Table 7.2 Comparison of the attributes of accepted existing and developing (or potential) technologies for detection and delineation of subsurface oil (revised from API 2014)

	Existing Procedures				Developing Technology		
Attributes	**Pits/ Trenches**	**Cores**	**Jetting**	**Canines**	**Push Probes**	**Geo-physical**	**Surface Gas**
Delineation (Horizontal)	○	–	–	●	–	●	●
Delineation (Vertical)	●	●	○	–	●	○	–
Survey Speed	–	–	○	●	○	●	●
Oil Character	●	●	○	–	●	–	–
Relative Cost	○	–	○	●	○	●	●

○ indicates a favourable application

● indicates that the method may be effective, depending on the circumstances

– indicates important limitations or "not applicable"

Visual examination in pits and trenches, when used with a systematic SCAT documentation program has generally been adequate to meet operational needs. However, these procedures are typically labour intensive, excessively time consuming, and are limited in their ability to accurately and efficiently delineate the three-dimensional extent of subsurface oiling, particularly in the horizontal dimension. This limitation is largely because the excavations rely on discontinuous, or spot, samples which are collected either randomly or on fixed sampling grids. The accuracy of delineations using excavations can be improved through collection of additional samples, but only with additional expenditures of time and resources. Even with an intensive excavation survey, pitting and trenching may only cover a small percentage (< 0.1%) of the subsurface area. To a large degree, the selection of sample locations is based on the interpretation, by an experienced coastal geomorphologist or sedimentologist, of shoreline morphology and the recent history (typically days to weeks) of processes that cause erosion and deposition. This professional judgment does not guarantee that subsurface oil will be detected in the sample locations.

The speed and accuracy limitations of a pit or trench sampling survey can be overcome in some situations by oil detection canines ("detection dogs"; Section 7.4).

When a large number of pits are dug, the use of hand-held devices such as smart phones or tablets running any number of customizable data collection applications can be used to quickly collect spatial data, attribute information on oiling, and photographs of a large number of subsurface pits in a timelier manner. Relatively simple computer applications can document the pit observations efficiently, minimize paper transfers and provide a file for direct integration into a desktop GIS.

7.3 Submerged and Sunken Oil

Most oils have a density less than water and float in still-water conditions. Fresh water typically has a density of 1000 kg/m^3 and oils that exceed that density may be submerged, temporarily or for lengthy time periods, or may sink to a lake or river bed. An oil that has a density less than fresh water may become denser due to weathering or emulsification or if it is mixed with macroscopic (>1 mm) shoreline, river bank or river bottom sediments (Section 4.1.6).

7.3.1 Definitions

Submerged Oil

Oil below the surface of the water that is suspended within the water column (Figure 7.11). The primary controlling environmental factor is that of water movement:

- Oil that is neutrally or slightly positively buoyant may be temporarily submerged due to turbulence associated with wave action or currents and would float to the surface in the absence of that turbulence.
- Turbulent mixing on lakes and ponds typically is limited to the surface waters and is a function of the level of wave energy; essentially this is a two-dimensional process within the upper water layer.
- In rivers, streams and creeks, under energetic flow conditions turbulent mixing typically is throughout the water column, irrespective of water depth; essentially, a three-dimensional process.

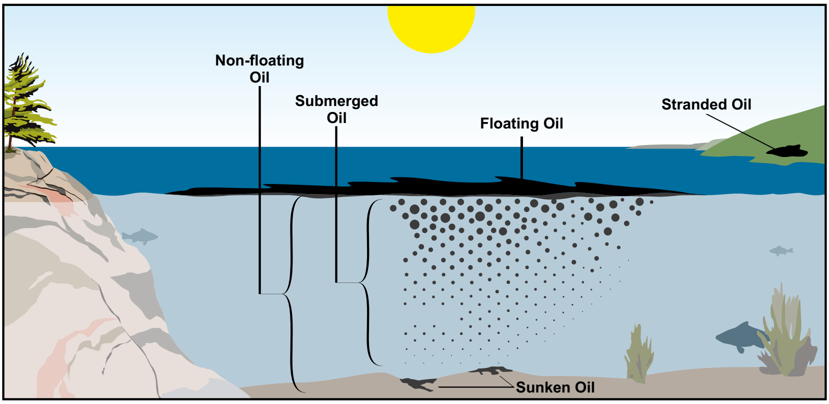


Figure 7.11 Submerged and sunken oil

Sunken Oil

Oil that is negatively buoyant deposited on the lake bed or river bed. Sunken oil may be reworked transported as bed load or buried ("subsurface sunken oil"). The primary sources and pathways for sunken oil include:

- Oil which is denser than the water body.
- Oil whose density has increased through weathering processes and becomes denser than the water body (this can include residues from in situ burning).
- Oil whose density has increased as a result of entrainment of macroscopic sediments (> 1 mm) so that the oil-sediment aggregate becomes denser than the water body (Section 4.1.6).
- Turbulence associated with wave action or currents may temporarily suspend sunken oil.
- Some sunken oil may be relatively fixed in position (immobile) and some may be very susceptible to movement and relocation due to slight changes in currents or even water temperatures (Figure 7.12).
- Sunken oil accumulations typically are very patchy in distribution.
- In some cases, lowering seasonal water levels may expose previously sunken oil, to a more readily accessible stranded oil form; or the opposite may occur, and oil may be inundated with increasing water levels.

Figure 7.12 Sunken oil in shallow, nearshore freshwater environments

7.3.2 Detection and Delineation

Many challenges exist for the detection and delineation of submerged and sunken oil. The most common constraining factors include water depth, visibility, currents, and the mobility of oil in the water column, unless the environment is a still-water location. Submerged and sunken mats may be visible from the air, boats, shorelines, or by snorkel or diver teams.

A range of techniques are available to detect and delineate sunken oil. The operating environments and the advantages and limitations of currently available detection and delineation techniques for sunken oil (Table 7.3) are described in API 2016.

Operationally, detection, delineation and response techniques may be broadly divided into shallow water/shore-based options (Figure 7.13) versus those that are deeper water and boat-based.

Table 7.3 Sunken oil detection and delineation options (revised from API 2016)

Sunken Oil Detection and Delineation Techniques	Water Depth Range (m)
Manual Shovel, Pits and Agitation	0 - 2
Oil Detection Canines (Section 7.4)	0 - 1+
Visual Observations (aerial, snorkels, viewing tubes, etc.)	0 - 10
Bottom Samplers	0 - 250+
Diver (SCUBA or surface air) Observations	2 - 50
Stationary Sorbents	2 - ~25
Towed Sorbents	2 - ~ 25
Laser Fluorosensor	3 - 25
Camera/Video on AUV	3 - 250
Acoustic Camera	3 - 250
Side Scan Sonar System	3 - 250
Water Column Samples	5 - 100+

Figure 7.13 Shallow water/shore-based options for sunken oil detection and delineation

7.3.3 Response Options

Many challenges exist for the recovery of submerged oil of which the most constraining factor is the mobility of oil in the water column, unless the environment is a still-water location. The only practical options for submerged visible oil mats within the water column are vacuums/pumps (depending on oil viscosity), trawls, nets, and sorbents.

A range of techniques are available to recover sunken oil (Figure 7.14). The operating environments and the advantages and limitations of currently available recovery techniques for sunken oil (Table 7.4) are described in API 2016. All dive activities in the vicinity of submerged or sunken must be conducted by commercial divers with appropriate PPE.

Figure 7.14 Sunken oil recovery options in shallow water with good visibility

Table 7.4 Sunken oil recovery options (revised from API 2016)

Sunken Oil Recovery Options	Water Depth Range (m)
Manual Removal by Wading (includes Vacuum or Pump)	< 2
Manual Removal by Snorkel or Divers	0 - 15
Excavator	0 - 2
Agitation/Refloating/Recovery	0 - 10
Trawls and Nets	0 - 25
Grab Dredge	0 - 50
Environmental Clamshell	0 - 50
Diver-Held Vacuum or Pump	2 - 50
Suction Dredge	2 - 15
Sorbents	2 - 25

7.4 Oil Detection Canines

Recent advances for the detection and delineation of both surface and subsurface oil on shorelines have resulted from controlled field trials and participation in oil spill response operations using trained oil detection canines (ODCs) and professional handlers. In particular, field trials have demonstrated that:

- Trained canine teams have the potential for accurate (> 99%) and rapid detection and horizontal delineation of subsurface oil.
- The survey speed for subsurface oil detection or area clearance is many times faster than can be achieved by walking or mobile SCAT teams.
- A team approach involves:
  - Trained and imprinted detection canine(s);
  - Certified professional handler(s);
  - A K9-SCAT Liaison (who has trained with canine detection teams).

The proven applications of ODCs to support shoreline oiling assessment surveys (K9 SCAT) are summarized in Table 7.5.

Table 7.5 Applications of an oil detection canine team to support SCAT field surveys

Clearance missions	Clearance of shorelines or areas with no detectable surface or subsurface oil (at least to 1 m depths and in concentrations on the order of low parts per million)
Difficult to observe oils	Detection and delineation of low concentrations of surface (as well as subsurface) oil that may be difficult to observe, such as light fuel oils, in concentrations to low parts per million
Subsurface oil in sediments	Detection and delineation of subsurface oil in sediments oil (at least to 1 m depths and in concentrations on the order of low parts per million)
Oil in vegetation or debris	Detection and delineation of oil in shoreline vegetation or within vegetation/woody debris or wrack lines
Subsurface oil in snow	Detection and delineation of subsurface oil in snow (to undetermined depths)
Shallow underwater oil	Detection of shallow underwater oil (at least to a 1 m water depth)

An ODC team can survey at track line speeds on the order of 3 to 6 km/hr on sand beaches and 2.5 to 4.5 km/hr on more difficult coarse-sediment beaches. These speeds equate to an equivalent alongshore subsurface detection coverage speed up to 2.4 km/hr on sand beaches and 200 to 500 m/hr on coarse-sediment beaches. Field trials showed that an ODC can locate subsurface oil and can achieve this detection and delineation with a better efficiency and greater accuracy (high confidence, low risk) compared to traditional manual or mechanical excavation based on spot samples (low confidence, high risk). This capability is particularly valuable for clearance surveys in which an ODC team can cover large areas rapidly with a high confidence of No Detectable Oil (NDO) (Figure 7.15), thus saving considerable amounts of time and effort and freeing experienced SCAT Team Leads to focus on oiled areas where treatment actions may be required.

On many responses, 50% or greater of the SCAT survey effort is spent surveying areas that have No Observed Oil (NOO).

Figure 7.15 Oil Detection Canine (ODC) team conducting search of wide mud flat with vegetation

7.5 Unmanned Aerial Systems (UASs)

Unmanned Aerial Systems (UASs) are a valuable tool with specific applications for shoreline surveys or in the broader context of an oil spill response, particularly for freshwater environments without pre-existing segmentation and/or video coverage (e.g. a large proportion of Canadian inland waterways).

Small UASs (sUASs; <25 kg) are a relatively easy-to-use, rapidly deployable, and practical local surveillance tool on oil spills for many over-water and over-land applications, including SCAT surveys on shorelines. In addition, advances in larger, longer endurance fixed-wing UAS vehicles offer the potential to perform extended Beyond Visual Line of Sight (BVLOS) surveys covering larger geographic regions than is feasible with sUAS, which offers the potential to replace typical missions performed by manned fixed-wing or helicopter platforms.

The most common, applicable and readily available platforms for conducting SCAT field surveys are summarized in Table 7.6.

Table 7.6 Current sUAS platforms available to support SCAT field surveys

Platform Type	Advantages	Constraints
Multi-Rotor – common uses include aerial photography and video aerial inspection	– accessibility – ease of use – Vertical Takeoff and Landing (VTOL) and hover flight – good camera control – able to operate in a confined area	– short flight times – small payload capacity
Fixed-Wing – common uses include aerial mapping, and pipeline and power line inspections	– long endurance – large area coverage – fast flight speed	– launch and recovery need a lot of space – no VTOL/hover – harder to fly – more training needed – expensive
Tethered Systems (balloons), Single-Rotor (helicopter) and Fixed-Wing Hybrid VTOL – tethered or balloon systems have seen limited action in a testing environment – the latter options are either too expensive or under development at this time to be considered for application in oil spill reconnaissance	– extended flight times – ability to monitor single locations for longer periods of time	– limited by range and the presence of objects which may interfere with tether lines and further limit coverage areas – more dangerous – harder to fly – more training needed – expensive – still in development

There currently exist several options for shoreline survey methodology with sUASs. Similar to K9 SCAT surveys, these types of survey are unique in that a qualified SCAT person is needed as well as a trained professional to operate the UAS (or handler in the case of K9 surveys). Ideally these are not the same person thus allowing each to focus on their specific responsibilities. Most sUASs can be operated from a tablet atop the controller allowing the SCAT team lead to observe imagery mid-flight. This however can be difficult depending on the lighting conditions and may interfere with the pilot's ability to safely operate the unit.

sUAS surveys are documented in much the same manner as traditional foot, boat or aircraft surveys. However, because of the variables involved an alternate, simplified oiling summary form is more practical. The Shoreline Oiling Aerial Reconnaissance (SOAR) form has been developed to meet the data capture needs of a sUAS shoreline survey. Although some components of the form are familiar to traditional SCAT there are modifications to the oiling Information section to streamline and simplify the capture of oiling data (Figure 7.16).

7. ZONE ID ________	***Description of Oil Conditions in Supra / Upper / Mid / Lower Intertidal Zone** (circle one)*				
Oil Band	**Surface Oil Distribution**	**Surface Oil Thickness**	**Surface Oil Type**	**Subsurface Oil**	
Width x Length:	<1 %	Film	Fresh Liquid	**Penetration**	**Burial**
______m x ______m	1 – 10 %	Stain	Mousse	< 1 cm	**Clean layer (above):**
Start Waypoint #: ______	11 – 50 %	Coat	Tar Balls	1 – 5 cm	______cm - ______cm
End waypoint #: ______	51 – 90 %	Cover	Tar Patties	5 – 10 cm	**Oiled layer:**
Sediment type(s): ______	91 – 100 %	Thick	Asphalt Pavement	> 10 cm	______cm - ______cm
______	______%	______ cm	Other ______	______cm	**Clean below?** Y / N

Figure 7.16 Shoreline Oiling Aerial Reconnaissance (SOAR) Form

For traditional shoreline surveys, sUASs could be considered as a replacement to foot- and boat-based surveys when access and/or safety are an issue. However, sUAS surveys do not provide the same level of detail as a foot inspection and this should be factored into the decision process. sUAS imagery can be very reliable for large area, bulk oiling situations or highly visible and contrasting visual oiling scenarios. However, sUASs will likely not suffice for final or sign-off inspections unless access or safety concerns are an issue.

8 | Response – Completion and Monitoring

8.1 Response Objectives and Shoreline Treatment Criteria

Response objectives are broad statements of guidance necessary for the selection of appropriate response strategies and tactics (Sections 6.2, 6.3 and 6.4). These objectives and strategies must be realistic (i.e. feasible and practicable), measurable, and prioritized. They should be set early in the shoreline response planning stage (Section 1.2.2) and reviewed and revised as appropriate by spill management throughout the response.

At a more specific level of detail and precision, shoreline treatment criteria or standards are developed for each segment to facilitate treatment decision-making and guide operations during the response. Historically, treatment criteria were called endpoints or endpoint criteria, or treatment targets. The use of treatment criteria (i.e. endpoint criteria) in shoreline treatment operations has a long history of usage and is detailed in Sergy and Owens (2007; 2008) and ECCC (2018), and for submerged and sunken oil in Harper et al. (2018). The prime function of shoreline treatment criteria is to provide clear targets for response operations and subsequently provide an inspection team with measurable criteria and standards with which to evaluate the condition of the shoreline.

Treatment criteria are assigned to a specific segment, shoreline type or defined area of shoreline and are developed through collaboration with the various stakeholders, technical experts, and any affected Indigenous communities. This collaboration is key, and helps to ensure that the relevant environmental, socio-economic, and cultural considerations are incorporated into the overall decision-making process regarding shoreline treatment. It is important that both stakeholders and response personnel are calibrated to these treatment criteria so that expectations are managed and that everyone understands what the final goals for a given segment look like. As with the response objectives, treatment criteria must be realistic and measurable. An effective and successful response is far more likely when all parties share the same expectation of what must be accomplished.

There are no set shoreline treatment criteria, however there are guidelines available for selecting treatment criteria for oil spill response that can provide spill management with a framework for working through this process (Sergy and Owens 2007; 2008). It should be noted that while there are provincial and territorial regulations for contaminated sites, these standards are based on existing numerical guidelines (limits) or narrative statements for chemical parameters of concern (contaminants) and are not considered appropriate for the development of treatment criteria for shoreline activities.

Because each freshwater oil spill is different, treatment criteria must be developed for each response. Shoreline types, oil type and behaviour, sensitivities, land use, access issues, safety, and net environmental benefit of various response tools will all affect the decisions around treatment criteria.

There may be sequential stages of shoreline treatment defined in a plan, each of which may have treatment criteria, for example:

- The Emergency Response Phase may have interim criteria to guide field operations to focus on removal of bulk oil, oil that could be easily remobilized, and/or high-priority oiled segments.
- While the initial stage is in progress, the spill management team can develop the treatment criteria as part of the Planned Response Phase for those segments that require specific treatments.
- The Monitoring and Completion phase after completion of treatment may subsequently have its own set of criteria addressing residual oil left to naturally weather.
- Some segments may have progressive stages of treatment using different tactics, with each stage having its own criteria.
- Additionally, there may be a process of establishing phased treatment criteria for situations where there is difficulty or reluctance to setting final criteria in the initial stages of an oil spill. This flexible approach was used during a pipeline spill into the North Saskatchewan River (Section 9.1.10), during which No Further Treatment (NFT) criteria were established for the 2016 and 2017 phases of the response.

Whatever type and form treatment criteria take (i.e. interim or final, staged or phased), it is important that they be defined in advance of SCAT field surveys and response operations. For examples and additional discussion concerning shoreline treatment criteria, refer to ECCC (2018).

The following Tables 8.1 and 8.2 provide an example of shoreline treatment criteria for a lake environment and a riverine system, respectively.

