

Response to oil spills:  
FROM FIRST ALERT TO FINAL CLEANUP

# PRACTICAL HANDBOOK FOR EMERGENCY OPERATIONS

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*The different procedures described in this handbook are aimed at cleaning up spills on land, underground, or in medium-sized bodies of fresh water (lakes, rivers and ponds). The Great Lakes, major rivers, seaways, and oceans, are not included.*



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# **PRACTICAL HANDBOOK FOR EMERGENCY OPERATIONS**

This handbook was produced by  
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# INTRODUCTION



This guidebook contains instructions and practical advice for immediate response in countering the devastating effects of an oil spill when it occurs on land or on water. It is addressed to those who are in the front line and will have to take an active part in cleanup and recovery operations.

The procedures described in the following pages cover the entire period of the spill, from first alert to final cleanup. They apply only to oil spills and are not to be used for toxic chemical spills.

The instructions are valid for land and small watercourses in Canada; they do not include large bodies of water such as major rivers, seaways, the Great Lakes, or oceans.

The methods presented on the following pages are meant to help those who are dealing with an oil spill so they can rapidly control the disaster that affects their environment. The suggestions, ideas, techniques and "tricks" that are proposed, here, are in no way a substitute for the specific knowledge that emergency workers have about their area and unexpected circumstances which may arise. The methods described here must be adapted for each spill, bearing in mind that every situation is unique and subject to change.

## Steps adapted to the circumstances

Oil spills on land and on water are both numerous and frequent. There are many causes (trans-shipments, accidents, leaks) and there are many types of petroleum products involved (gasoline, fuel oil, bunker oil). The vast majority of accidents are due to human error, although a few stem from mechanical failures. Whatever the cause of the spill, however, one must be prepared to deal with it.

Predicting, and subsequently, preventing an oil spill is very difficult, but it is possible to limit the damage resulting from it. To succeed, two conditions must be met. First, the cleanup

operation must take place rapidly and, secondly, it must be highly efficient, i.e., adapted to the circumstances. Those in charge must immediately assess the situation accurately and institute appropriate measures at once.

An accurate assessment involves determining where the spill took place (land or water), and what kind of oil was involved. At the same time, it is clearly useful to estimate the quantity of oil that was spilled as well as the amount that is likely to spread. These factors will determine the measures to be taken and the scale of the operation.

The appropriate response will be obvious if there has been careful preparation of a contingency plan for the area where the spill took place.

## Above all, the procedures must:

- Ensure the safety of emergency workers as well as that of the public at large;
- Protect sensitive areas: wildlife reserves, water intakes, marinas, recreation centers;
- Minimize long-term environmental effects and make every effort to prevent the spill from penetrating the subsoil and, particularly, the watertable and underground water.

## PART ONE

# GENERAL REMARKS

*No two spills are exactly alike. Each case is unique. Complete success of an operation hinges on the judgement that is used in evaluating several elements; weather conditions, the type of oil, the size of the spill, the type of land and watercourse.*

Bearing in mind the specifics of the situation, you will be able to decide which measures to take and what equipment to use.

However, even though no two spills are identical, the measures to be taken are based on common principles and require the use of similar equipment. For this reason, setting up a contingency plan is the best guarantee of efficiency.

### High-risk areas

In Canada, most oil spills take place on land. They occur primarily from pipeline leaks or leaks in reservoirs. The pipeline network and storage facilities for oil products in your area are generally well-known: it would be wise to examine how they can be reached.

Many spills take place at the time oil is being transported. Although such spills are frequent, for the most part, they are not very large. Therefore, they have fewer consequences than spills on the water, which particularly affect marinas, beaches and fisheries that are near lakes or watercourses. Clearly, all of these are sensitive areas.

### Fragile Resources

There is always a great risk that an oil spill on land will contaminate a water-



course. Following an accident, a spill can penetrate the subsoil or run off the side of a hill into the watercourse at the foot of its slopes. For this reason, it is important to try to identify facilities that might spring a leak (a pipe-

line across a river, reservoirs, etc.). Furthermore, the following factors must be taken into consideration:

- Ease of access by land or by water;
- Type of current, turbulence and depth of the water;

- Possibility of staking posts for snow barriers and other containment devices;
- Favorable natural anchors (trees, rocks, docks) to which barriers can be attached.