Table 8.1 Shoreline treatment criteria for Lake Wabamun, AB (Section 9.1.4)

1) Shorelines Fronting Residences and First Nation Shoreline (and other shoreline with First Nation significance)	
Shoreline Type	**Treatment Criteria**
1a. Sand, or Mixed Sand/Gravel Beach	No Visible Surface or Subsurface Oil
1b. Peat Beach (due to added 'sphagnum sorbent')	No Visible Oil
1c. Natural Cobble/Boulder	Stain (<0.01 cm thick) and <20% distribution
1d. Man-made Cobble/Boulder or Riprap	Stain (<0.01 cm thick)
1e. Vegetated Cut Bank	Coat (<0.1 cm thick) and <10% distribution on cut bank. Coat (<0.1 cm thick) on larger tree roots (i.e. tree root diameter >5 cm)
1f. Bulrush/Reed Bed	Non-sticky Coat (<0.1 cm thick)
1g. Wetland Fringe	Non-sticky Coat (<0.1 cm thick). Mudflats - no tar balls >2 cm diameter. Total tar balls <2 cm diameter not to exceed 10% distribution. Treatment Advisory Group (TAG) will be contacted to give specific instructions if questions arise during treatment
1h. Piling	No Visible Oil
2) Shorelines Not Fronting Residences	
Shoreline Type	**Treatment Criteria**
2a. Sand or Mixed Sand/Gravel Beach	Coat (<0.1 cm thick) and <10% distribution (Surface). Oil residue as Coat (Sub-surface)
2b. Peat Beach (due to added 'sphagnum sorbent')	Coat (<0.1 cm thick) and <10% distribution
2c. Natural Cobble/Boulder, or Man-made Cobble/Boulder or Riprap	Coat (<0.1 cm thick) and <20% distribution

2d. Vegetated Cut Bank	Coat (<0.1 cm thick) and <20% distribution on cut bank. Coat (<0.1 cm thick) on larger tree roots (i.e. >5 cm diameter)
2e. Bulrush/Reed Bed	Non-sticky Coat (<0.1 cm thick)
2f. Wetland Fringe	Non-sticky Coat (<0.1 cm thick). Mudflats - <2 tar balls 2 cm diameter per metre square. Total tar balls <2 cm diameter not to exceed 20% distribution. TAG will be contacted to give specific instructions if questions arise during treatment
2g. Piling	Stain (<0.01 cm thick)

Table 8.2 Shoreline treatment criteria for Lemon Creek, BC (Section 9.1.8)

Location	Types of shoreline	Use	Treatment Criteria
Lemon Creek km 0 (spill site) to km 2 downstream	Coarse sediment bank	Residential + drinking water	– No sheen – No consistent odour – WQ analyses (surface water) satisfies BC WQG for Aquatic Health and Drinking Water
Lemon Creek km 2 to km 4 downstream to confluence with Slocan River	Coarse sediment bank	Residential + drinking water	– No sheen – No consistent odour – WQ analyses (surface water) satisfies BC WQG for Aquatic Health and Drinking Water
Slocan River	Coarse sediment bank	Environmental use	– No rainbow sheen

Location	Types of shoreline	Use	Treatment Criteria
Slocan River	Vegetated bank	Environmental use	– No rainbow sheen
Slocan River	Log jammed	Environmental use	– No free product – No rainbow sheen
Slocan River	Fine sediment beach	Environmental use	– No rainbow sheen
Slocan River (first 10 km)	Coarse sediment bank	Residential + recreational use	– No sheen – No consistent odour
Slocan River (first 10 km)	Vegetated bank	Residential + recreational use	– No sheen – No consistent odour
Slocan River (first 10 km)	All types of shoreline	Agriculture	– No sheen – No consistent odour

8.2 Monitoring and Follow-up

Throughout the response, there is a need for ongoing monitoring to provide information on changes in oiling conditions and to evaluate the effectiveness of treatment. This oversight is meant to complement the expertise that Operations has and ensure that response objectives and treatment criteria are being met. There may be a need for monitoring during treatment in specific areas due to a sensitive resource, ensuring that Best Management Practices are being upheld. These monitors would be experts in specific fields, available to guide and advise operations (e.g. cultural monitors, biologists, SCAT-Ops Liaisons).

Photo-monitoring can be used as a means of monitoring a specific site over time. Photo-monitoring sites are selected early in the response and a photo library is developed by taking photos at the same exact locations over specific time-intervals. Stakes or other natural markers provide a visual reference point that enable the photographer to relocate at the exact same location and to frame the image for comparison with earlier imagery (Figure 8.1).

Figure 8.1 View onshore of stakes (with tape flagging) and natural marker (dead tree in backshore) for monitoring location

Time-series photographs may illustrate changes in oil character and distribution and can help to visualize how a certain type of shoreline is responding to and recovering from either treatment or natural attenuation (Figure 8.2).

Figure 8.2 Monitoring location showing: shoreline oiling with mobile product on water surface in late July (left panel); no mobile oil on water surface in mid August (middle panel); erosion and slumping of bank with no oil observed in mid September (right panel)

Another means of monitoring shoreline is through shoreline profiling. Shoreline profile surveys are periodic or scheduled across-shore surveys used to monitor and document topographic changes to lake shores and channel banks as they undergo erosional-depositional processes associated with ice gouging, flooding, and other events. The Emery Method, a simple but accurate technique that relies upon two, centimetre-incremented profile rods and a measured distance between them, is easy to use, easy to train people on, and involves simple equipment (Emery 1961). Stakes are established in the backshore and near the water line (may be a geo-referenced location) and the positions are recorded. The elevation of the back stake is considered the reference point (benchmark) for the survey, as well as the profile's location. The front and back profile rods are aligned with the water line and back stakes. The reader notes where the horizon (or another Table reference point if the horizon is not visible) intersects one of the profile rods (reading off back stake indicates an elevation drop and reading off the front stake indicates a rise in elevation). This type of monitoring is done to determine if there is erosion or deposition along a shoreline, which can in help in determining whether there is any potential for oil to become buried based on the timing of oil standing.

8.3 Inspection and Completion

Considerations for terminating a response include ensuring that: sensitive areas are no longer threatened; there is no recoverable oil remaining on the water; only residual oil remains on the shorelines; and shoreline treatment criteria have been met. For treatment on a given segment of shoreline to be deemed complete, there must be a formal process for inspection and completion. This includes post-treatment surveys where SCAT teams determine if the segment meets the treatment criteria, gain consensus in the field, and generate a Shoreline Inspection Report (SIR) documenting the results. Treatment is completed when one of the following applies:

No Observed Oil (**NOO**)
Oiling meets criteria, therefore **NFT**
Oiling does not meet criteria, but **NFT** is recommended with a specific reason(s): – Net Environmental Benefit (**NFT-NEB**); – Monitored Attenuation (**NFT-MON**); – As Low as Reasonably Practicable (**NFT-ALARP**); – Access (**NFT-Access**); – Safety Concerns (**NFT-SAFETY**)

Once a segment of shoreline is deemed complete and the pertinent stakeholders and Indigenous representatives agree, it passes to the Completion and Monitoring Phase. This includes post-incident assessments, evaluation of the effectiveness of the treatments, and monitoring the effects of oiling and subsequent treatment.

After spill response activities have terminated, additional activities may continue for some time. These may include investigations, legal challenges, financial claims, restoration, long–term monitoring, and human resource activities. Staging areas, roads and other access points, fences, etc. are restored or repaired. At this stage, a project team may continue long-term incident-related activities such as monitoring. After completion, spill managers should initiate an evaluation of the response. This evaluation is focused on how the response was managed, not the cause of the incident. All appropriate personnel and external responders that participated in the response may be asked to contribute to the evaluation through a formal or informal lessons-learned briefing. The evaluation may include, but is not limited to, the following items:

- general site characterization information;
- description of incident type and circumstances;
- immediate emergency actions undertaken;
- notification and alert;
- organization and efficiency of Incident Management Team;
- resources utilized and their efficiency;
- lessons learned.

The final report may include, but is not limited to:

1. Initial event summary.
2. Key response activities.
3. Response resource use and efficacy.
4. Summary of lessons learned.
5. Recommended improvements in response planning or preparedness.
6. Financial consequence analysis.
7. Legal consequence analysis.
8. Future operational or business recommendations.

It is important for future response that the lessons learned from a given response are documented and shared with the response community so that everyone can benefit and improve their knowledge. End-of-Spill Reports and Lessons Learned Reports are required in some jurisdictions, such as BC, to ensure that these learnings are captured and shared, and that there is final, formal documentation of the incident details. This is an opportunity for response teams to re-evaluate their processes, procedures and training requirements.

9 | Case Studies: Freshwater Spills

Each of the following freshwater oil spill responses are described using the following sections:

- Incident Summary;
- Challenges Identified;
- Lessons Learned and Best Management Practices.

Section 9.3 provides an overview of key lessons learned from these various freshwater oil spill responses.

9.1 Canadian Freshwater Oil Spill Response

9.1.1 NEPCO 140, The St. Lawrence River (1976)

Case Studies: Freshwater Spills

NEPCO 140, THE ST. LAWRENCE RIVER (1976)

INCIDENT SUMMARY

- The tank barge NEPCO 140 on route from Murray Bay, Canada to Oswego, New York, USA, with a cargo of 17.1 million L of No. 6 fuel oil grounded on Wellesley Island in the American Narrows section of the St. Lawrence River on June 23, 1976.
- An estimated 1,167,000 L of oil were reported lost before operations to secure the discharge were completed.
- Water levels were high when the spill occurred – the high water and swift current carried the oil downstream at a rapid rate.
- The oil spread 137 km downstream and contaminated more than 482 km of island and mainland shoreline.
- Due to river currents of 2-7 knots and prevailing westerly winds, the oil contaminated an intricate network of bays, inlets, and islands.

OVERHEAD VIEW OF GROUNDED TANK BARGE

OVERHEAD VIEW OF ISLANDS AND BAYS WITH OIL ON WATER

CHALLENGES IDENTIFIED

- Boom deployment to limit downstream movement of oil was ineffective due to wind, current, and channel depth and width.
- Inability to mitigate damage resulted in a time consuming and expensive treatment and contamination of highly developed residential areas (e.g. Alexandria Bay, New York), wilderness shoreline, wildlife refuges, and very productive marshes.
- Due to the large geographical area affected, the On-Scene Commander (OSC) could not adequately direct treatment in all areas in a timely manner.

Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

OVERHEAD VIEW OF BOOM FAILURE

LESSONS LEARNED AND BEST MANAGEMENT PRACTICES

- Creation of sub-areas controlled by a specific individual (on behalf of the OSC) and supported by treatment supervisors who directed contractor activities.
- Need to reduce the affected area through planning and preparation for an incident of this nature (i.e. need to consider a variety of plausible difficulties as part of preparedness planning efforts).
- Documentation is necessary for future reference and to make more knowledgeable daily decisions (e.g. create a master log for the spill where all major daily events are recorded).
- Establish a centralized point for communications with the public.
- Contingency planning should consider expected oil behaviour in various geographical locations (e.g. water depth, current patterns, tides, seasonal conditions) to gain a better understanding of how a specific product will behave in given conditions and allow for pre-establishment of control points or recovery sites.
- Following the spill, there was confusion with respect to what the effects of such a large spill would be in a riverine environment – there was very little documentation to answer questions posed by the public and scientists.
- Highlighted the importance of funding and conducting research regarding oil spill related effects in non-marine environments.

MANUAL TREATMENT OF SPILL WITH INADEQUATE PPE (FROM USCG)

HAND REMOVAL OF ORGANIC MATERIAL AND FREE OIL CONTAINED BY BOOM (FROM USCG)

9.1.2 Pine River, BC (2000)

Case Studies: Freshwater Spills

PINE RIVER, BC (2000)

INCIDENT SUMMARY

- On August 1, 2000, a pipeline transporting sour light crude (BC Light) from Taylor to Kamloops in northern BC ruptured, spilling approx. 985 m^3 (6200 bbls).
- The incident occurred on the Pine River, approx. 110 km upstream of the community of Chetwynd – the Pine River flows into the Peace River.
- The environmental effects included mortality to fish, insects, and some wildlife – estimates of potential fish mortalities as a result of the spill ranged from 15,000 to 250,000.
- The river water supply to the District of Chetwynd was shut off and the use of many groundwater wells near the river was discontinued.
- Product recovery was high: 450 m^3 removed from the river; 415 m^3 removed in contaminated soil; and approx. 80 m^3 spread throughout the environment.
- The unaccounted-for amount was estimated to include volumes dissolved in the water, absorbed in the sediments of the river's banks and bed, and trapped in backwaters, eddies and log jams.

VIEW OF EXCAVATION NEAR PIPELINE RUPTURE

CHALLENGES IDENTIFIED

- The Pine River is a high-flow body of water – oil was stranded at a high-water mark and there was a sense from the public that not enough was done to recover oiled materials before a rain event or winter and subsequent freshet.
- Lack of consensus with respect to treatment of oiled woody material on the shoreline (i.e. oiled log jams) – options discussed were treat, burn, remove, or leave in place.
- Closure of the recreational fishery in the area took several days and the process to do so was not clear.

Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

LESSONS LEARNED AND BEST MANAGEMENT PRACTICES

- Fish kills in moderate-size rivers can extend far downstream if the spill is not contained quickly.
- Implementation of a SCAT program would have provided information to address extent and nature of shoreline oiling and improved communications with the public.
- Formation of a Treatment Advisory Group (TAG) with representation from various agencies (including biologists, scientists, and managers), First Nation, and responsible party may have helped to focus discussions and reach a decision(s) with respect to treatment of oiled woody material – regulatory authorities of agencies involved also needed to be clearly understood.
- River booming was successfully implemented at 22 km and 30 km downstream of the ruptured pipeline and this minimized the downstream extent of shoreline oiling.

RIVER BOOM WITH PRODUCT CONTAINED FOR RECOVERY

9.1.3 Mystery Spill/Land Based, Used Oil, Rouge River into Detroit River, ON (2002)

Case Studies: Freshwater Spills

MYSTERY SPILL/LAND BASED, USED OIL, ROUGE RIVER INTO DETROIT RIVER, ON (2002)

INCIDENT SUMMARY

- Following a heavy rain event, a mixture of diesel fuel and lube waste oil was observed on April 9, 2002, in the Rouge River. Another heavy rainfall on April 12, 2002 caused a second oil spill.
- It appeared the oil came from one of the combined sewer outfalls on the Rouge River (Baby Creek Outfall). This release was trapped in the Rouge River due to booming at the mouth, preventing further releases of oil into the Detroit River.
  - › Estimated 115,000 to 230,000 L of oil spilled.
- Oil released affected approximately 27 km of shoreline in the USA and almost 16 km on the Canadian side of the Detroit River, including approximately 1.6 km of shoreline at the Lake Erie Metropark where oiled marsh vegetation was cut and removed.

SOURCE WAS A DRAIN FLOWING INTO THE ROUGE RIVER THAT EMPTIED INTO THE DETROIT RIVER

OIL ALONG SHORELINE

CHALLENGES IDENTIFIED

- The ice had only recently receded, and water temperatures were still quite cold even with warmer air temperatures.
- Limited shoreline access by boat, shallow water around the affected islands, often with steep rocky shorelines posed challenges for response efforts.
- Identifying the source of the spill was a challenge with many kilometres of sewers and storm drains; some dating back decades with few existing plans.
- Significant historic oiling along the shoreline made it difficult to determine if treatment was being done for recent spill.
- Spilled product analysis identified arsenic, lead, and other hazards that required higher levels of PPE.
- The shoreline of the river had a significant number of rusty/used syringes (medical waste) in the area being treated.

Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

SHARPS BEING IDENTIFIED AND REMOVED FROM SHORELINES WITH METAL TONGS

ROCKY SHORELINES

LESSONS LEARNED AND BEST MANAGEMENT PRACTICES

- The United States of America and Canada joint contingency plan was invoked and Canadian Coast Guard (CCG) acting as on scene command called on ECRC as response contractor.
- ECRC provided the equipment and personnel to treat areas identified by REET (now the Science Table), under daily work orders with CCG

LEVEL OF PPE FOR CONTAMINANTS

SHALLOW SHORELINES MEANT SHUTTLING BAGGED MATERIALS IN FLAT BOTTOM PUNTS TO BOATS IN DEEPER WATER

9.1.4 Lake Wabamun, AB (2005)

Case Studies: Freshwater Spills

LAKE WABAMUN, AB (2005)

INCIDENT SUMMARY

- A derailment of train cars at 05:20 MST on August 3, 2005 occurred adjacent to Lake Wabamun, approximately 60 km west of Edmonton, Alberta, Canada.
- Of the 46 rail cars that derailed, 25 were carrying ‘Bunker C’ and one was ‘Imperial pole treating oil’ (PTO).
- Eleven cars lost all or part of their loads of Bunker C (total spill volume of approximately 712,000 L):
  - 320,000 L recovered as free liquid oil;
  - 231,500 L removed in contaminated soil;
  - 160,500 L unaccounted for (e.g. absorbent, shoreline, emergent aquatic vegetation).
- The PTO car lost approx. 88,000 L of product with some recovery from soil and groundwater.
- Bunker C was heated and placed inside insulated tanker cars for transport; this affected the product viscosity and it was able to flow into the lake within a few hours of the derailment.
- The lake had a high profile at the time of the incident due to the variety of surrounding land uses (agriculture; forested areas; two surface coal mines supporting three coal-fired power plants; permanent residences; recreation – provincial park and cottages).

OVERHEAD VIEW OF DERAILMENT SITE

RUPTURED CARS AND FREE PRODUCT

CHALLENGES IDENTIFIED

- Sensitivity mapping exercise had not previously been completed for this waterbody; as sensitivities were not documented, setting of priorities for shoreline treatment was problematic.
- Emergent vegetation beds had trapped oil and were acting as a reservoir for oil remobilization.
- Concerns with cutting oiled emergent vegetation potentially affecting the recovery of beds.
- Submerged and sunken oil was identified as a potential issue early in the response.

Environment and Climate Change Canada / Environnement et Changement climatique Canada

Canada

EMERGENT VEGETATION WITH STRANDED OIL

SUNKEN TAR BALLS IN EMERGENT VEGETATION BED

LESSONS LEARNED AND BEST MANAGEMENT PRACTICES

- Oil behaviour was unique due to the rapidity at which tar balls formed:
  - Likely related to the uptake of materials (e.g. grass, insects, sediments, coal particles) by the heated oil as it flowed overland before entering the lake;
  - Continued entrainment of material once in the lake;
  - Most submerged/sunken oil was in shallow, nearshore waters.
- Oil was observed to re-surface:
  - Loss of solid matter by break up, sloughing of surface, loss of heavier entrained material (e.g. sand), and density changes due to temperature changes in the lake (particularly in the shallow, nearshore water that more readily undergoes heating/cooling throughout day/night) and in the oil.
- A Treatment Advisory Group (TAG) was formed in response to challenges.
- TAG was chaired by Alberta Environment and Environment Canada, and included membership from residents, First Nation, Provincial, and Federal partners, and the responsible party (RP).
- TAG provided review and guidance with respect to:
  - Site-specific treatment plans for 'Very Sensitive Areas' (e.g. large emergent vegetation beds; segments adjacent to fish spawning habitat);
  - Shoreline areas covered under the general shoreline treatment plan that required a type of specialized treatment, i.e. areas that presented challenges for treatment teams (e.g. oiled beaver lodge).
- Led to improved understanding among stakeholders of feasibility and success of shoreline treatment.

TEST CUT OF OILED EMERGENT VEGETATION

MONITORED SITE-SPECIFIC TREATMENT OF NEARSHORE SUNKEN OIL

9.1.5 Charette, QC (2006)

Case Studies: Freshwater Spills

CHARETTE, QC (2006)

INCIDENT SUMMARY

- On June 4, 2006, a train derailment of 14 cars containing chemicals (sulphuric acid) and light petroleum products (gasoline and diesel) occurred at the junction of a railway bridge crossing the rivière du Loup near the town of Charrette, QC.
- Approximately 110,000 L of gasoline and 122,000 L of diesel were spilled and contaminated soils adjacent to the track and near the river. An undetermined quantity of hydrocarbons reached the rivière du Loup by percolation through the ground as well as an overflow of water pits following heavy precipitation.
- An artificial lake dam (Chute-à-Magnan) facilitated the deployment of a boom in calm water near the site.
- A SCAT survey was conducted of the sector downstream of the river. No contamination was found on the banks. However, oil contamination was observed on the water in areas where organic material accumulated.

SOIL CONTAMINATION AND PERCOLATION TO THE RIVER

EMULSIFIED PRODUCT MIXED WITH ORGANIC MATERIAL AND STRANDED ON SHORELINE

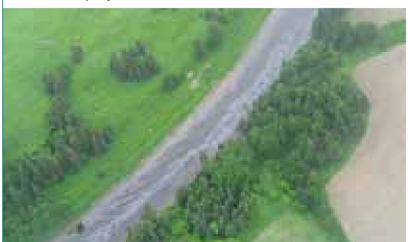
DERAILED TANK CARS NEAR THE RIVER

Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

CHALLENGES IDENTIFIED

- River flow was transporting oil downstream towards a populated area (Louisville) and Lac St-Pierre which is a UNESCO Biosphere reserve (migratory birds and vast areas of marshes).
- There was very little access to the upper and mid parts of the river.
- In addition, the significant vertical drop in the upper section of the river limited the number of effective boom deployments.

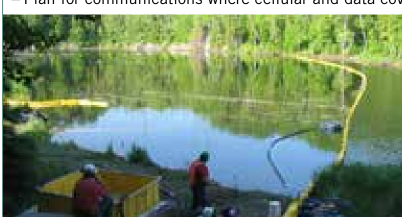


OIL SLICK OBSERVED ON THE RIVER

THE PRESENCE OF ORGANIC MATERIAL ADVERSELY AFFECTED THE SKIMMER RECOVERY CAPACITY

LESSONS LEARNED AND BEST MANAGEMENT PRACTICES

- Initiate early communication with population on risks related to the presence of hydrocarbon odours.
- Considering variations in water levels in the river, the booms were initially deployed at access points where the river slope was low.
- The containment booms were first deployed at the most downstream section of the river and then subsequent deployments were conducted further upstream.
- Since the spilled hydrocarbons were light refined products, effects on the environment were minimal and of short-term duration.
- Lack of communication between "environment" people and "operation" people resulted in unexpected delays during the initial response phase.
- Identification in advance of spill control points would have sped up response and prevented further oil migration.
- Plan for communications where cellular and data coverage is unreliable.



CONTAINMENT AND RECOVERY NEAR THE SOURCE

LAST BOOM BEFORE LAC ST-PIERRE

9.1.6 Lac-Mégantic, QC (2013)

Case Studies: Freshwater Spills

LAC-MÉGANTIC, QC (2013)

INCIDENT SUMMARY

– On July 6, 2013 a train of 72 cars carrying 7.7 million L of crude oil derailed in downtown Lac-Mégantic, QC. A fire ensued causing multiple explosions as well as the emission and discharge of petroleum products into the environment. Approximately 1.57 million L of petroleum remained contained in the cars.
– Of the approximately 6 million L spilled or burned, it was estimated that 300,000 L of light bakken crude oil reached the Chaudière River, whose head flows from Lake Mégantic.
– The Chaudière River is the source of drinking water for three municipalities and two agro-food industries.
– The water levels of Lake Mégantic are controlled by a dam at the head of the river. It was closed during the first hours of the operation, causing variations in the water level of the river.
– The oil spilled indirectly into the Chaudière River through Lake Mégantic and directly by travelling through municipal drains.
– The Chaudière River is 185 km long and has a steep drop in its upper portion (2.5 m per km).
– Series of booms were installed at 14 different strategic points along the river.

LAKE MÉGANTIC AND THE OUTFLOW TO THE CHAUDIÈRE RIVER

LIMITED ACCESS POINTS FOR BOOM DEPLOYMENT ALONG THE RIVER

Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

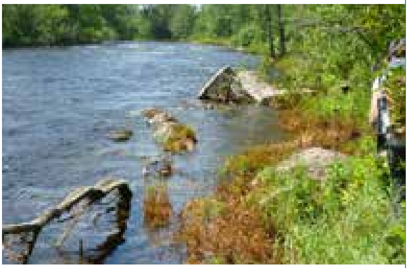
CHALLENGES IDENTIFIED

- Exposure to heat and to the flame retardant used to fight the fire affected the physicochemical properties of some of the hydrocarbons discharged into the river.
- Shoreline vegetation was burned by the product and turned yellow.
- Fluctuating water levels and high-water turbulence dispersed the hydrocarbons in the water column, which resulted in some of the oil accumulating within the coarse sediments of the river bed. As such, these light hydrocarbons had a longer environmental persistence than if exposed to the air.
- Identifying access points to the river and the owners of land whose shorelines were oiled was a challenge – due to thick shoreline vegetation, SCAT was conducted on foot in the shallow nearshore water.

LIGHT CRUDE OIL ALTERED BY HEAT EXPOSURE

OIL ACCUMULATION FOUND UNDER A STONE IN THE RIVER BED

SCAT CONDUCTED BY FOOT IN THE SHALLOW NEARSHORE WATER



SHORELINE VEGETATION BURNED BY PRODUCT

LESSONS LEARNED AND BEST MANAGEMENT PRACTICES

- Shorelines were assessed for oiling using SCAT and treatment recommendations provided. Precise segmentation of the river's shoreline was done using kilometre points from the source of the spill.
- Specific surveys to locate oil trapped in river bed sediments were made in parallel with the river bank SCAT surveys. More than 40 transects were investigated to establish the extent and locations of the contamination.
- The initial treatment of the river was carried out in two phases:
  - Shoreline treatment using manual recovery methods.
  - Agitation of oiled river bed sediments through deluge and manual wet tilling.
- The deluge and wet tilling treatment methods were effective for coarse sediments.
- Sensitization of and consultations with the river bank property owners were paramount to reaching the work sites along the river.

TRANSECTS ACROSS THE RIVER TO LOCATE OIL TRAPPED IN SEDIMENTS

WET TILLING WITH WATER AND AIR INJECTION

9.1.7 Cheecham Pipeline, AB (2013)

Case Studies: Freshwater Spills

CHEECHAM PIPELINE, AB (2013)

INCIDENT SUMMARY

- Incident occurred on June 22, 2013 in northern AB, Canada.
- The source was a pipeline located 70 km southeast of Fort McMurray between Anzac and Janvier.
- Approximately 750 bbls (119,240 L) of synthetic crude oil released from a pipeline failure following land movement due to unusually heavy rainfall in the region.
- Oil flowed downslope through a fen/wetland area and then into an unnamed lake south of Fort McMurray.

OVERHEAD VIEW OF INCIDENT

OIL FLOWED THROUGH FEN/WETLAND AND REACHED UNNAMED LAKE

CHALLENGES IDENTIFIED

- Heavy rainfall continued to challenge workers at the site. Access and site conditions were difficult. Access was by foot, all-terrain vehicle and helicopter.
- Health and safety issues included: access; soft substrate; and vapours.
- Needed a new contamination survey methodology as site was not linear (small length of shoreline).
- Very sensitive environment with very limited oil movement due to <5% slope.

Environment and Climate Change Canada | Environnement et Changement climatique Canada

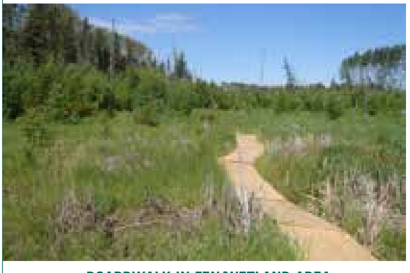
Canada

ALL-TERRAIN VEHICLE ACCESS

APPROPRIATE PERSONAL PROTECTIVE EQUIPMENT FOR VAPOURS

LESSONS LEARNED AND BEST MANAGEMENT PRACTICES

– Limiting the effects on sensitive fen/wetland habitat through use of boardwalks.
– Used systematic spot flushing combined with general flushing.
– High capacity pumps required as the limited slope prevented oil movement. High volume of water needed to move oil towards collection points. Nearby lake used as a water source, but water level monitor required at all times to prevent drying of the lake.
– Selective cutting of vegetation to provide defined pathways for water and oil to flow.



BOARDWALK IN FEN/WETLAND AREA

SELECTIVE CUTTING OF VEGETATION

9.1.8 Lemon Creek, BC (2013)

Case Studies: Freshwater Spills

LEMON CREEK, BC (2013)

INCIDENT SUMMARY

- On July 26, 2013, a tanker truck carrying Jet A-1 fuel rolled into Lemon Creek, a fast-flowing tributary of the Slocan and Kootenay River System in the Kootenay Region of south-eastern BC, Canada.
- The incident site on Lemon Creek was approximately 4 km upstream of the confluence with the Slocan River.
- The Lemon Creek Forest Service Road was closed, and residents evacuated. A "Do Not Use" water order was issued for Lemon Creek, Slocan River and Kootenay River downstream to the Columbia River confluence.
- A recreational and water use ban was also implemented for the same restricted area.
- Approximately 32,850 L of Jet A-1 fuel was released into Lemon Creek:
  - 2,000 L of mixed water and product was recovered from the incident site by vacuum truck;
  - 1,600 tonnes of soil were removed during remedial excavation;
  - 20,000 kg of contaminated absorbent material and vegetation was contained and removed from the area.

PRODUCT ON-WATER IN COARSE SEDIMENTS

Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

CHALLENGES IDENTIFIED

- Jet A-1 fuels are generally highly volatile, relatively insoluble and less dense than water; following the spill most of the components dispersed downstream on the surface of the water, however some components accumulated in slower moving reaches often associated with wood and log materials or held in coarser sediments.
- Moving water hindered booming and recovery efforts of the product.
- Flushing techniques were used to release product from stream banks and vegetation, accessible product was recovered using a vacuum truck.
- Sensitivity mapping had not previously been completed for this waterbody; as sensitivities were not documented, setting priorities for assessments and treatment was initially challenging.
- Watercraft restrictions required that most shoreline assessment efforts be carried out via downstream rafting.
- Assessment of the residual Jet A-1 product in the environment by SCAT required a new oiling matrix classification to provide traditional reporting of Heavy, Moderate, Light, Very light and Trace oiling.

WOODY MATERIAL ACCUMULATIONS TRAPPED PRODUCT

BOOMS ON RIVER

LESSONS LEARNED AND BEST MANAGEMENT PRACTICES

- An Incident Command Post (ICP) implementing a basic Incident Command System (ICS) was quickly established by the responsible party (RP), agencies, and response organizations (RO's) with the development of an Incident Action Plan (IAP) to instigate the emergency and remediation phase of the response.
- Activities to assess and manage source stabilization, salvage, containment and recovery, resources at risk, shoreline protection and recovery, wildlife protection and rehabilitation, human health and safety, and community concerns were undertaken, including sediment and water sampling programs.
- Aerial, boat and ground surveys were conducted to assess the scope of the affected area and to prioritize and direct treatment activities.
- The establishment of treatment criteria necessitated a unique set of guidelines to evaluate residual oil product in the environment. SCAT assessments for operational treatment criteria were developed based primarily on visible sheen and odour characteristics, while longer-term ecosystem recovery and human health treatment criteria were based on monitoring and sampling programs.
- The Slocan and Kootenay River System is a high-use recreational area and the restricted access during the summer months required an expedited, however thorough, assessment and treatment program.
- On August 6, 2013 the "Do Not Use" water restriction on the Kootenay River was lifted, on August 9, 2013 all remaining water restrictions were lifted except for lower Lemon Creek with ongoing monitoring.

SHORELINE ASSESSMENTS BY RIVER RAFT

ASSESSING SEDIMENT RETENTION OF PRODUCT

RAINBOW SHEEN ON WATER IN LEMON CREEK

9.1.9 Gogama, ON (2015)

Case Studies: Freshwater Spills

GOGAMA, ON (2015)

INCIDENT SUMMARY

- A derailment of 37 train cars occurred on March 7, 2015 located approximately 3 km northwest of the community of Gogama, ON, Canada.
- The product that was spilled was synthetic crude oil derived from heavy oil sources in western Canada.
  - › Approximately 2.63 million L of crude oil were released to the environment (air, water, and ground).
- Crude oil was released directly into the Makami River and onto the ground north of the river.
- Effects were initially observed up to approximately 90 m upstream of the rail bridge and along the river from the rail bridge downstream to Lake Minisinakwa.
- In addition to the containment, collection, and remedial activities completed at the site, monitoring and sampling were completed along the river and in the lake.

OVERHEAD VIEW OF DERAILMENT SITE

SPILLED OIL MIXED WITH CRUSHED ICE

CHALLENGES IDENTIFIED

- Working on ice and in extreme cold weather (heavy snow and freezing rain).
- Oil present on and under ice as well as oil contaminated water between layers of ice at times.
- Oil emulsification.
- Small community with very limited logistics support and infrastructure – nearest populated towns are Timmins 114 km to the north and Sudbury 191 km to the south.
- Sensitive area with respect to biodiversity: fish spawning areas – silt sensitive; adjacent wetlands; significant use by migratory wildlife in spring.
- Fluctuating water level and river flow – hydroelectric generating station (dam) on river.

Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

ICE PROFILE HOLE WITH PRESENCE OF SUBSURFACE OIL

BASKETS FILLED WITH OIL SNARE INSPECTED DAILY TO DETECT THE PRESENCE OF SUBSURFACE OIL

LESSONS LEARNED AND BEST MANAGEMENT PRACTICES

– Extensive ice slotting used to facilitate boom deployments to contain product close to source.
– Submerged wire baskets filled with oil snare, observation at ice profiling holes and under-ice video used to detect presence of submerged or subsurface oil during response.
– Extensive use of bubbling systems using compressed air and perforated weighted hose to:
  › maintain open-water;
  › create open-water between two ice slots;
  › melt ice containing oil;
  › aid in oil recovery.
– Water injection used to flush oil trapped in the water layer between layers of ice.
– Retaining ice along river banks during oil recovery prevented shoreline oiling.
– Pieces of ice covered with oil washed off in recovery area and treated ice placed in segregated area to melt.
– Pieces of ice with encapsulated oil removed and melted in frac tanks to recover oil.
– Oil was collected from the river and placed in temporary storage tanks – oil and oily water were transported off-site for disposal at various treatment facilities.
– Numerous SCAT assessments were completed on the Makami River and in Lake Minisinakwa from 2015 to 2017.

BUBBLING SYSTEM USED TO OPEN AND MAINTAIN ICE FREE AREA FOR OIL RECOVERY

CHAIN SAW SLED FOR ICE SLOTTING

BANK TO BANK ICE SLOT WITH SOLID FLOTATION BOOM/SORBENT BOOM

WATER INJECTION SYSTEM

9.1.10 Pipeline Spill, North Saskatchewan River, SK (2016)

Case Studies: Freshwater Spills

PIPELINE SPILL, NORTH SASKATCHEWAN RIVER, SK (2016)

INCIDENT SUMMARY

- On July 21, 2016, an estimated 225 m^3 (1,415 bbls) of blended heavy oil and condensate was released from a 16-inch (40 cm) pipeline, 33 km northeast of Lloydminster, SK, Canada.
- The break occurred on land along the south side of the North Saskatchewan River, approximately 160 m from the river bank. Post release geotechnical engineering reports cited ground movement, caused by rain, as the cause of the pipeline failure.
- An estimated 60% of the released product was contained on land and the remaining 40% migrated to the river.
- Surveys following the release indicated that initial shoreline oiling was limited from the point of entry (POE) downstream 190 km; however a high-water flood event in late August 2016 redistributed oiled material, which had not been removed, further downstream with oiled woody material observed on shorelines as far as 486 km from the POE.
- SCAT surveyed over 960 km of river bank within 1,025 segments.
- Over 2,600 people supported the emergency response, including over 400 members from various Indigenous communities.

PIPELINE SPILL SITE

SHORELINE OILING CLOSE TO THE RELEASE POINT

CHALLENGES IDENTIFIED

- Fresh water intakes from the North Saskatchewan River for North Battleford, Melfort and Prince Albert were closed downstream of the POE, necessitating expeditious assessments and operations activities.
- Large project area (500 km of river) requiring access to both banks and multiple mid-channel islands. Most of the river access for survey and operations teams was via boat with only a few usable launch points. Limited access points increased transit times by road and boat, and shallow water and changing water levels made boat transit challenging.
- The length of the affected area, on the order of 2,000+ km of total river bank shorelines, meant that decisions on geographic priorities and on the level of detail for documentation were necessary – i.e. in 2017, a complete survey of the entire shorelines was impractical between ice breakup and the spring freshet.

Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

- During the 2016 and 2017 field seasons, the changes in water levels associated with the spring freshets and unexpected summer flood conditions greatly influenced the oil distribution patterns and oil character producing four distinct data sets, making comparison over time difficult and necessitated innovative approaches to data processing and presentation.
- Turbulent flow during high water events also redistributed sediments within the river resulting in buried oil layers with varying degrees of unoiled overburden complicating the delineation of oiling and treatment operations.
- The abundance of beaver lodges along the river banks hindered both survey and operations activities – very large woody material piles were difficult for field teams to survey and treat.

OVERBURDEN REMOVAL TO ACCESS BURIED OIL LAYERS

REDISTIBUTION OF MATERIAL DOWNSTREAM DURING FLOOD EVENT

LESSONS LEARNED AND BEST MANAGEMENT PRACTICES

- A Unified Command (UC) centre was setup at in Lloydminster implementing an Incident Command system (ICS) protocol for the response. The emergency response was large, dynamic, and multi-disciplinary in nature, including contributions from the responsible party (RP) staff, Indigenous communities, government personnel representing various provincial and federal agencies, and many technical professionals from independent consulting firms.
- A Technical Working Group, consisting of representatives from regulatory agencies, the RP, and third-party technical experts, was established to provide technical and scientific guidance for the response efforts.
- As the response evolved, long-term water and shoreline evaluation programs were undertaken, with survey and sampling programs in 2016, 2017, 2018, and 2019 to support treatment and remedial actions as well as monitoring both ecological and human health concerns along the river.
- The North Saskatchewan River had no existing detailed character mapping information requiring the development of a segmentation system to provide an effective documentation framework for river bank assessments and operational logistics planning. The system developed used mid-channel kilometre point (KP) markers (1 km apart) along the river with right bank, left bank and mid-channel (island) designations for individual shoreline segments between KP markers.
- Documentation and reporting procedures after the 2016 emergency phase were re-aligned (2017-2019) to follow the statutes as defined in the Saskatchewan Environmental Code, using a Corrective Action Plan (CAP) and Resource Based Objective (RBO) protocol in place of the standard Shoreline Treatment Recommendations (STR) and treatment criteria.
- Another feature of the multi-year program was the importance of recognizing that field data collection techniques must be flexible. SCAT documentation and survey procedures evolved (Forms, Apps and Database) to better meet the changing response requirements and reporting expectations.
- The need for calibration in space and time between SCAT teams and operations personnel was critical to provide consistent documentation and effective treatment options, particularly when the different water level events significantly altered the oiling character and shoreline conditions.