### GENERAL PRINCIPLES

Faced with an oil spill,  
you must immediately take the appropriate measures:

- to identify the type of oil involved;
- to ensure the safety of the cleanup team and of the public at large;
- to alert the designated authorities;
- to stop the leak;
- to contain the product that has spread;
- to recuperate the oil;
- to dispose of the recovered oil;
- to clean up the contaminated area and restore it to its natural state;
- to see that final cleanup is carried out.

Naturally, some of these measures may overlap.

## PART TWO

# OILS

*Petroleum, also known as crude oil, is a hydrocarbon mixture.*

### Identify the type of oil

First of all, the oil in the spill must be identified. The measures to be taken are indeed quite different if one is dealing with a light, volatile product or with a heavy oil spill. In the first instance (gasoline or diesel spill), it will be possible to restore the site much more rapidly than in the second instance (crude oil spill), where it may sometimes take years before the environment can be restored to its original condition.

### Light and heavy oils

In an order of increasing density, petroleum derivatives are as follows: gasolines, kerosene, fuel oils, lubricating oils, residual fuels

### APPEARANCE OF OIL ON A CALM WATER SURFACE

Identification	Appearance	Thickness		Quantity	
		$\mu\text{m}$	$\mu\text{in}$	l/km <sup>2</sup>	gal/mi <sup>2</sup>
Imperceptible	Barely visible under most favorable light conditions	0.04	1.5	40	25
Silvery	Silvery sheen on water surface	0.08	3	90	50
Lightly colored	First trace of color may be observed	0.15	6	175	100
Very colorful	Bright bands of color	0.3	12	350	200
Dull	Color turns brown	1.0	40	1 200	666
Dark	Dark brown or black	2.0	80	2 300	1 332

and lastly, asphalt and paraffin.

Crude oils are complex and variable mixtures of hydrocarbons. They contain fractions similar to those in gasoline, as well as heavy

fractions of tar and paraffin. For this reason, the consistency of crude oil can range from a light, volatile liquid to a viscous semi-solid. These differences become significant at the time of a

spill and during the subsequent cleanup operations.

Refined products include fuel oils, gasolines and lubricating oils.

### COMPARISON OF FOUR TYPES OF OIL

	<b>Group A: Products with low viscosity</b>	<b>Group B: Products with medium viscosity</b>	<b>Group C: Products with high viscosity</b>	<b>Group D: Solid and semi-solid products</b>
<b>Product</b>	Gasoline Kerosene Diesel Heating oil	Light crudes Medium crude oil	Heavy crude Fuel oil #4 Aged products, groups A and B	Very aged products groups B and C Products have reached their pour point
<b>Characteristics</b>	Low viscosity (like water) Very volatile	Medium viscosity (from milk to paint) Medium volatility	High viscosity (like molasses) Little or no volatility	Semi-solid
<b>Behaviour</b>	Rapid evaporation Rapid spreading Rapid biodegradation	Rapid partial evaporation (up to 40%) Heavy fractions will form an emulsion Can penetrate into sediments (diminishing with the emulsion)	Very little evaporation Will form an emulsion Poor penetration in sediments	Almost no spreading No penetration in sediments
<b>Dangers</b>	Ignition Light toxic fractions (fauna/flora in intertidal)	Ignition of light fractions Less toxic than group A	Low toxicity	Very low toxicity
<b>Response</b>	Permit evaporation Protect from danger of ignition Approach from downwind	Protect against risk of ignition Approach from downwind during first few minutes Use booms	Use booms	Use booms

## PHYSICAL AND CHEMICAL PROPERTIES OF OIL

The physical and chemical properties of a spill, as well as the behaviour of a slick and the efficiency of cleanup measures, depend in great part on the kind of oil that has been spilled. Its physical and chemical properties are in direct proportion to the thickness of the slick and the speed at which it spreads. Consequently, these two factors will determine which cleanup measures will be most effective.