– A Complete-as-You-Go (CAYG) protocol was established with operations personnel embedded within the SCAT teams to treat light oiling found on shorelines. This approach was a significant time saver as three separate missions could be combined into one survey; initial oiling assessments, operations treatment and post treatment inspections (SCA-CAYG-SIR).

– The application of oil detection canines (ODCs) for surface detection in areas with light oiling conditions or with access constraints and for subsurface oil detection greatly increased the efficiency and accuracy of field assessment evaluations – also aided in relationship building with affected Indigenous communities.

– The use of SCAT assistants was introduced in order to ensure a consistent and calibrated field team as support from other response representatives was not always available.

MANUAL SHORELINE TREATMENT

LARGE OILED WOODY MATERIAL PILE

CAYG TEAM ACCOMPANYING SCAT TEAM

CANINE SCAT SURVEY ON SHORELINE WITH DIFFICULT FOOT ACCESS

9.1.11 South Salmo River, BC (2019)

Case Studies: Freshwater Spills

SOUTH SALMO RIVER, BC (2019)

INCIDENT SUMMARY

- The incident occurred on March 27, 2019, 10 km south of Salmo, BC, when a double tanker truck went off the road near the Highway 3 and 6 junction spilling approx. 50,000 L of gasoline and diesel directly into the South Salmo River.
- A Unified Command (UC) was established and directed a SCAT survey program to locate and delineate the fuel below the point of entry (POE). Most of the product observed was in the South Salmo River from the POE to the confluence with the Salmo River 2 km downstream (Division A) and a small section of the Salmo River below the confluence (Division B).
- Water level forecasts indicated that the spring freshet would not be expected for some weeks and the UC determined that allowing natural attenuation was not acceptable and that a treatment action would be required.
- A Menzi Muck walking excavator ("spider excavator") equipped with an articulating "grabber" attachment agitated the coarse river bed sediments (primarily cobble and boulders) to release the entrapped product.

CONTINUOUS RAINBOW SHEEN UPON DISTURBANCE OF SEDIMENTS – TREATMENT RECOMMENDED

WALKING EXCAVATOR MIXING COARSE RIVER BED SEDIMENTS TO RELEASE PRODUCT

CHALLENGES IDENTIFIED

- The South Salmo and Salmo rivers are high-flow, relatively shallow rivers with limited backshore access beyond the POE.
- Access along steep river banks was possible using the walking excavator.
- SCAT support for the operations below the POE, where foot access was challenging, included real-time video feeds from a small Unmanned Aerial System (sUAS).
- Channel margins further downstream in the Salmo River (Divisions B and C) with mixed sediment substrate and natural collection areas (e.g. eddies, mid-channel bars, outside channels) were specifically targeted for oiling condition "spot checks" by a River Raft SCAT Team using a certified river raft guide and accompanied by a swift water rescue specialist.

Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

LESSONS LEARNED AND BEST MANAGEMENT PRACTICES

- Although a relatively small release that affected a limited section of river, the SCAT program followed standard protocols with three (3) Shoreline Treatment Recommendations (STRs) generated to direct the operations and Segment Inspection Reports (SIRs) to document closure when the treatment criteria were achieved.
- One STR was generated for the POE area, the second for the shallow river downstream in Division A, and the third for the few oiled areas in Division B that required action; the latter two STRs were for locations with a relatively similar and uniform river bank character.
- Fifteen (15) SIR recommendations were completed and submitted to the UC for individual segments identified for treatment in Divisions A and B, and for the remaining untreated downstream areas.
- Safety was addressed by: (1) personnel with swift water rescue training and river rescue response equipment maintained during the entire response; (2) swift water rescue personnel positioned with walking excavator operations, SCAT shoreline surveys, and downstream raft surveys; (3) air monitoring maintained throughout the response during all operations (along shorelines and with the operator of the excavator while working in the river).

RIVER RAFT SCAT TEAM TRAVERSING RAPIDS

SWIFT WATER RESCUE SUPPORT FOR OPERATIONS

9.2 International Freshwater Oil Spill Response

9.2.1 Kolva River, Komi Republic, Russia (1994-95)

Case Studies: Freshwater Spills

KOLVA RIVER, KOMI REPUBLIC, RUSSIA (1994-95)

INCIDENT SUMMARY

- A series of large crude oil spills at multiple locations occurred during the summer and fall of 1994 in a 70 km section of pipeline in the Komi Republic of Russia.
- The total volume of crude oil that was spilled in the project area was estimated to be over 1 million bbls.
- The spills created the threat that, in the spring of 1995, a large volume of this oil could be transported by a series of tributaries to the nearby Kolva River and then into the Pechora River – both rivers have large subsistence populations and there is a sensitive delta at the Arctic Ocean coast.

OILED STREAM BEFORE SPRING RUN-OFF

OILED STREAM BANK AFTER SPRING RUN-OFF HIGH WATER

CHALLENGES IDENTIFIED

- Multiple heavily oiled habitats: dry scrub and upland forest; lowland seasonally-submerged forest; raised and floating bogs; streams.
- Remote location with a few forest tracks and roads; Right Of Way access required amphibious, tracked vehicles; nearest town (Usinsk) 50 km distant by poor road; Usinsk only accessible by rail or air.
- Six individual major work areas with multiple spill locations along a 30 km length of the pipeline, each with unique challenges from small creeks to rivers and bogs.
- The strategy for containment was developed that involved the construction of temporary containment dams on the streams that drained the affected areas. The largest dam was a 1000 m long semi-circle, 5 m in height, with multiple siphon pipes to allow river through flow. The floating and raised bogs were divided into cells on the order of 750 m wide to allow access and oil recovery.
- The only construction materials available were glacial outwash silts, which were excavated from nearby borrow pits.

Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

FLUSHING AND MANUAL TREATMENT OF STREAM CHANNEL

HIGH ANGLE DIVERSION BOOM IN THE KOLVA RIVER

LESSONS LEARNED AND BEST MANAGEMENT PRACTICES

- Strategic choices in winter/spring 1995 before the spring high discharge that involved habitat modification with aggressive treatment to prevent oil reaching the Kolva and Pechora rivers.
- Multiple innovative techniques were required including the use of sections of pipe that were pulled across the floating bog within work cells to squeeze oil from the surface vegetation; new plant growth was observed within only a few weeks in the bog cells.
- SCAT survey methodologies developed for marine coastal environments and modified for the small streams of the spill region proved to be highly effective for describing and documenting the pre- and post-treatment oil conditions in the riverine environments.

FLOATING BOG DIVIDED INTO WORK CELLS (APPROX. 750 M WIDE)

BOG CELLS IN JULY 2016

SECTION OF PIPE USED TO SQUEEZE OIL FROM THE FLOATING BOG

RIVER CONTAINMENT DAM WITH SIPHON PIPES

9.2.2 Rio Desaguadero Pipeline Spill, Bolivia (2000)

Case Studies: Freshwater Spills

RIO DESAGUADERO PIPELINE SPILL, BOLIVIA (2000)

INCIDENT SUMMARY

- On January 30, 2000 an estimated 29,000 bbls (4,610,600 L) of mixed crude oil and condensate was spilled from a pipeline, which was damaged during summer flood conditions, at the Desaguadero River crossing on the Bolivian Altiplano (approx. altitude of 3,700 m).
- The timing of the spill coincided with bankfull, flood conditions during the period of the highest rainy-season water levels – the oil was subjected to high energy and extremely turbulent flow conditions.
- The oil was transported as far as 350 km downstream and deposited along a total of approximately 400 km of river bank channels, meander floodplains, and irrigation ditches, as well as on several hundred hectares of low-lying floodplain.
- The downstream reaches of the river system are an extremely important habitat for aquatic birds; fortunately, the environmental effects were minimal and the ecologically important lakes (Uru Uru and Poopó) were spared the effects of the spill as an extensive delta wetland system acted as a filter to trap the southerly moving oil.
- A second high-water level associated with high run-off in early March 2000 caused some of the stranded oil to be buried by an unoiled layer of silt.
- A treatment program using local labour was organized that peaked at a total of 3,200 in March and most of the oil removal was completed by the end of April 2000. A second phase program to remove oiled vegetation was carried out through the winter months to address perceived effects on forage and grazing animals.

RIO DESAGUADERO, BOLIVIA

HIGH ALTITUDE (COLD DESERT) ENVIRONMENT WITH LARGE SHEEP FLOCKS

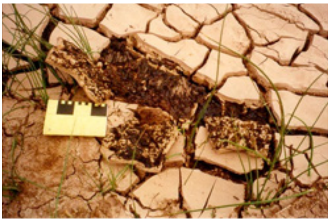
Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

CHALLENGES IDENTIFIED

- Treatment operations were constrained by few crossing points over the river (bridges or hand-drawn ferries) and by the problems of access in the wetlands of the floodplain zone during the summer season.
- Oil was often stranded on the overbank regions of the river margins and across low flood plains making finding residual oil deposits difficult – most of the shoreline oiling was identified via aerial surveys.
- High altitude provided physical challenges for the non-Bolivian response team members.
- Helicopter and fixed-wing operations were limited due to drastically reduced payloads, and either fuel caches or fuel trucks were needed to support the survey activities.
- A rural population of about 30,000 that was dependent on family-based subsistence agriculture and animal husbandry (mainly cows and sheep, with some llama and pigs) – the river is the water supply for domestic use, cattle and irrigation.

GE STRIP OR "BATH-TUB RING" OILING ALONG RIVER MARGINS



SUBSURFACE OILING BELOW MUD OVERBURDEN

LESSONS LEARNED AND BEST MANAGEMENT PRACTICES

- Aerial (helicopter) reconnaissance with video surveys covered more than 6,000 km of river to locate the oil and provide direction and priorities for the treatment program; pre-GPS systematic grid survey pattern used for the video survey of the delta areas.
- Access to the wetlands was difficult during the winter season and a decision was made to delay treatment of these areas until they dried out to avoid damage to the soil and vegetation.
- Treatment Criteria:
  - › no 100% oil cover patches >3 mm thick and >50 by 50 cm (approximately the size of a shovel),
  - › no single patches of >20% surface oil cover >10 m long, >1 m wide, and >3 mm thick, and
  - › no liquid oil patches >1 m diameter that could be potentially remobilized.
- Vegetation Removal Criteria:
  - › more than 30% of stems with weathered oil or stain, or
  - › more than 10% of stems with unweathered (fresh or sticky) oil).
- A 7-step procedure was developed in March for the approval of treatment activities on an area-by-area basis. The government chose not to participate in the process so that the "sign-off" process became an internal activity of the response team. Considerable emphasis was placed on the systematic and complete documentation of all residues that remained after the treatment criteria had been met.

– Sample analyses demonstrated a significant amount of Oil-Mineral Aggregate (OMA) formation in the low salinity waters. This promoted dispersion of the oil in the flood plains and enhanced natural biodegradation rates.
– The overall environmental risk was reduced due to the extensive and rapid weathering of the spilled oil. The water-soluble fractions were lost rapidly, within a few weeks if not days, in the weathering process. As much as 70% of the total hydrocarbons and 90% of the total PAH were lost so that the residual oil was primarily heavy hydrocarbons that were immobile and not readily bio-available.
– An extensive veterinarian program examined more than 400,000 animals to provide inoculations in areas of oiled forage.

MANUAL REMOVAL ON THE OILED FLOOD PLAIN

MANUAL TREATMENT OF OILED CANAL

9.2.3 Pipeline Spill, Yellowstone River, USA (2011)

Case Studies: Freshwater Spills

PIPELINE SPILL, YELLOWSTONE RIVER, USA (2011)

INCIDENT SUMMARY

- On July 1, 2011 a 30 cm (12 inch) crude oil pipeline breached in the vicinity of or under the Yellowstone River near Laurel, MT releasing an estimated 750 to 1,000 bbls (119,240 to 158,987 L) of crude oil into the river.
- The 22.5 km (14 mile) section of pipeline between adjacent pump stations, which crossed beneath the flooded Yellowstone River where the breach is suspected to have occurred, likely filled with river water, displacing a significant amount of oil that floated to the surface.
- The oil was observed in Billings, MT approximately 24 km (15 miles) east early in the morning (02:00) of July 2, 2011 and by 09:00 approximately 64 km (40 miles) downriver (east) from the spill site.
- The oil was widely dispersed along the banks and adjacent overbank lowland areas due to the flood stage conditions of the river at the time of the release.
- Assessments of the river indicate that the high flow conditions had washed away a significant fraction of the oil, with only limited amounts pooled in the floodplain or riparian wetland areas and substantial amounts of soiled vegetation and upland (overbank) tracts along the river.
- Shoreline oiling was confirmed as far as 116 km (72 miles) downstream from the spill site.

OVEBANK FLOOD CONDITIONS AT THE TIME OF THE RELEASE

Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

CHALLENGES IDENTIFIED

- The river was in flood stage at the time of the release, which posed significant safety risks for responders and hindered efforts at containment booming and recovery on the main river channels.
- Conditions on the river including high velocity flow, flood stage water levels, and large material (trees and logs) floating in the current dictated that conservative measures be used until the water level receded – limited use of smaller boats near shorelines, in backwaters and side channels were used to recover oil and employ sorbent materials
- Due to high water levels initial SCAT team reconnaissance observations were performed by air or boat; later SCAT surveys and oiling documentation were performed on foot along shorelines and potential overbank areas.
- The process of initiating remediation activities required gaining permission to access river shorelines from property owners and trusties, including private parties, Bureau of Land Management (BLM), State of Montana and various county authorities.
- Culturally sensitive areas identified by the Local Apsáaloke Tribe required both archaeological and tribe personnel during assessments and subsequent treatment activities.
- Where land access was not granted by the landowner, SCAT surveys were limited to on-boat shoreline observations only, with no overbank documentation for treatment or damage assessments.

TREES AND LOGS ON RIVER RESTRICTED ACCESS

HIGH-FLOW MAIN CHANNEL RIVER CONDITIONS

LESSONS LEARNED AND BEST MANAGEMENT PRACTICES

- A Unified Command (UC) was established by the US Environmental Protection Agency (USEPA) and the responsible party (RP) with State and local agency participation
- An Incident Action Plan (IAP) was developed to manage the response activates as specified under Incident Command System (ICS) procedures.
- In addition, the USEPA issued an administrative order requiring certain activities to remediate the release pursuant to the Clean Water Act.
- A SCAT Plan was developed, and SCAT teams were established ensuring a multi-agency consensus approach with potential participation from the USEPA, Montana Department of Environmental Quality (MDEQ), United States Coast Guard (USCG), City of Laurel Public Works, Apsáalooke Tribe, Montana Department of Natural Resources and Conservation (DNRC), Bureau of Land Management (BLM), and the RP and their contractors.
- The RP mobilized hundreds of response contractors to the affected areas between Laurel and Billings, while maintaining a reserve strike force to address any pockets of oil that were found anywhere along the river by aerial reconnaissance, ground surveillance, and reports from the public and local officials.
- During the response, International Bird Rescue (IBR), US Fish and Wildlife Service, and Montana – Fish, Wildlife and Parks identified locations where oiling presented a greater than normal hazard to wildlife.
- As specified in the Wildlife Plan implemented for the response, inspections continued in many segments following closure of the segment by the SCAT process in order to ensure that all wildlife hazards had been identified and abated.

BOOM DEPLOYMENT IN BACKSHORE CHANNEL

OILING IN SIDE CHANNEL

OILING ON OVERBANK FIELD

OILING ON SHORELINE VEGETATION

9.3 Key Lessons Learned from Case Studies

Based on a review of the freshwater oil spill responses presented in the previous sections, the following Table 9.1 provides an overview of key lessons learned, some specific to select habitats or freshwater environments and others more general in nature, that are important to consider in preparation for the next incident to affect a freshwater waterway. Specific lessons learned or best management practices for treatment techniques are reflected in **Shoreline Treatment Information Sheets (Section 6.4.1)**.

Table 9.1 Freshwater spills – key lessons learned from case studies

Preparedness is essential
For high use and/or sensitive areas (environmental, socio-economic), prepare Geographic Response Plans (GRPs), including site-specific Tactical Plans
Pre-SCAT data provides operational response datasets in association with preparedness plans for timely and effective coordination of resources during a response
For larger rivers, consider implementing the segmentation system described in Section 5.3.2 to provide an effective documentation framework for river bank assessments and operational logistics planning
It is more practical to collect/assess data before an incident when there is more time available to address important issues, rather than under the time constraints of an initial emergency response
For every incident, it is key to document and implement lessons learned as part of plans, exercising, and training to be better prepared for the next
Build relationships
Engage Indigenous and other communities, various levels of government, and industries ahead of time – if an incident occurs, you will already have important contacts established
Implement a spill management system
The ICS system is used by most first responders and emergency organizations throughout Canada, the United States, the United Kingdom, and by the United Nations
As part of preparedness planning, ICS should be exercised with all partners, Indigenous communities, various level of government, and non-governmental organizations so that roles and responsibilities within the system are understood

During an incident, consider utilizing an ICS ‘coach’ until all personnel are comfortable with the system
Improved communications among response partners will limit delays during the initial response phase
Communication is important
Develop a communications plan ahead of time – important to initiate communications with affected population early and often
Important to include the public, various levels of government, Indigenous communities, stakeholders, industry, and Response Organizations (ROs)
Plan ahead of time for communications where cellular and data coverage is unreliable
Know your sensitive habitats
Complete sensitivity mapping for high use and/or sensitive areas ahead of time – if sensitivities are documented, setting of priorities for shoreline treatment will be less problematic
Consider treatment approaches for sensitive habitats or critical infrastructure (e.g. wetlands, municipal water intakes) ahead of time with input from an advisory group that includes informed members from various levels of government, Indigenous communities, industry, and ROs
Regulatory authorities of various agencies need to be clearly understood
During a larger-scale response, establish a Technical Working Group consisting of representatives from regulatory agencies, the RP, and third-party technical experts to provide technical and scientific guidance for response efforts
Response strategies for fast water environments
In fast water environments, need to continue to better our understanding of factors that limit the effectiveness of equipment and techniques used to contain and recover oil
Spill response technologies have continued to improve over time, along with the training for effective implementation – fast water systems are available, but their key limitation is proper deployment
Know your river – test and refine your strategies, particularly for high priority locations
Being able to act quickly in the event of an incident will ultimately minimize the downstream extent of shoreline oiling

Expect substantial amounts of oiled woody material in flowing water environments
Oiled woody debris on banks, floodplains, and mid-channel islands should be expected for spills during flood events
Application of oil detection canines (ODCs) for surface detection in areas with light oiling conditions or with access constraints and for subsurface oil detection greatly increases the efficiency and accuracy of field assessment evaluations
Review options ahead of time for in-situ treatment vs removal to reduce contact hazard and remobilization risk
Regulatory authorities of various involved agencies need to be clearly understood
Response streamlining
Complete As You Go (CAYG) protocol may be established with operations personnel embedded within the SCAT teams to treat light oiling found on shorelines. This approach can be a significant time saver as three separate missions are combined into one survey; initial oiling assessments, operations treatment and post-treatment inspections (SCA-CAYG-SIR)
The application of ODCs for surface detection in areas with light oiling conditions or with access constraints and for subsurface oil detection greatly increases the efficiency and accuracy of field assessment evaluations – also aids in relationship building with affected communities
Use of SCAT Assistants helps to ensure a more consistent and calibrated field team as support from other response representatives may not always be available

10 | Bibliography

Addassi, Y., J. Yamamoto, and T.M. Cullen, "The Refugio Oil Spill Response: Case Study and Lessons' Learned/Best Practices for the Future", in *Proceedings of the International Oil Spill Conference (IOSC)*, 20 p., 2017.