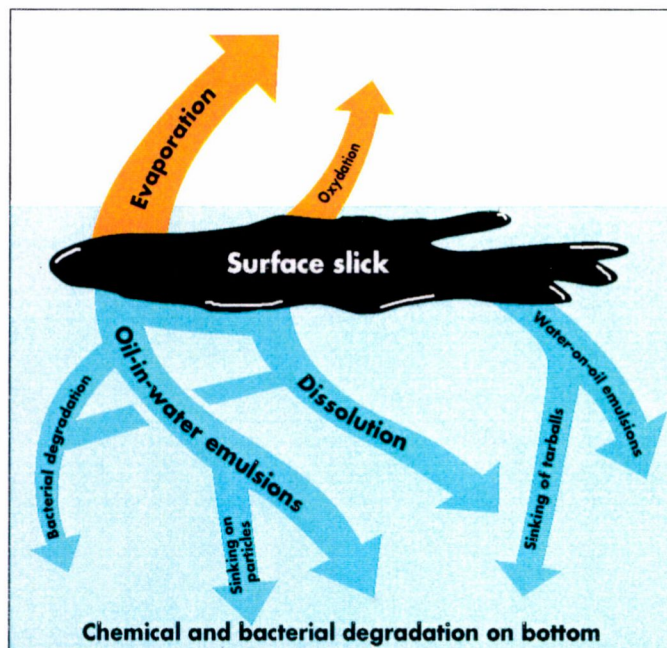
### *On water*

The physical and chemical properties that determine how oil will behave in water are density, surface tension, viscosity, pour point, flash point and water solubility. These properties can vary depending on the length of

the process and the general conditions: wind, current and water turbulence.

### *On land*

The properties of oil spilled on land are, above all, density and viscosity. The type of soil, be it permeable or impermeable, is a determining factor as to whether the spill stays at the surface or penetrates underground.



## Weathering

Oil that is spilled on water or on land undergoes a series of changes in its physical and chemical properties that is known as weathering. Major processes which contribute to weathering are: evaporation, dissolution, oxidation, emulsification and microbial degradation. Light, volatile oils are the first to disappear. Therefore, slicks composed of gasoline, kerosene and light fuels, disappear almost entirely after 24 hours, whereas slicks of heavy oil remain.

## BEHAVIOUR OF OILS

As a rule, be it on water where it floats or on land where it spreads, a spill has a tendency to spread out and cover a wide surface.

It is therefore necessary to contain the expansion of the slick. The next step, particularly in the case of a land

spill, is to prevent, or at least reduce, in-depth penetration.

### Behaviour on water

The first phenomenon that can be seen, is the formation of a slick at the surface of the water. The speed at which the slick spreads is in direct proportion to the volume spilled. Afterwards, viscosity and surface tension slow down the spreading.

## PHYSICAL CHARACTERISTICS OF SELECTED REFINED PETROLEUM PRODUCTS AND CRUDE OILS

	Specific gravity (15° C)	API gravity (15° C)	Viscosity cS (38° C)	Pour point (° C)	Flash point (° C)	Initial boiling point (° C)
<b>Crude oils</b>	0.8 to 0.95	5 to 40	20 to 1000	-35 to 10	Variable	30 to 500
<b>Gasolines</b>	0.65 to 0.75	60	4 to 10	na	-40	30 to 200
<b>Kerosene</b>	0.8	50	1,5	na	55	160 to 290
<b>Jet fuel</b>	0.8	48	1,5	-40	55	160 to 290
<b>No. 2 Fuel-oil</b> (Furnace, diesel, stove)	0.85	30	15	-20	55	180 to 360
<b>No. 4 Fuel-oil</b> (Plant heating)	0.9	25	50	-10	60	180 to 360
<b>No. 5 Fuel-oil</b> (Bunker B)	0.95	12	100	-5	65	180 to 360
<b>No. 6 Fuel-oil</b> (Bunker C)	0.98	10	300 to 3000	+2	80	180 to 500

It should be pointed out that certain crude oils whose density is greater than 1.0 and oils whose pour point is higher than that of the surrounding water, have a tendency to form tarry masses. Viscous water-in-oil emulsions are created by the moving waves; these emulsions, which are as thick as butter, stop the slick from spreading. They do have the disadvantage, however, of being hard to pump, and they make cleanup operations more difficult by increasing the volume of the material to be collected.

A slick moves according to the current and the wind that affect the water surface. As a rule, the speed of the slick is about 3% of that of the wind. In fact, the speed is the combined result of both the force of the wind and that of the current; violent gales can therefore move the slick countercurrent. When winds are greater than 16km/h, they tend to draw out the slick into long strips.

#### OIL SLICK EVAPORATION (% VOLUME)

Time	Light crude	Medium crude	Gasoline	Diesel	Fuel oil #6
8 minutes			50%		
48 hours	30%	20%	93%	20%	2%
120 hours	36%	25%	99%	35%	5%

Lastly, evaporation must be taken into consideration, particularly in the case of light crude oils and gasoline, which generally disappear within 24 hours.

#### Behaviour of oil on or under ice

Surface ice is generally quite porous and can absorb up to 25% of the volume of oil, depending on its type. The oil penetrates the first few centimetres below the surface.

Oil spilled below the ice surface, sticks to the underside of the ice and collects in the irregularities found there.