Alaska Clean Seas, *Alaska Clean Seas Technical Manual - Volume 1: Tactics Descriptions*, Alaska Clean Seas, 186 p., 2012.

American Petroleum Institute (API), *Canine Oil Detection* (K9-SCAT) Guidelines, American Petroleum Institute Technical Report No. 1149-4, 81 p., 2016

American Petroleum Institute (API), *Canine Oil Detection: Field Trials Report*, American Petroleum Institute Technical Report No. 1149-3, 48 p., 2016.

American Petroleum Institute (API), *Improvements for the Mechanized Cleanup of Oiled Sand Beaches: Phase 1 - Final Report*, American Petroleum Institute Technical Report No. 1151-1, 76 p., 2013.

American Petroleum Institute (API), *Oil Spill Response in Freshwater Environments: Impacts on the Environment of Clean-up Practices*, American Petroleum Institute Technical Report No. 4567, Washington, DC, 58 p., 1993.

American Petroleum Institute (API), *Oil Spill Response: Options for Minimizing Adverse Ecological Impacts*, American Petroleum Institute Technical Report No. 4398, Washington, DC, 84 p. 1985.

American Petroleum Institute (API), *Options for Minimizing Environmental Impacts of Inland Spill Response*, American Petroleum Institute Technical Report No. 425, 112 p., 2016.

American Petroleum Institute (API), *Petroleum in the Freshwater Environment, an Annotated Bibliography 1946-1983*, American Petroleum Institute Technical Report No. 4508, Washington, DC, 60 p., 1992.

American Petroleum Institute (API), *Shoreline Protection on Sand Beaches: Phase 1 - Final Report*, American Petroleum Institute Technical Report No. 1150-1, 46 p., 2013.

American Petroleum Institute (API), *Shoreline Protection on Sand Beaches: Phase 2 - Field Guide*, American Petroleum Institute Technical Report No. 1150-2, 24 p., 2013.

American Petroleum Institute (API), *Subsurface Oil Detection and Delineation in Shoreline Sediments: Phase 1 – Final Report*, American Petroleum Institute Technical Report NO. 1149-1, 56 p., 2013.

American Petroleum Institute (API), *Subsurface Oil Detection and Delineation in Shoreline Sediments: Phase 2 – Final Report*, American Petroleum Institute Technical Report No. 1149-2A, 34 p., 2014.

American Petroleum Institute (API), S*unken Oil Detection and Recovery Technical Report*, American Petroleum Institute Technical Report No. 1154-1, 126 p., 2016.

American Petroleum Institute (API), *Sunken Oil Detection and Recovery Operational Guide*, American Petroleum Institute Technical Report No. 1154-2, 36 p., 2016.

Anderson, K., K. Hale, T. Festa, D. Farrar, K. Kolwaite, S. Stanton, P. Alberti, L. Reid, R. Schrader, J. Maddox, and V.L. Trumbull, "New York State's Inland Geographic Response Plans", in *Proceedings of the International Oil Spill Conference (IOSC)*, 2017.

Aurand, D. and L. Essex, *Ecological Risk Assessment: Consensus Workshop. Environmental Trade-offs Associated with Oil Spill Response Technologies. Northwest Arctic Alaska*, Report for the US Coast Guard, Sector Anchorage by Ecosystem Management & Associates, Inc., Lusby, MD. Technical Report 12-01, 54 p., 2012.

Barton, K., J. Michel, D.E. Fritz, E.H. Owens, A.E. Steen, "Options for Minimizing Environmental Impacts of Freshwater Spill Response", in *Proceedings of the International Oil Spill Conference (IOSC)*, pp. 987-989, 1995.

BC Ministry of Forests (1996). *Channel Assessment Procedure Guidebook*. www.for.gov.bc.ca/ftp/hfp/external/!publish/FPC%20archive/old%20web%20site%20contents/fpc/fpcguide/CHANNEL/CHAN-TOC.HTM

BC Ministry of Forests, *Fish-Stream Identification Guidebook*, (2nd Ed.), British Columbia Forest Service, Victoria, BC, 77 p. 1998

BC MOE, *British Columbia Inland Oil Spill Response Plan*, BC MOE, 104 p., 2013.

BC MOE, *Lemon Creek Spill: Shoreline Treatment End Points*, BC MOE, 6 p., 2013.

Birtwell, I., "Comments on the Effects of Oil Spillage on Fish and their Habitat - Lake Wabamun, Alberta", Hearing Order OH-001-2014; Upper Nicola IR #2, Document B, 198 p., 2008.

Boufadel, M.C. and F. Fitzpatrick, "Computation of the Mixing Energy in Rivers for Oil Dispersion", in *Proceedings of the Thirty-ninth Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, pp. 429-433, 2016.

Brandvik, Per Johan, Kristin Rist Sorheim, Ivar Singsaas and Mark Reed, *Short state-of-the-art report on spills in ice-infested water Oil behaviour and response options*, Report no. 1, Oil in Ice - JIP, website, 2006.

Burgess, C. and R. Wheeler, "Canadian National Railway Ruel 88.7 Gogama Derailment: An Account of Mattagami First Nation Involvement", in *Proceedings of the Thirty-ninth Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, pp. 668-685, 2016.

Burkholder, A. and Y. Addassi, "Geographic Response Plans: Preparing for Inland Oil Spills in California Waterways", in *Proceedings of the International Oil Spill Conference (IOSC)*, 2017.

Camlin, T.E., "Upland/Inland Spill Response: Use of Underflow Dams", in *Proceedings of the International Oil Spill Conference (IOSC)*, 1381-1389, 2001.

Camlin, T.E., "Upland/Inland Spill Response: Use of Underflow Dams", in *Proceedings of the US EPA Freshwater Spill Symposium*, 18 p., 2006.

Challenger, G., G.A. Sergy, and A. Graham, "Vegetation Response and Sediment Polycyclic Aromatic Hydrocarbon Attenuation in a Carex Lyngbyei Marsh in Howe Sound, British Columbia, Canada following a Spill of Bunker C Fuel Oil", in *Proceedings of the International Oil Spill Conference (IOSC)*, pp. 847-854, 2008.

Church, M., "Channel morphology and typology", in *The rivers handbook: hydrological and ecological principles*, P. Calow and G. Petts (eds.), Blackwell Scientific Publications, Oxford, UK, Vol. 1, pp. 126-143, 1992.

CONCAWE, *A field guide to inland oil spill cleanup techniques*, Report No. 10/83, Oil Spill Cleanup Technology Special Task Force No. 3, Den Haag, 104 p., 1983.

Cook, M.D., "Advance Fast Water Spill Response Tactics", in *Proceedings of the International Oil Spill Conference (IOSC)*, pp. 1621-1632, 2014.

de Santiago-Martin, A., G. Guesdon, J. Diaz-Sanz, and R. Galvaz-Cloutier,"Oil spill in Lac Megantic, Canada: Environmental monitoring and remediation, *International Journal of Water and Wastewater Treatment*, 6 p., 2015.

Dollhopf, R.H. and M. Durno, "Kalamazoo River/Enbridge Pipeline Spill 2010", in Proceedings of the International Oil Spill Conference (IOSC), 7 p., 2011. https://ioscproceedings.org/doi/full/10.7901/2169-3358-2011-1-422

Dollhopf, R.H., F.A. Fitzpatrick, J.W. Kimble, D.M. Capone, T. P. Graan, R.B. Zelt, and R. Johnson, "Response to heavy, non-floating oil spilled in a Great Lakes River environment: A multiple-lines-of-evidence approach for submerged oil assessment and recovery", in *Proceedings of the International Oil Spill Conference (IOSC)*, 2014.

Drieu, M.D. and K.A. Hansen, "Fast Water Response Equipment Performance in Two Inland Rivers", in *Proceedings of the International Oil Spill Conference (IOSC)*, pp. 1291-1296 , 2003.

Dubach, H. and E.H. Owens, "Shoreline In Situ Treatment (Sediment Mixing and Relocation) Tools", in *Proceedings of the Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, pp. 1091-1101, 2016.

Dubach, H.C. and E.H. Owens, *Shoreline In Situ Treatment (Sediment Mixing and Relocation) Fact Sheet*, Technical report prepared for American Petroleum Institute, Technical Report 1155-2, 20 p., 2016.

Dubach, H.C. and E.H. Owens, *Shoreline In Situ Treatment (Sediment Mixing and Relocation) Job Aid*, Technical report prepared for American Petroleum Institute, Technical Report 1155-3, 30 p., 2016.

Ducks Unlimited, *Enhanced Wetland Classification Inferred Products User Guide*. Version 1.0, Ducks Unlimited Canada, 30 p., 2011.

Emergencies Science Division, Environment and Climate Change Canada, (2001). *Oil Properties Database*. www.etc-cte.ec.gc.ca/databases/Oilproperties/oil_prop_e.html

Emery, K.O., "A simple method of measuring beach profiles", *Limnology and Oceanography*, 6:90-93, April 1961.

Energy Institute, *Inland waters oil spill response. A guidance document incorporating the strategies and techniques for responding to inland surface water oil spills in the United Kingdom*, Energy Institute, London, UK, 44 p., 2004.

Environment and Climate Change Canada (ECCC), *Canadian Aquatic Biomonitoring Network Field Manual: Wadeable Streams*, Government of Canada, 57 p., 2012.

Environment and Climate Change Canada (ECCC), *Shoreline Cleanup Assessment Technique (SCAT) Manual*, Third Edition, prepared and provided by Triox Environmental Emergencies, Owens Coastal Consultants, Environmental Mapping Ltd, Ottawa, ON, 2018. https://buyandsell.gc.ca/cds/public/2019/01/17/11bcca72f6b0cb7b6a4b4aaf8684334d/scat_manual.pdf

Environment and Climate Change Canada, *A Field Guide to Oil Spill Response on Marine Shorelines*, Environment and Climate Change Canada, Ottawa, ON, 239 p., 2016.

Environment Canada, *A Bibliography on Freshwater Oil Spills*, Environment Canada, Manuscript Report EE-21, Ottawa ON, 332 p., 1976.

Environment Canada, *Canadian Inland Waters: Coastal Environments and the Cleanup of Oil Spills*, EPS-3-EC-82-3, Report prepared by E.H. Owens for Environment Canada, Ottawa, ON, 33 p., 1982.

Environment Canada, *The Canadian Great Lakes: Coastal environments and the cleanup of oil spills*, EPS-3-EC-79-2, Report prepared by E.H. Owens for Environment Canada, Ottawa, ON, 252 p., 1979.

Ewing, J.T., W.D. Grimes, M. Baccigalopi, and A. McElroy, "Response Strategies to a Remote Inland Oil Spill and Fuel Transfer after a Hurricane", in *Proceedings of the International Oil Spill Conference (IOSC)*, pp. 969-972, 2008.

ExxonMobil, *Oil Spill Response Field Manual*, ExxonMobil Research and Engineering Company, 368 p., 2014.

Fieldhouse, B., "Dispersion Characteristics of Oil Treated with Surface Washing Agents for Shoreline Cleanup", in *Proceedings of the Thirty-first Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, pp. 373-394, 2008.

Fieldhouse, B., "Water-in-crude Oil Emulsion Formation and Stability for Crude Oils in Fresh, Brackish and Salt Water", in *Proceedings of the Thirtieth Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, pp. 897-901, 2007.

Fingas, M., B. Hollebone, and B. Fieldhouse, "The Density Behaviour of Heavy Oils in Freshwater: The Example of the Lake Wabamun Spill", in *Proceedings of the US EPA Freshwater Spill Symposium*, 15 p., 2006. https://archive.epa.gov/emergencies/content/fss/web/pdf/fingas_1.pdf

Fingas, M., *The Basics of Oil Spill Cleanup*, (2nd Ed.), Lewis Publishers, CRC Press, LLC, 233 p., 2001.

Fisheries and Oceans Canada, (2019). *Fluctuations in Lake Levels – types*. www.waterlevels.gc.ca/C&A/fluctuations-eng.html

Fitzpatrick, F., M. Boufadel, R. Johnson, K. Lee, T. Graan, A. Bejarano, Z. Zhu, D. Waterman, D. Capone, E. Hayter, S. Hamilton, T. Dekker, H. Garcia, and J. Hassan, *Oil-particle interactions and submergence from crude oil spills in marine and freshwater environments - Review of the science and future science needs*, U.S. Geological Survey Open-File Report 2015-1076, 33 p., 2015.

Foley, J.P. and S.J. Tresidder, "The St. Lawrence River Oil Spill of June 23, 1976 - Are You Ever Truly Ready?", in *Proceedings of the International Oil Spill Conference*, pp. 81-85, 1977.

French McCay, D.P., N. Whittier, T. Isaji, and W. Saunders, "Assessment of the Potential Impacts of Oil Spills in the James River, Virginia", in *Proceedings of the Twenty-sixth Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, pp. 857-877, 2003.

Fritz, D.E. and D. Mueller, "Inland In-Situ Burn Guide/Checklist", in *Proceedings of the International Oil Spill Conference (IOSC)*, 2011.

Fritz, D.E., "In Situ Burning of Spilled Oil in Freshwater Inland Regions of the United States", *Spill Science and Technology Bulletin*, 8(4): 331-335, 2003.

Fritz, D.E., "In-situ burning in inland regions", in *Proceedings of the Interspill Conference*, 10 p., 2006.

Fritz, D.E., E. Taylor, A.E. Steen, and J.R. Williams, "An Annotated Bibliography of Environmental and Human Health Effects from Inland Freshwater Oil Spills", in *Proceedings of the Seventeenth Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, pp. 501-504, 1994.

Gangstad, E.O., *Glossary of Biolimnological Terms*, Corps of Engineers, Washington, DC, 23 p., 1979.

Goodman, R.H., "Oil Spill Research: Salt Water and Fresh Water", in *Proceedings of the Twenty-ninth Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, pp. 195-198, 2006.

Goodman, R.H., "Wabamun: A Major Inland Spill", in *Proceedings of the US EPA Freshwater Spill Symposium*, 12 p., 2006. https://archive.epa.gov/emergencies/content/fss/web/pdf/goodman.pdf

Goudie, A., *Alphabetical Glossary of Geomorphology*, Version 1.0, International Association of Geomorphologists, 2014.

Government of Canada (2020). *Ice Archive - Search Criteria* https://iceweb1.cis.ec.gc.ca/Archive/page1.xhtml?lang=en

Government of Canada, Canadian Centre for Occupational Health and Safety (CCOHS) www.ccohs.ca

Government of Canada, Environment and Climate Change Canada, Water Office (2020. *Historical Hydrometric Data Search*. https://wateroffice.ec.gc.ca/search/historical_e.html

Government of Canada, *Beaufort Regional Coastal Sensitivity Atlas*, Environment Canada, Ottawa, ON, 387 p., 2015.

Goyer, D., K. Khun, A. Lamarche, C. Codjia, S. Laforest, and S. Grenon, "Automated Identification of Shoreline Types in a Freshwater Environment Using Imagery Collected with an Unmanned Aerial Vehicle (UAV)", in *Proceedings of the Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, pp. 218-229, 2018.

Grenon, S., D. Goyer, A. Lamarche, S. Macdonald, L. Zrum, and G. Nepveu, "Development of Area Specific Emergency Response Plans for Linear Energy Transport Infrastructure", in *Proceedings of the Forty-first Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, pp. 199-209, 2018.

Grenon, S., J. Howes, and E.H. Owens, "Application of SCAT Methodology in Fen following a Pipeline Spill", in *Proceedings of the Clean Gulf Conference*, 2014.

Guenette, C., "Case Studies from a Canadian Response Organization: 20 Years in Review", in *Proceedings of the International Oil Spill Conference (IOSC)*, 2017.

Hansen, K.A. and T.J. Coe, *Oil Spill Response in Fast Currents - A Field Guide*, U.S. Coast Guard Research and Development Center Report No. CG-D-01-02, 122 p., 2001.

Hansen, K.A. and P. Tebeau, *Oil Spill Response in Fast Water Currents: A Decision Tool*, U.S. Coast Guard Research and Development Center Report No. CG-D-03-03, 28 p., 2002.

Hansen, K.A., "Physical Spill Countermeasures on Water - Response in Fast Currents", in *Oil Spill Science and Technology*, M. Fingas (ed.), pp. 455-482, 2017.

Hansen, K.A., “Results for Oil-in-Ice Response Demonstration in the Great Lakes”, in *Proceedings of the Thirty-sixth Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, pp. 916-930, 2013.

Harper, J.R., G. Sergy, and L.A.S. Britton, u*SCAT Technical Reference Manual: Underwater Seabed Cleanup Assessment Technique for Sunken Oil*, Technical Report, Coastal and Ocean Resources, 99 p., 2018.

Hollebone, B.P. and Z. Yang, “Biofuels in the Environment: A Review of Behaviours, Fates, Effects and Possible Remediation Techniques”, in *Proceedings of the Thirty-second Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, pp. 127-139, 2009.

Hollebone, B.P., B. Fieldhouse, G. A. Sergy, P.G. Lambert, Z.D. Wang, C. Yang, M. Landriault, E.H. Owens, and H.A. Parker, “The Behaviour of Heavy Oil in a Fresh Water Lake”, in *Proceedings of the Thirty-fourth Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, pp. 668-709, 2011.

Horn, M. and D. French McCay, “Trajectory and Fate Modeling with Acute Effects Assessment of Hypothetical Spills of Diluted Bitumen into Rivers”, in *Proceedings of the Thirty-eighth Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, pp. 549-581, 2015.

Hospital, A., J. Henderson, P. Mazzocco, A. St.-Amand, M. Stephenson, J.A. Stronach, and H. Ward, “Stochastic Spill Modelling in Support of the Ecological Risk Assessment (ERA) of Hypothetical Pipeline Diluted Bitumen Spills in the Lower Fraser River as Part of the Trans Mountain Expansion Project”, in *Proceedings of the Thirty-ninth Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, pp. 35-57, 2016.

Hospital, A., J.A. Stronach, and J. Matthieu, “A Review of Oil Mineral Aggregates Formation Mechanisms for the Salish Sea and the Lower Fraser River”, in *Proceedings of the Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, pp. 434-454, 2016.

Howard, G.A., “Asphalt Barge MM53 and the Ohio River”, in *Proceedings of the International Oil Spill Conference (IOSC)*, pp. 957-962, 2008.

Hutchinson, G.E., *A treatise on limnology, Volume 1, Geography, Physics and Chemistry*, Wiley, New York, 1015 p., 1957.

IPIECA/API/IOGP, *Guidelines on implementing spill impact mitigation assessment (SIMA) – A technical support document to accompany the IPEICA-IOGP guidance on net environmental benefit analysis (NEBA)*, IOGP Report 593, 46 p., 2017.

IPIECA-IOGP, *A guide to oiled shoreline clean-up techniques: Good practice guidelines for incident management and emergency response personnel*, IOGP Report 521, 68 p., 2015.

IPIECA-IOGP, *Impacts of oil spills on shorelines: Good practice guidelines for incident management and emergency response personnel*, IOGP Report 534, 56 p., 2016.

IPIECA-IOGP, *Oil spill waste minimization and managment: Good practice guidelines for incident management and emergency response personnel*, IOGP Report 507, 52 p., 2014.

IPIECA-IOGP, *Oil spills: inland response - Good practice guidelines for incident management and emergency response personnel*, IOGP Report 514, 36 p., 2016.

IPIECA-IOGP, *Response strategy development using net environmental benefit analysis (NEBA) – Good practice guidelines for incident management and emergency response personnel*, IOGP Report 527, 44 p., 2015 (r2016).

ITOPF, *Fate of Marine Oil Spills*, ITOPF Technical Information Paper 2, 12 p., 2011.

Kellerhals, R. and M. Church, “The Morphology of Large Rivers: Characterization and Management”, in D.P. Dodge (ed.) *Proceedings of the International Large River Symposium*, Canadian Special Publication of Fisheries and Aquatic Sciences, pp. 31-48, 1989.

Laforest, S., M. Boule, and V. Martin, “Quebec Region’s Shoreline Segmentation in the St. Lawrence River: Response Tool for Oil Spills”, in *Proceedings of the Twenty-seventh Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, pp. 731-739, 2004.

Laforest, S., M. Boule, and V. Martin, “Quebec Region’s Shoreline Segmentation in the St. Lawrence River: Response Tool for Oil Spills”, in *Proceedings of the International Oil Spill Conference (IOSC)*, pp. 317-320, 2005.

Lamarche, A. and V. Martin, “Managing Shoreline Assessment Data during the Lake Wabamun Incident”, in *Proceedings of the Thirty-fourth Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, pp. 189-206, 2011.

Lambton, J.W., "Spill Response on Rivers, Lakes and Sheltered Marine Waters: An Alternative Approach", in *Proceedings of the Thirty-seventh Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, pp. 693-700, 2014.

Lambton, J.W., "Summary of Field Equipment Requirements for Responding to Riverine Oil Spills in Ice", *Spill Science and Technology Bulletin*, 7(3/4):173-181, 2002.

Lee, K., M. Boufadel, B. Chen, J. Foght, P. Hodson, S. Swanson, and A.D. Venosa, "High Priority Research Needs for Oil Spills in Canada: Summary of a Royal Society Expert Panel Report on the Behaviour and Environmental Impacts of Crude Oil Released into Aqueous Environments", in *Proceedings of the Thirty-ninth Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, pp. 966-991, 2016.

Lee, K., M. Boufadel, B. Chen, J. Foght, P. Hodson, S. Swanson, and A.D. Venosa, *Expert Panel Report on the Behaviour and Environmental Impacts of Crude Oil Released into Aqueous Environments*, Royal Society of Canada, Ottawa, ON, 489 p., 2015.

Lee, K., P. Stoffyn-Egli, and E.H. Owens, "The OSSA II Pipeline Oil Spill: Natural Mitigation of a Riverine Oil Spill by Oil–Mineral Aggregate Formation", *Spill Science and Technology Bulletin*, 7(3/4)149-154, 2002.

Luchun, R.E., "Open River Spills – Strategies and Tactics, A Primer", in *Seminar on Physical Recovery of Spills*, 20 p., 1992.

Massoura, S.T., "Shoreline Clean-up Methods: Biological Treatments", in *Proceedings of the Thirty-third Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, pp. 245-257, 2010.

McCleneghan, K., G.A. Reiter, J.E. Hardwick, and P.T. McGovern, "Management of Oil Spill Response and Cleanup in a River under Severe Winter Conditions", *Spill Science and Technology Bulletin*, 7(3/4):163-172, 2002.

McCourt, J. and L. Shier, "Preliminary Findings of Oil-Solids Interaction in Eight Alaskan Rivers", in *Proceedings of the Twenty-third Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, pp. 11-17, 2000.

McGowan, G, M. Algots, and J. Gravenmier, "Inland Geographic Response Plan (GRP) for Complex, Variable, Limited Access River Settings", in *Proceedings of the International Oil Spill Conference (IOSC)*, 11 p., 2017.

Michel, J. and E. DiMicco, “Operational Limiting Factors for Response to Spills Affecting Inland Waterways”, in *Proceedings of the Clean Gulf Conference*, 2017.

Michel, J. and K.A. Hansen, “Sunken and Submerged Oil”, in *Oil Spill Science and Technology,* M. Fingas (ed.), pp. 731-758, 2017.

Michel, J. and N. Rutherford, *Oil Spills in Marshes: Planning and Response Considerations*, Report for American Petroleum Institute, Technical Report 1146, 126 p., 2013.

Michel, J., C.B. Henry and S. Thumm, “*M/T Westchester* Oil Spill: Shoreline Assessment and Cleanup along the Lower Mississippi River”, in *Proceedings of the International Oil Spill Conference (IOSC)*, pp. 1109-1114, 2003.

Michel, J., C.B. Henry, and S. Thumm, “Shoreline Assessment and Environmental Impacts from the M/T Westchester Oil Spill in the Mississippi River”, *Spill Science and Technology Bulletin*, 7(3/4): 155-161, 2003.

Miley, K., “Management of Debris, Waste, and Operational Issues at a Multi-Jurisdictional Inland Oil Spill: A Coffeyville, Kansas, Refinery Oil Spill Case Study”, in *Proceedings of the International Oil Spill Conference (IOSC)*, 6 p., 2011.

Montgomery, D.R. and J.M. Buffington, “Channel Processes, Classification and Response”, in *River Ecology and Management*, R. Naiman and R. Bilby (eds.), Springer-Verlap, NY, pp. 13-42, 1998.

National Academy of Sciences, Engineering, and Medicine, *The Use of Dispersants in Marine Oil Spill Response*, The National Academies Press, Washington, DC, 377 p., 2019.

National Academy of Sciences, *Spills of Diluted Bitumen from Pipelines: A Comparative Study of Environmental Fate, Effects, and Response*, The National Academies Press, 167 p., 2016.

National Oceanic and Atmospheric Administration (NOAA), *Options for Minimizing Environmental Impacts of Freshwater Spill Response*, American Petroleum Institute Technical Report, 145 p., 1994.

National Oceanic and Atmospheric Administration (NOAA), *Shoreline Countermeasures Manual – Inland Oil Spills Template*, Hazardous Materials Response and Assessment Division, National Oceanic and Atmospheric Administration, Seattle, WA, 1992.

National Research Council (NRC), Spills of Non-floating Oils: Risk and Response, National Academy of Science, National Research Council, Washington, DC, 88 p., 1999.

National Wetlands Working Group, *The Canadian Wetland Classification System*, (2nd Edition), B.G. Warner and C.D.A. Rubec (eds.), Wetlands Research Centre, University of Waterloo, Waterloo, Ontario, 76 p., 1997.

Nepveu, G. and A. Lamarche, "Mobile SCAT Data Management and Mapping System to Support Oil Spill Response Teams", in *Proceedings of the Thirty-eighth Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, pp. 941-947, 2015.

Nuka Research and Planning Group, LLC, *Spill Tactics for Alaska Responders*, Report prepared for Alaska Department of Environmental Conservation, 274 p., 2014.

Oil Spill Response Limited (OSRL), *Inland Operations Field Guide: An operational guide to the containment and recovery of oil spills in the inland environment*, OSRL, 24 p., 2013.

Overstreet, R. and J.A. Galt, *Physical Processes Affecting the Movement and Spreading of Oils in Inland Waters*, US EPA HAZMAT Report 95-7, 58 p., 1995.

Owens Coastal Consultants Ltd., *Velocity Study of the Fraser River for Oil Spill Response: Summary of Fate and Behaviour of Spilled Oils into Rivers with a Focus on the Upper Fraser River*, BC, Report prepared for Husky Oil Operations Ltd., 25 p., 2013.

Owens, E.H. and C.E. Haselwimmer, "Recent Field Activities Using Unmanned Aerial System (UAS) Vehicles to Support Shoreline Oiling Assessment Programs", in *Proceedings of the Forty-first Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, pp. 230-253 , 2018.

Owens, E.H. and D.F. Dickens, *Guide on Oil Spill Response in Ice and Snow Conditions*, Report prepared for IMO, London, Publication number 1585E, 227 p., 2017.

Owens, E.H. and D.F. Dickens, *Guide to Oil Spill Response in Snow and Ice Conditions in the Arctic*, Report prepared for Arctic Council, Emergency Prevention, Preparedness and Response (EPPR), 184 p., 2015.

Owens, E.H. and G. A. Sergy, *A Field Guide to Oil Spill Response on Marine Shorelines*, Environment Canada, Ottawa, ON, 223 p., 2010.

Owens, E.H. and G.A. Sergy, "A Shoreline Response Decision-Making Process", in *Proceedings of the International Oil Spill Conference (IOSC)*, pp. 443-449, 2008.

Owens, E.H. and G.A. Sergy, "Treatment and Cleanup Standards: The Development of End-Point Criteria for Oil Spills", in *Proceedings of the International Oil Spill Conference (IOSC)*, pp. 1163-1169, 2003.

Owens, E.H. and G.A. Sergy, *The Arctic SCAT Manual – A Field Guide to the Documentation of Oiled Shorelines in Arctic Regions*, Environment Canada, Edmonton, AB, 172 p., 2004.

Owens, E.H. and G.A. Sergy, *Treatment Criteria and Endpoint Standards for Oiled Shorelines and Riverbanks*, Manuscript Report EE-171, Environment Canada, Ottawa, ON, 41 p., 2003.

Owens, E.H. and H.C. Dubach, *Subsurface Oil Detection and Delineation in Shoreline Sediments: Phase 2 – Field Guide*, Report for American Petroleum Institute, Technical Report No. 1149-2, 22 p., 2013.

Owens, E.H. and J. Michel, Options for Minimizing Environmental Impacts of Freshwater Spill Response, American Petroleum Institute Publication No. 4558, 135 p., 1995.

Owens, E.H. and J.Y. Nelson, *The Oil Spill Shoreline Cleanup and Assessment Team (SCAT) Manual for the Ontario Great Lakes and St. Lawrence River Shorelines, Procedures for the Assessment of Oiled Shorelines and Cleanup Options*, Environment Canada, Ottawa, ON, 243 p., 1995.

Owens, E.H. and K. Lee, "Interaction of oil and mineral fine on shorelines: review and assessment", *Marine Pollution Bulletin*, 47(9-12):397-405, 2003.

Owens, E.H. and L. Douglas, "Spill Response Strategies for Rivers in a Remote Deltaic Environment", in *Proceedings of the International Oil Spill Conference (IOSC)*, pp. 453-458, 1999.

Owens, E.H. and P. Bunker, "K9 SCAT Subsurface Oil Detection and Delineation Field Study on Coarse-Sediment Beaches in Prince William Sound, Alaska", in *Proceedings of the Forty- first Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, pp. 342-353 , 2018.

Owens, E.H. and P.D. Reimer, “River Shoreline Response and SCAT on the North Saskatchewan River: Streamlined Surveys, Segmentation, and Data Management Evolutions”, in *Proceedings of the Forty-first Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, pp. 318-341, 2018.

Owens, E.H. and R. Marty, “Freshwater Spills - Response Strategies and Physical Recovery”, in *Proceedings of the Seminar on Physical Recovery of Spills*, 11 p., 1992.

Owens, E.H. and T. Henshaw, “The OSSA II Pipeline Oil Spill: the Distribution of Oil, Cleanup Criteria, and Cleanup Operations”, S*pill Science and Technology Bulletin*, 7(3/4):119-134, 2002.

Owens, E.H., “A small river oil spill: A large step back for cleanup technology”, *Spill Technology Newsletter*, 7(1), Environmental Protection Service, Environment Canada, Ottawa ON, pp. 7-10, 1982.

Owens, E.H., “Classifying the coasts of the Canadian Great Lakes Great Lakes”, *Coastal Erosion and Sedimentation Workshop*, pp. 3-9, 1978.

Owens, E.H., “Contingency Plans and Response Strategies for Oil Spills into Rivers”, in *Proceedings of the Rio Pipeline Conference and Exposition*, 8 p., 2003.

Owens, E.H., “Response Strategies for Spills on Land”, *Spill Science and Technology Bulletin*, 7(3/4):115-117, 2002.

Owens, E.H., “Response to spills on land”, in *Proceedings of the Interspill Conference*, pp. 197-207, 2000.

Owens, E.H., “Shoreline Countermeasures”, in *Oil Spill Science and Technology*, M. Fingas (ed.), pp. 677-698, 2017.

Owens, E.H., *Canadian coastal environments, shoreline processes, and oil spill cleanup*, No. EC/ESD--EPS-3/SP/5. Environment Canada, Ottawa, ON, 360 p., 1994.

Owens, E.H., D. Fitzgerald, and J. Michel, “Job Aids for Shoreline protection on beaches and tidal inlets”, in *Proceedings of the Interspill Conference*, 5 p., 2012.

Owens, E.H., D.F. Dickens, and G.A. Sergy, “The behaviour and documentation of oil spilled on snow- and ice-covered shorelines”, in *Proceedings of the International Oil Spill Conference (IOSC)*, pp. 513-519, 2005.

Owens, E.H., E. Taylor, and H.A. Parker, "Spill site characterization in environmental forensic investigations", in *Standard Handbook Oil Spill Environmental Forensics*, 2nd ed., S.A. Stout and Z. Wang (eds.), pp. 1-24, 2016.

Owens, E.H., E. Taylor, R. Marty, and D.I. Little, "An Inland Oil Spill Response Manual to Minimize Adverse Environmental Impacts", in *Proceedings of the International Oil Spill Conference (IOSC)*, pp. 105-109, 1993.

Owens, E.H., *Field Guide for the Protection and Cleanup of Great Lakes Oiled Shorelines*, Environment Canada, Ottawa, ON, 211 p., 1996.

Owens, E.H., H.C. Dubach, P. Bunker, S. MacDonald, Z. Yang, P. Lambert, and S. Laforest, "Canine Oil Detection (K9-SCAT) following 2015 Releases from the *T/V Arrow Wreck*", in *Proceedings of the International Oil Spill Conference (IOSC)*, pp. 2629-2641, 2017.

Owens, E.H., L.B. Solsberg, and D.F. Dickins, *Field Guide for Oil Spill Response in Arctic Waters*, 2nd Edition, Report prepared for Arctic Council, Emergency Prevention, Preparedness and Response (EPPR), 443 p., 2017.

Parete, P., Detroit River Oil Spill Response, Environment Canada, Ontario Region, 25 p., 2002. https://archive.epa.gov/emergencies/content/fss/web/pdf/parete_04.pdf

Perez, S., P. Furlan, N. Hussein, D. Shinn, and R. Crook, "Interaction between oil and suspended sediments in class 1-2 rivers", in *Proceedings of the International Oil Spill Conference (IOSC)*, 2014.

Perth-Andover NB Fire Department (2020). *Ice Jam*. www.pafd.ca/ice-jam

Petts, G. and P. Calow, *River Flows and Channel Forms*, Blackwell, Oxford UK, 262 p., 1996.

Pfeifer, C., L. Coleman, C. Burns, J. McGaver, and A. Whelan, "Implementing the SCAT Process for a Major Inland Oil Spill: Lessons Learned from the Kalamazoo River Pipeline Release Incident", in *Proceedings of the International Oil Spill Conference (IOSC)*, 2011. https://ioscproceedings.org/doi/pdf/10.7901/2169-3358-2011-1-424

Piraino, E., E.H. Owens, J. Rios, and A. Graham, "Oil behaviour and the response to a sunken oil spill of slurry in Quintero Bay, Chile", in *Proceedings of the International Oil Spill Conference (IOSC)*, 10 p., 2017.

POSOW, *Oiled Shoreline Cleanup Manual*, Preparedness for Oil-polluted Shoreline Cleanup and Oiled Wildlife Interventions (POSOW), 62 p., 2013. www.posow.org/documentation/cleanupmanual.pdf

Prairie Climate Centre, (2020). *Climate Atlas*. https://climateatlas.ca/map/canada/frostdays_2060_85#lat=57.8&lng=-90.62

RMB Environmental Laboratories Inc., (2020). *Lakes Monitoring Program*. www.rmbel.info/primer/lake-trophic-states-2

Roberts, A., *River Processes: An Introduction to Fluvial Dynamics*, Routledge, 224 p., 2003.

Robertson, D.R. and J.H. Maddox, "Shoreline Surface Washing Agent Test and Evaluation Protocol for Freshwater Use in the Great Lakes Region", in *Proceedings of the International Oil Spill Conference (IOSC)*, pp. 319-325, 2003.

Rosgen, D.L., "A classification of natural rivers", *Catena*, 22:169-199, 1994.

Schmidt Etkin, D., D. French McCay, and J. Rowe, "Use of Trajectory Modeling to Analyze Variations on the Response Strategies for Inland Spills", in *Proceedings of the US EPA Freshwater Spill Symposium*, 15 p., 2006. https://archive.epa.gov/emergencies/content/fss/web/pdf/etkin_1.pdf

Schumm, S.A., Patterns of Alluvial Rivers, *Rev. Earth and Planetary Sciences*, 13:5-27, 1985.

Schumm, S.A., *The Fluvial System*, Wiley-Interscience, New York, 338 p., 1977.

Sergy, G.A. and E.H. Owens, "Differences and Similarities in Freshwater and Marine Shoreline Oil Spill Response", in *Proceedings of the International Oil Spill Conference (IOSC)*, 10 p., 2011.

Sergy, G.A. and E.H. Owens, "Indices to Rate the Degree of Oiling on Shorelines", in *Proceedings of the Thirty-second Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, pp. 167-175, 2009.

Sergy, G.A. and E.H. Owens, "Selection and Use of Shoreline Treatment Endpoints for Oil Spill Response", in *Proceedings of the International Oil Spill Conference (IOSC)*, pp. 435-441, 2008.

Sergy, G.A. and E.H. Owens, *Guidelines for Selecting Shoreline Treatment Endpoints for Oil Spill Response*, Emergencies Science and Technology Division, Environment Canada, Ottawa, ON, 30 p., 2007.

Sergy, G.A., "The Environment Canada Standard Shoreline Classification Scheme for SCAT and Oil Spill Response in Canada", in *Proceedings of the Thirty-first Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, pp. 811-819, 2008.

Sergy, G.A., A. Lamarche, E.H. Owens, P.D. Reimer, and L. Zrum, "SCAT Shoreline and Nearshore Surveys following the Lake Wabamun Oil Spill", in *Proceedings of the Thirty-fourth Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, 710-728 p., 2011.

Sergy, G.A., J. Harper, S. Laforest, and P.G. Lambert, "Scientific Support Information and Response Guidance for Dilbit Spills Impacting Marine Shorelines", in *Proceedings of the Fortieth Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, pp. 50-66, 2017.

Sienkiewicz, A.M. and E.H. Owens, "Stream-bank Cleanup Assessment Team (SCAT) survey techniques on the Kolva River basin oil recovery and mitigation project", in *Proceedings of the Nineteenth Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, pp. 1321-1333, 1996.

Solsberg, L.B., N.W. Glover, and M.T. Bronson, "Best Available Technology for Oil in Ice", in *Proceedings of the Twenty-fifth Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, pp. 1207-1224, 2002.

Splinter, D.K. and B.K. Marston (2016). http://dx.doi.org/10.1093/obo/9780199874002-0126

Steen, A., D.E. Fritz, W. Stubblefield, and J. Giddings, "Environmental Effects of Freshwater Oil Spills", in *Proceedings of the International Oil Spill Conference (IOSC)*, pp. 607-612, 1999.

Stephenson, M., J. Henderson, P. Mazzocco, and A. St.-Amand, "Ecological Risk Assessment of Hypothetical Spills of Diluted Bitumen in Rivers", in *Proceedings of the Thirty-eighth Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, pp. 607-630, 2015.

Taylor, E.T., *Technical Data Report: River Control Points for Oil Spill Response*, Polaris Applied Sciences Inc., 100 p., 2010.

Thormann, M.N. and S.E. Bayley, *Impacts of the CN Rail Oil Spill on Softstem Bulrush-Dominated Lacustrine Marshes in Wabamun Lake*, Report prepared for Alberta Environment, AB, 66 p., 2008.

Törling, G., "Response to spills in inland and coastal waters", in *Proceedings of the Interspill Conference*, 2000.

United States Coast Guard, *Incident Management Handbook, Incident Command System (ICS)*, COMDTPUB P3120.17B, Washington, DC 20593, 2014

United States Department of Agriculture (USDA), "Rosgen Geomorphic Channel Design", Part 654 in *Stream Restoration Design National Engineering Handbook*, Chap. 11, 82 p. 2007.

US Army Corps of Engineers, Detroit District, (2019). *Great Lakes Hydraulics and Hydrology*. www.lre.usace.army.mil/Missions/Great-Lakes-Information/Great-Lakes-Information-2/Water-Level-Data

US Environmental Protection Agency (US EPA), *FOSC Desk Report for the Enbridge Line 6b Oil Spill Marshall*, Michigan, US EPA, 241 p., 2016.

US EPA, (2018). *Classification and Types of Wetlands. Classification of Wetlands*. www.epa.gov/wetlands/classification-and-types-wetlands#marshes

Venosa, A.D. and X. Zhu, "Biodegradation of Crude Oil Contaminating Marine Shorelines and Freshwater Wetlands", *Spill Science and Technology Bulletin*, 8(2):163-178, 203.

Wang, Z., M. Fingas, P. Lambert, G. Zeng, C. Yang, and B. Hollebone, "Characterization and identification of the Detroit River mystery oil spill (2002)", Journal of Chromatography A, 1038(1–2):201-214, 2004. www.sciencedirect.com/science/article/pii/S0021967304003917

Wang, Z.D., M. Fingas, S. Blenkinsopp, G. Sergy, M. Landriault, L. Sigouin, and P. Lambert, "Study of the 25-Year-Old Nipisi Oil Spill: Persistence of Oil Residues and Comparisons between Surface and Subsurface Sediments", *Environ. Sci. Technol.*, 32:2222-2232, 1998.

Wang, Z.D., M.F. Fingas, and P.G. Lambert, "Characterization and Identification of Detroit River Mystery Oil Spill", in *Proceedings of the Twenty-sixth Arctic and Marine Oilspill Program (AMOP) Technical Seminar*, pp. 169-192, 2003.

Whelan, A., J. Clark, G. Andrew, J. Michel, B. Benggio, "Developing cleanup endpoints for inland oil spills", in *Proceedings of the International Oil Spill Conference (IOSC)*, 2014.

Wikipedia (1976), *NEPCO 140 oil spill*. https://en.wikipedia.org/wiki/NEPCO_140_oil_spill

Wikipedia (1988), *Ashland spill*. https://en.wikipedia.org/wiki/Ashland_oil_spill

Wikipedia, (2010) *Kalamazoo River oil spill*. https://en.wikipedia.org/wiki/Kalamazoo_River_oil_spill

Williams, G.W., A.A. Allen, R. Gondek, and J. Michel, "Use of in Situ Burning at a Diesel Spill in Wetlands and Salt Flats, Northern Utah, U.S.A: Remediation Operations and 1.5 Years of Post-Burn Monitoring", in *Proceedings of the International Oil Spill Conference (IOSC)*, pp. 109-113, 2003.

Wood, P. and R. Swannell, "Response to spills involving ground penetration and contaminated land remediation", in *Proceedings of the Interspill Conference*, pp. 208-240, 2000.

Wynja, V., A-M. Demers, S. Laforest, M. Lacelle, J. Pasher, J. Duffe, B. Chaudhary, H. Wang, and T. Giles, "Mapping Coastal Information across Canada's Northern Region on Low-altitude Helicopter Videography in Support of Emergency Preparedness Efforts", *Journal of Coastal Research*, 31(2):276-290, 2015.

Yapa, P.D., H.T. Shen, and K.S. Angammana, "Modeling Oil Spills in a River-Lake System", *Journal of Marine Systems*, 4:453-471, 1994.

11 | Shoreline Forms

Management Forms

The following forms provide templates to aid in the management of the shoreline program; they may be modified to align with specific requirements defined in various provincial statues. For example, in the Saskatchewan Environmental Code a Corrective Action Plan (CAP) may be used in place of the standard Shoreline Treatment Recommendations (STR). For additional forms refer to ECCC (2018).

Shoreline Treatment Recommendation (STR) Form

Incident: ____ **STR #:** ____ **Survey Date:** ____

Site Location (Coordinates) ____

Segment: ____ **STR shoreline Length (m):** ____ **STR Width (m):** ____

Shoreline Type: ____ **Substrate(s)** ____ **Character:** ____

Box 1 - Oiled Area for Treatment (SCAT / EU)

Box 2 - Treatment Recommendations (SCAT / EU)

Box 3 - Staging and-or Logistic Recomendations / Constraints / Waste Issues (SCAT / OPS)

Box 4 - Ecological Resource Issues Comments

Box 5 - Historical / Cultural / First Nations Issues Comments

Box6 - Safety Issues Comments (SCAT / EU / OPS / Response Safety Officer)

Attached: ☐ Segment Map ☐ Sketch Map ☐ SOS Form ☐ Fact Sheet Other ____

STR APPROVALS Signatures (Stake Holder)

( )	( )	( )
( )	( )	( )

Prepared By: ____ **Date Prepared:** ____

Date							
Time							
	To ( )	To ( )	To ( )	To ( )	To ( )	To ( )	To ( )

Generated from the SCAT Database

Post Treatment Assessment (PTA) Form (STR Number:)

Segment ID:________________________ **Assessors Name :** ____________________

Survey Date:________________________ **Survey Time:**______:______ **to** ______:______
(dd/mmm/yyyy) (Please use 24 hour time)

Water Level:________________________ **Weather:**___________________________

Inspection Completed Along Entire Segment: Yes / No

Result/Recommendation:

☐ Segment is Ready for SIR

(Describe work completed to meet STR requirements)

☐ Continue with STR

(Provide written details of issues and required actions)

☐ Additional Treatment Recommended – new or modified STR

(Provide written details of issues and required actions)

MAP: Yes / No | SKETCH: Yes / No | PHOTOS / VIDEO: Yes / No (-)

TRACKLINE: Yes / No | WAYPOINTS: Yes / No

Photographer/Camera(s):____________________ GPS Person/Device:_______________________

Shoreline Inspection Report (SIR)

Incident: ____

Segment ID:____________________**Team Lead:**___________________________

Survey Date:____________________**Survey Time:**___________________________

Water Level:____________________**Weather:**___________________________

Inspection Completed Along Entire Segment: Yes No

Result/Recommendation:

- ☐ No oil observed (NOO)
- ☐ Meets established NFT criteria
- ☐ No further treatment recommended (NEB / ALARP / Safety / Access / Other)

Survey Team Members:

STAKE HOLDER (RP, agency) / FN	NAME (representative)	SIGNATURE

- ☐ Further treatment recommended (continue under existing STR)
- ☐ Additional treatment recommended (provide documentation and comments)
  Prepare new STR as required

(Provide written details of observations, issues and required actions)

Field Forms

SOS field forms should be selected and **modified as appropriate** to include new terms or definitions that describe oiling conditions or features specific to an incident. The following Table lists examples and a description for those forms that would need to be modified for specific environments. For additional forms refer to ECCC (2018).

Field Form 1 *Lake Temperate SOS*

LAKE TEMPERATE (SOS) Form **Incident:** ______________________________ **Page**______ **of** ______

1.GENERAL INFORMATION	**Date** (dd/mmm/yyyy)	**Time** (24h standard/daylight) _____:_____ to _____:_____	Water Level: ____________ Low / Mean / High / Flood Falling / Steady / Rising
Segment ID:	Segment Location:		
Survey Type:	Ops Zone:	STR #:	

Survey By: Foot __ ATV__ Boat__ Overlook___ Helicopter__ sUAS__ Other _____________	**Weather**: Sun / Clouds / Fog / Rain / Snow Windy / Calm	**Exposure**: Exposed / Semi-Exposed Semi-Protected / Protected / Very Protected

2. SURVEY TEAM	**Name**	**Organization**	**Name**	**Organization**
Team Number				

3. SEGMENT	Total Length: (m)	Length Surveyed: (m)	Maximum Shoreline Width: (m)	
Survey Start GPS:	WP:	LAT: .	LONG: .	Entire Segment Surveyed Yes / No	Datum:
Survey End GPS:	WP:	LAT: .	LONG: .		

4a. SHORELINE TYPE *Indicate only ONE Primary(dominant) type and ALL Secondary types. CIRCLE those OILED*

BEDROCK: Cliff____ Ramp____ Shelf____
Sediment Cliff/Bluff ____
MAN-MADE: Solid ____ Permeable____
Description:________________________
ESI code (primary) _____ (secondary) ______

Sediment BEACH: Sand___ Mixed___ Pebble/Cobble___ Boulder___ Organic ___
Sediment FLAT: Mud___ Sand ___ Mixed___
WETLAND: Reed/Rush (deeper) ____ Grassy (shallow, nearshore) ____
Vegetated Shore ____ Woody Material ____
Tundra ____ TYPE: ________________
OTHER:________________________________ *Snow-Covered or Ice use Winter SOS*

4b. BACKSHORE CHARACTER *Indicate only ONE Primary (P) and ANY Secondary (S) types.*

Cliff/Hill:____ ht._____ m. Flat / Lowland / Field:____ | Beach____ Dune____ Inlet/Channel____ Delta____ Lagoon____ Wetland____
Sloped: > (5^o) (15^o) (30^o) Wooded/Vegetated/Grass | Man-Made____:______________________Other:_________________________

5. OPERATIONAL FEATURES	Debris: Types _________________________	Oiled: Yes / No	Amount: (bags/trucks)
Direct backshore access? Yes / No	Alongshore access adjacent segment? Left / Right / Both / No	Suitable for backshore staging? Yes / No	
Access Description / Restrictions:			Strong Currents? Yes / No

6. OILING DESCRIPTION: *Use letters A-Z, Indicate 100% overlapping oil zones in different swash zones by numbering them (e.g. A1, A2)*

Zone ID	WP Zone Start	WP Zone End	Substrate Type(s) or ESI Code	Swash Zone			Oil Cover						Oil Thickness					Oil Character							
							Area		Distribution		Size														
				LSZ	USZ	SSZ	Length (m)	Width (m)	Dist % (> 1) or	Number per unit area	Avg Size (cm)	Large Size (cm)	TO	CV	CT	ST	FL	FR	MS	TB	PT	TC	SR	AP	NO

7. SUBSURFACE OILING CONDITIONS: *Format: Indicate Zone ID in Pit #, e.g., A-1, B-2, B-3, (use only number if not in zone e.g. 4 , 5)*

Pit #	WP #	Substrate Type Surface/Subsurface	Swash Zone			Pit Depth (cm)	Oiled Interval (cm-cm)	Subsurface Oil Character								Water Table (cm)	Sheen Color B,R,S,N	Clean Below Yes / No
			LSZ	USZ	SSZ			AP	OP	PP	OR	OF	TR	NO	%			
		/					-											
		/					-											
		/					-											
		/					-											
		/					-											
		/					-											

8. COMMENTS: Cleanup Recommendations; Ecological/Recreational/Cultural/Economic Issues; Wildlife Observations; Other Descriptions

MAP: Yes / No | SKETCH: Yes / No | PHOTOS / VIDEO: Yes / No (-) | TRACKLINE: Yes / No | WAYPOINTS: Yes / No
Form Completed By: | Photographer(s): | GPS Person / Unit:

RIVER (SOS) Form **Incident:**____ **Page**______ **of** ______

1. GENERAL INFORMATION	**Date** (dd/mmm/yyyy)	**Time** (24h standard/daylight) _____:_____ to _____:_____	Gauge Location: _________________ Water Level: __________ m Low / Mean / Bankfull / Overbank Falling / Steady / Rising
Segment ID:	**Bank:** L / R / MC ____	**Segment Location:**	
Survey Type: RECON **/** SCA / SIR / PTA / ________		**Ops Zone:**	**STR #:**

Survey By: Foot __ ATV__ Boat__ Helicopter__ sUAS __ Other ________ | Weather: Sun / Overcast / Fog / Rain / Snow | Windy / Calm

2. SURVEY TEAM	Name	Organization	Signature	Name	Organization	Signature
Team Number						
K9 (Yes / No)						

3. SEGMENT	Total Length: (m)	Length Surveyed: (m)	Maximum Bank Width: (m)	
Survey Start GPS:	WP:	LAT: .	LONG: .	Entire Segment Surveyed Yes / No	Datum:
Survey End GPS:	WP:	LAT: .	LONG: .		

4a. SHORE TYPE: *Indicate only ONE Primary(dominant) type and ALL Secondary types. , circle specifics as appropriate*

BEDROCK: Cliff_____ Ramp_____ Shelf_____
Sediment Cut Bank _____
MAN-MADE: Solid______ Permeable______
Description:__________________________________
ESI Code (primary) _________ (secondary) _________

Sediment BANK: Mud__ Sand__ Mixed__ Pebble/Cobble__ Boulder__ Organic __
Sediment FLAT: Mud__ Sand __ Mixed__
WETLAND: Reed/Rush (deeper) ____ Grassy (shallow, nearshore) _____
Vegetated Bank _____ Woody Material _____
Vegetated/Wooded-Upland _____ Tundra ____ TYPE: ________________
OTHER:_____________________________ *Snow-Covered or Ice use Winter SOS*

4b. OVERBANK / BACKSHORE TYPE: *Indicate only ONE Primary (P) and ANY Secondary (S) types, , circle specifics as appropriate*

Cliff/Hill:____ ht._____ m. Sloped: > (5^0) (15^0) (30^o)
Flat/Lowland/Field____ (Rock/Bare/Wooded/Vegetated)

Dune___ Inlet/Channel____ Delta____ Lake/Pond ____ Marsh/Wetland____
Man-Made____:_________________________ Other:__________________

4c. RIVER CHARACTER: *Circle or select as appropriate.*

Channel Width: <10 m 10-100 m >100 m estimate _______ m
Water Depth: <1 m 1-5 m >5 m estimate_______ m

Shoal(s) Present: Y / N Bars Present: Y / N
Bar-Shoal substrate: silt /sand/mixed/cobble/boulder/bedrock/debris

VALLEY FORM: Canyon ____ Confined or Leveed Channel ____ Flood Plain Valley ____ Other: ______________________________
RIVER FORM: Straight ____ Meander ____ Anastomosed ____ Braided ____ Other: ______________________________
CHANNEL FORM: Cascade ____ Rapids ____ Pool ____ Riffle ____ Glide ____ Jam ____ Other:______________________________

5. OPERATIONAL FEATURES	Debris Types:	Oiled: Yes / No	Amount: (bags/trucks)
Direct backshore access: Yes / No	Alongshore access adjacent segment: Up / Down / Both / No	Suitable for backshore staging: Yes / No	
Access Description / Restrictions:			Strong Currents: Yes / No

6. OILING DESCRIPTION: *Indicate 100% overlapping oil zones in different river bank zones by adding a sub-Id designation (e.g. Aa, Ab, Ac)*

Zone ID	WP # Zone Start	WP # Zone End	River Bank Material & Form Codes	River Bank Zone				Oil Cover: Area		Distribution		Size		Oil Thickness					Oil Character								BURIED	STATUS
				MS	LB	UB	OB	Length (m)	Width (m)	Dist % or (> 1)	Number per unit area	Avg Size (cm)	Large Size (cm)	TO	CV	CT	ST	FL	FR	MS	MT	PT	BA	OC	SR	SN		

7. SUBSURFACE OILING CONDITIONS: *Format: Indicate Zone ID in Pit #, e.g., A-1, B-2, B-3, (use only number if not in zone e.g. 4 , 5)*

Pit #	WP #	Substrate Type Surface/Subsurface	River Bank Zone				Pit Depth (cm)	Oiled Interval (cm-cm)	Subsurface Oil Character								Water Table (cm)	Sheen Color B,R,S,N	Clean Below Yes / No
			MS	LB	UB	OB			AP	OP	PP	OR	OF	TR	NO	%			
		/						-											
		/						-											
		/						-											

8. COMMENTS: Cleanup Recommendations; Ecological/Recreational/Cultural/Economic Issues; Wildlife Observations; Other Descriptions

**Use RIVER Supplemental (SOS) Form for additional oiling zones, pits, and comments/sketches.*

MAP: Yes / No | SKETCH: Yes / No | PHOTOS / VIDEO: Yes / No (-) | TRACKLINE: Yes / No | WAYPOINTS: Yes / No
Form Completed By: | Photographer(s): | GPS Person / Unit:

<u>Please Print Double Sided</u>

(6) Oiling Descriptions (Please insure this data is fully completed to allow oil zone category and status processing and mapping)

- Document initial survey zone oiling information. <u>If Complete-As-You-Go (CAYG) treatment is conducted, complete an "**after treatment**" description of the zone on a separate line</u>, label the zones A1 and A2 respectively ***(<u>Not to be confused with across-shore zone numbering with 100% overlapping zones, that uses a,b,c seconday zone codes, i.e. Aa, Ab, Ac.</u>*** *Codes can be combined as required, i.e. Aa1, Aa2*
- Oil thickness/character types reflect the nature of the oiling on the shoreline, indicate as many as present, **<u>circle the primary.</u>** Sub-codes can be used to further define the oiling character by placing a code in the oil character box instead of an "X" or check mark.
  -

Oiling Character Codes	***Oiling Character Sub-Codes)***
FR = Fresh (typically liquid oil product)	
MS = Mousse (emulsified oil product)	
MT = Oil Mats (> 50cm) - oil conglomerates with varying degrees of mixed sediment, wood, debris and vegetation)	D = debris, V = vegetation, S = sunken, i.e. "D" indicates oiled debris mats (ODM)
PT = Patties (10-50cm) - typically weathered oil product with mixed sediment, debris and vegetation	R = residue, implies more sediment, D = Debris, V= Vegetation
BA = Balls (< 10cm) – typically weathered oil product with mixed sediment, debris and vegetation)	R = residue, implies more sediment, D = Debris, V= Vegetation, i.e. "D" indicates oiled debris ball (ODB)
OC = Oil coat/cover (typically on coarser sediments, debris (including logs and woody debris) or manmade features	F = fresh, W = weathered, S = Sticky
SR = Sediment residue (typically in-cohesive oil product mixed with surface sediments	A = asphalt, implies more cohesive mixture
SN = Surface Sheen	B = Brown, R = Rainbow, S= Silver

Note: The "NO" (no "observed" oil) character is no longer included in the oil character section, if no oil is observed in the zone this is now reported in the zone status column as described below.

- A new column has been added to the far right side of the oil zone section (Box 6) to allow documentation of a "**STATUS**" criterion for each individual zone in the segment, providing additional metrics on oiling assessments and treatment activities for tracking.
  (1) NOO (use this column to describe a "No observed oil" character zone)
  (2) Oiling meets endpoints; therefore No Further Treatment (NFT)
  (3) Oiling does not meet endpoints; however NFT is recommended (NEB, ALARP, Access, Monitor, or Safety); provide details
  (4) Oiling does not meet endpoints, however was removed by CAYG crew at the time of the SCAT survey
  Please ensure that an <u>After Treatment</u> zone description is recorded on a separate line
  (5) Oiling does not meet endpoints; however above CAYG capability, will require inclusion in a small operations actions plan.
  (6) Oiling does not meet endpoints; requires a site-specific Shoreline Treatment Recommendation (STR) plan
- A column has been added to indicate if any of the observed oiling in the zone is buried or partially buried (below 5cm). This does not replace the need to dig and document pits to delineate and describe subsurface oiling, however can be used to describe minor burial, i.e. a partially buried tar patty or indications of subsurface sheen. This box should be checked in all cases where there is any evidence of subsurface oiling or burial within the zone. As with the surface oiling use codes to further describe the subsurface oiling character, i.e. MS,BA,PT,SR,SN
- Survey method (foot, boat, K9) is important to considerations of confidence. This is reported in general in the header information in section (1), however survey methods often change with respect to individual zones. In order to record these changes, the use of sub-codes has been introduced to the "River Bank Zone" section of section (6) by simply using codes (F) foot, (B) boat, (K) Canine, (A) air, (U) Uav in the zone category instead of a simple "X" or check mark.
- The river segmentation is based on set 1 km distances downstream from the Point of Entry (POE) and not on changes in shoreline character as is typical in marine segmentation. Therefore, it is important to record the substrate and shoreline form within zones to fully document the shoreline character associated with the oiling along the river. *Even where there is no oiling observed (NOO), major changes in shoreline character should be documented with separate zones, i.e. eroding soil bank changing to vegetated flats.*
  Primary Zone Character Codes: Substrate / Form (*use two letters VB or separate with slash V/B, first code is always substrate)*

  (Examples: VB = vegetated banks, KE = soil eroding bank, TF = willow flats, VF = vegetated flats, SF= sand flats, WD = woody debris CA = riprap, AD = manmade debris, *RA = other manmade: describe in comments, i.e. concrete bulkhead)*

Substrate or Material		Form	
Name	Code	Name	Code
Bedrock	B	Cliff	C
Mud (silt and/or clay)	M	Platform or Shelf	P
Fines (mixed sand & mud)	F	Bank	B
Sand	S	Eroding Bank or Undercut	E
Mixed (sand, pebble, cobble)	X	Flats	F
Coarse (pebble, cobble, boulder, riprap)	C	Shoals (shoals, bars)	S
Organic (decaying wood, veg, peat, etc.)	O	Wetland (marsh, swamp)	W
Soil	K	Outcrop	O
Undifferentiated (mixed-stratified sediments)	U	Debris	D
Vegetated (grass, shrubs, plants, etc.)	V	Anthropogenic – Manmade)	A
Trees (i.e. willows)	T	Other (describe in comments)	R
Wood (i.e. sticks and logs)	W		
Anthropogenic (plastic bottles, etc.)	A		
Other (describe in comments)	R		

RIVER Winter (SOS) Form **Incident:**____ **Page**______ **of** ______

1.GENERAL INFORMATION		**Date** (dd/mmm/yyyy)	**Time** (24h standard/daylight) _____:_____ to _____:_____	**Water Level**
Segment ID:	**Bank:** L / R	**Segment Name:**		Low / Mean / Bank-full / Overbank
Ops Zone:		**Survey Type:**	**STR:**	Falling / Steady / Rising
Survey By: Foot ___ ATV___ Boat___ Helicopter___ sUAV ___ Other:____			Weather: Sun / Clouds / Fog / Rain / Snow | Windy / Calm Season: Open Water/Freeze-Up Transition/Frozen Period/Breakup-Thaw	

2. SURVEY TEAM	Name	Organization	Name	Organization
Team Number				

3. SEGMENT		Total Length: (m)	Length Surveyed: (m)	Maximum Bank Width (m)	
Survey Start GPS:	WP:	LAT: .	LONG: .	Entire Segment Surveyed Yes / No	Datum:
Survey Start GPS:	WP:	LAT: .	LONG: .		

4a. SHORE TYPE: *Indicate only ONE Primary(dominant) type and ALL Secondary types. CIRCLE those OILED*

BEDROCK: Cliff_____ Ramp_____ Shelf_____
Sediment Cut Bank _____
MAN-MADE: Solid______ Permeable______
Description:______________________________________
ESI Code (primary) _________ (secondary) _________

Sediment BANK: Mud__ Sand__ Mixed__ Pebble/Cobble__ Boulder__ Organic __
Sediment FLAT: Mud__ Sand __ Mixed__
WETLAND: Reed/Rush (deeper) _____ Grassy (shallow, nearshore) _____
Vegetated Bank _____ Woody Material _____
Vegetated/Wooded-Upland _____ Tundra _____ TYPE: ________________
OTHER:______________________________ *Snow-Covered or Ice use Winter SOS*

4b. SNOW AND ICE CONDITIONS: *Circle all bank/ bar locations as necessary – Midstream : Lower : Upper : Overbank*

Snow: Cover________(%) Thickness________(cm) Fresh: Y / N Compacted: Y / N Location: MS LB UB OB

Ice Type	**Width (m)**	**Thickness (cm)**	**Location**	**Other Descriptions**
Frozen Spray			N/A	
Ice Foot			MS LB UB OB	
Ice Ridges			MS LB UB OB	
Frozen Swash			MS LB UB OB	
Grounded Floes			MS LB UB OB	

4c. RIVER ICE CONDITIONS: *Circle one in each of the three categories*

CONCENTRATION: 0 / 10	**FORM: (m)**		**AGE and Thickness (cm)**
Open Drift <1/ 10	None		New = frazil – grease – slush
Very Open Drift 1/10 – 3/10	Pancake 0.3 – 3	Small Floes: 20 – 100	Nilas or ice rind <10
Open Drift 4/10 – 6/10	Brash <2	Medium Floes 100 – 500	Young: grey-white 10 – 30
Close Pack 7/10 – 8/10	Ice Cakes <20	Large Floe: 500 – 2000	>30
Very Close Pack 9/10		Vast-Giant Floe >2000	>250
Solid 10/10	Fast Ice: Y / N	Bank Cracks: Y / N	>300

Ice Movement: STATIC Y / N - BREAKUP/CREEPING SLOWLY Y / N - BREAKUP/MOVING RAPIDLY Y / N

4d. OVERBANK / BACKSHORE TYPE: *Indicate only ONE Primary (P) and ANY Secondary (S) types.*

Cliff/Hill:____ ht._____ m. | Flat/Lowland:____ Beach:____ Dune:____ Inlet/Channel:____ Delta:____ Lagoon:____ Marsh/Wetland:____
Sloped: > (5^0) (15^0) (30^o) | Man-Made: ___ Type ______________--- Tundra / Forested / Vegetated Primary Substrate: ___________

5. OPERATIONAL FEATURES	Oiled Debris? Yes / No	Type:	Amount: (bags/trucks)
Direct backshore access? Yes / No	Alongshore access from next segment? Yes / No		Suitable for backshore staging? Yes / No
Access Description / Restrictions:			Current Dominated Channel? Yes / No

6. OILING DESCRIPTION: *Use letters A-Z, Indicate 100% overlapping oil zones in different tidal zones by numbering them (e.g. A1, A2)*

Zone ID	WP # Start	WP # End	Substrate Type(s) or ESI Code	Bank Zone				Oil Cover						Oil Thickness					Oil Character							
								Area		Distribution		Size														
				MS	LB	UB	OB	Length (m)	Width (m)	Dist % (> 1) or	Number per unit area	Avg Size (cm)	Large Size (cm)	TO	CV	CT	ST	FL	FR	MS	TB	PT	TC	SR	AP	NO

7. SUBSURFACE OILING CONDITIONS: *Use RIVER Supplemental (SOS) Form for pits.*

8. COMMENTS: *Use RIVER Supplemental (SOS) Form for comments/sketches.*

Sketch / Map: Yes / No Photos/Video: Yes / No Numbers: (-) Photographer Name:

Field Form 4 *River Supplemental SOS*

RIVER Supplemental (SOS) Form **Incident:**______________________ **Page**______ **of** ______

1.GENERAL INFORMATION	**Date** (dd/mmm/yyyy)		**Time** (24h standard/daylight) _____:_____ to _____:_____	**Water Level** ____________
Segment ID:	**Bank:** L / R / MC	**Segment Location:**		Low / Mean / Bankfull / Overbank
Survey Type:	**Team #:**	**Ops Zone:**	**STR #:**	Falling / Steady / Rising
Survey By: Foot __ ATV__ Boat__ Helicopter __ sUAS __ Other _______			Weather: Sun / Clouds / Fog / Rain / Snow |	Windy / Calm

6. OILING DESCRIPTION: *Indicate 100% overlapping oil zones in different river bank zones by numbering them (e.g. A1, A2)*

Zone ID	WP # Zone Start	WP # Zone End	Substrate Type(s) or ESI Code	River Bank Zone				Oil Cover						Oil Thickness					Oil Character								
								Area		Distribution		Size															
				MS	LB	UB	OB	Length (m)	Width (m)	Dist % (> 1) or	Number per unit area	Avg Size (cm)	Large Size (cm)	TO	CV	CT	ST	FL	FR	MS	TB	PT	TC	SR	AP	SN	NO

7. SUBSURFACE OILING CONDITIONS: *Format: Indicate Zone ID in Pit #, e.g., A-1, B-2, B-3, (use only number if not in zone e.g. 4 , 5)*

Pit #	WP #	Substrate Type Surface/Subsurface	River Bank Zone				Pit Depth (cm)	Oiled Interval (cm-cm)	Subsurface Oil Character								Water Table (cm)	Sheen Color B,R,S,N	Clean Below Yes / No
			MS	LB	UB	OB			AP	OP	PP	OR	OF	TR	NO	%			
		/						-											
		/						-											
		/						-											
		/						-											
		/						-											
		/						-											
		/						-											
		/						-											

8. COMMENTS: Cleanup Recommendations; Ecological/Recreational/Cultural/Economic Issues; Wildlife Observations; Other Descriptions

MAP: Yes / No | SKETCH: Yes / No | PHOTOS / VIDEO: Yes / No (-) | TRACKLINE: Yes / No | WAYPOINTS: Yes / No
Form Completed By: | Photographer(s): | GPS Person / Unit:

STREAM (SOS) Form **Incident:**_______________________________ **Page**_____ **of** _____

1.GENERAL INFORMATION	**Date** (dd/mmm/yyyy)	**Time** (24h standard/daylight) ____:____ to ____:____	**Water Level**
Segment ID:	**Segment Name:**		Low / Mean / Bankfull / Overbank
Ops Zone:	**Survey Type:**	**STR:**	Falling / Steady / Rising

Survey By: Foot __ ATV__ Boat__ Helicopter__ sUAS__ Other _________ | Weather: Sun / Clouds / Fog / Rain / Snow / Windy / Calm

2. SURVEY TEAM	Name	Organization	Name	Organization
Team Number				

3. SEGMENT		Total Length: meters	Length Surveyed: meters	Datum:
Survey Start GPS:	WP:	LAT: .	LONG: .	Entire Segment Surveyed Yes / No
Survey End GPS:	WP:	LAT: .	LONG: .	

4a. SHORE TYPE: *Indicate only ONE Primary(dominant) type and ALL Secondary types. CIRCLE those OILED*

BEDROCK: Cliff_____ Ramp_____ Shelf_____
Sediment Cut Bank _____
MAN-MADE: Solid______ Permeable______
Description:_________________________________
ESI Shoreline Type (primary) _____ (secondary) _____

Sediment BANK: Mud__ Sand__ Mixed__ Pebble/Cobble__ Boulder__ Organic __
Sediment FLAT: Mud__ Sand __ Mixed__
WETLAND: Reed/Rush (deeper) ____ Grassy (shallow, nearshore) _____
Vegetated Bank _____ Woody Material _____
Vegetated/Wooded-Upland _____ Tundra _____ TYPE: _______________
OTHER:___________________________ *Snow-Covered or Ice use Winter SOS*

4b. OVERBANK TYPE: *Indicate only ONE Primary (P) and ANY Secondary (S) types.*

Cliff/Hill:____ ht._____ m. | Flat/Lowland/Field ____ | Dune____ Inlet/Channel____ Delta____ Lagoon____ Marsh/Wetland____
Sloped: > (5^o) (15^o) (30^o) | Wooded / Vegetated? | Man-Made____:___________________________Other:_____________________

4c. STREAM CHARACTER: *Circle or select as appropriate.*

Channel Width: <1 m 1-10 m >10 m ________m | Shoal(s) Present: Y / N Point Bar Present: Y / N
Water Depth: <1 m 1-3 m >3 m ________m | Bar-Shoal substrate: silt /sand/mixed/cobble/boulder/bedrock/debris

VALLEY FORM: Canyon _____ Confined or Leveed Channel _____ Flood Plain Valley _____ Other: _____________________________
STREAM FORM: Straight _____ Meander _____ Anastamosed _____ Braided _____ Other: _____________________________
CHANNEL FORM: Cascade _____ Rapids _____ Pool _____ Riffle _____ Glide _____ Jam _____ Other_____________________________

5. OPERATIONAL FEATURES	Oiled Debris? Yes / No	Type:	Amount: (bags/trucks)
Direct backshore access? Yes / No	Alongshore access from next segment? Yes / No		Suitable for backshore staging? Yes / No
Access Description / Restrictions:			Current Dominated Channel? Yes / No

6-L. LEFT BANK (facing downstream) SURFACE OILING DESCRIPTION*: Indicate 100% overlapping oil zones by numbering them (e.g. L-A1, L-A2).*

Zone ID	WP # Start	WP # End	Substrate Type(s) or ESI Code	**Stream Bank Zone (LB)** MS	LB	UB	OB	**Oil Cover** **Area** Length (m)	Width (m)	**Distribution** Dist % (> 1) or	Number per unit area	**Size** Avg Size (cm)	Large Size (cm)	**Oil Thickness** TO	CV	CT	ST	FL	**Oil Character** FR	MS	TB	PT	TC	SR	AP	NO

6-R. RIGHT BANK (facing downstream) SURFACE OILING DESCRIPTION*: Indicate 100% overlapping oil zones in by numbering them (e.g. R-A1, R-A2).*

Zone ID	WP # Start	WP # End	Substrate Type(s) or ESI Code	**Stream Bank Zone (RB)** MS	LB	UB	OB	**Oil Cover** **Area** Length (m)	Width (m)	**Distribution** Dist % (> 1) or	Number per unit area	**Size** Avg Size (cm)	Large Size (cm)	**Oil Thickness** TO	CV	CT	ST	FL	**Oil Character** FR	MS	TB	PT	TC	SR	AP	NO

8. COMMENTS: Cleanup Recommendations; Ecological/Recreational/Cultural/Economic Issues; Wildlife Observations; Other Descriptions

**Use RIVER Supplemental (SOS) Form for additional oiling zones, pits, and comments/sketches.*

Sketch / Map: Yes / No Photos/Video: Yes / No Numbers: (-) Photographer Name:

Field Form 6 *Reed Bed and Shoreline Edge Oiling Summary Form: Lake Wabamun Spill*

REED BED and SHORELINE EDGE OILING SUMMARY Form: Lake Wabamun Spill page ___ of ___

1 GENERAL INFORMATION	Date: Time: hrs to hrs	***2 SURVEY TEAM (name and org)***
Segment ID:	Sun / Clouds / Fog / Rain / Snow / Windy / Calm	
Reed Bed Name:	Air Temp ____ C / Water Clarity	
	Water Temp ____ deg C	

7 SUBMERGED/SUNKEN/FLOATING OIL OBSERVATIONS

GPS Waypoint Number	GPS Time	Zone Area		Cut Bed	Intact Bed	Sediment Type	Floating Oil		Parti-culate Oil	Obs. Method	Submerged Oil 'Tar' Distribution Category				Surface Oil Residue		Observations
		L	W				Sheen	Black	Y / N	V / S	Type	<2cm	2-10cm	>10cm	Reed	pb/cob	

8 COMMENTS

NOO	No Observed Oil	F=fresh tar
L (low)	1 -2 tars	W=weathered tar
M (mod)	3 - 8 tars	R=reed tar
H (high)	>8 tars	S=stain
NV		CT=coat
		CV=cover

For additional information:

Environment and Climate Change Canada
Public Inquiries Centre
12th Floor, Fontaine Building
200 Sacré-Coeur Boulevard
Gatineau, QC K1A 0H3
Telephone: 819-938-3860
Toll Free: 1-800-668-6767 (in Canada only)
Email: enviroinfo@ec.gc.ca