If there is a current, oil will move. The extent of the movement will depend on the roughness of the underside of the ice and on the strength of the current. After a frost, oil can be trapped in the ice and rise to the surface.

#### Behaviour on land

When oil is spilled on land it spreads over the surface of impermeable soil and fills the least depression in the soil. On the other hand, it penetrates into permeable soil. The degree of penetration depends on the type of land involved, as well as on the type of oil.

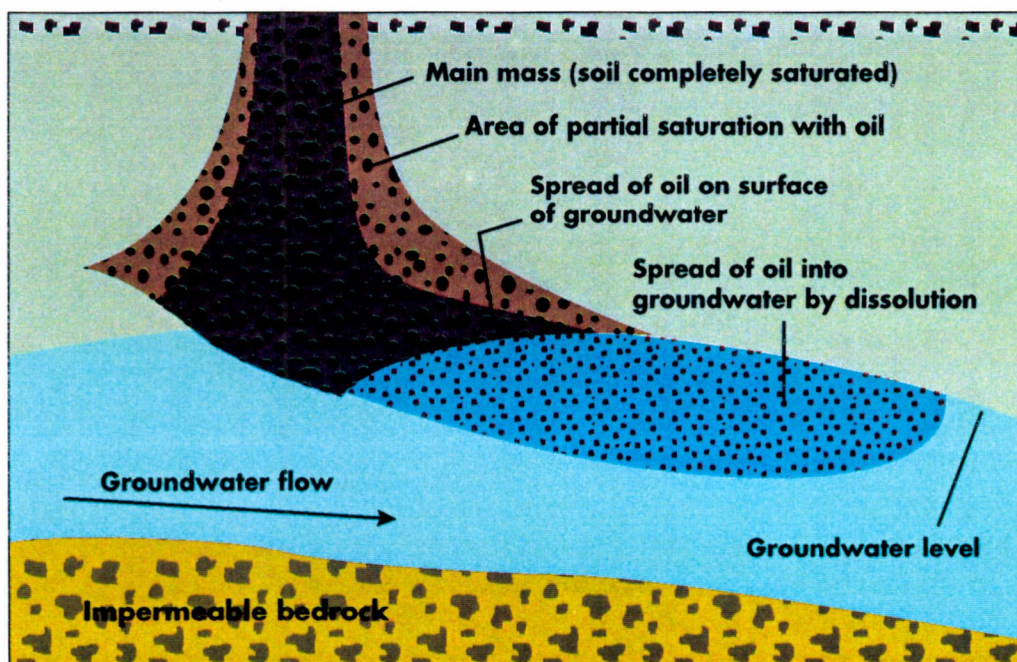
- Oil with *low viscosity* (gasoline, diesel oil) on dry, porous land (sand, gravel) will penetrate rapidly and spread less quickly on the surface. Clay or water-logged soil will be resistant to penetration.
- *Viscous oils* (light crude) will spread on the surface and penetrate the soil very slowly (this may sometimes take months).
- Oils with *high viscosity* will form a tarry mass, notably if the temperature is below their pour point.

On most arable land, oil will only saturate the upper 10 to 20 cm, regardless of its viscosity. It will rarely penetrate lower than 60 cm unless it forms pools in dry depressions. If these depressions contain water, there will be no penetration.

The speed of penetration depends both on the composition of the oil mixture and on the soil. The greater the permeability or absorbancy of the soil, the greater the damage. The speed of dispersal of oil varies considerably over time: 40% to 70% of the dispersal occurs in the 24 hours following the spill, and 60% to 90% occurs during the following week.

Unless it evaporates at the surface of impermeable land, oil will penetrate a permeable soil and sink with the force of gravity, until it reaches an impermeable layer or the watertable. The oil will follow its path until it is blocked by another impermeable barrier or until it is completely absorbed in the soil.

#### MOVEMENT OF OIL IN A POROUS SUBSOIL IN CONTACT WITH GROUNDWATER



## Behaviour in the watertable

The watertable can be defined as the upper part of underground water; it is generally undulated and conforms to the geological structure of the land.

Spills that reach the watertable are the most difficult to treat and the most expensive to clean up. They generally originate in leaks from pipelines or from underground reservoirs. They penetrate the soil and impregnate its texture. Once oil has reached the watertable, it will behave in the same way as it does on water. It will spread on the surface. It may be caught in a pocket depression, depending on the geology of the subsoil. However, if the watertable is mobile or if it is the source for underground watercourses, parts of the oil will be carried along by the current and will later contaminate neighboring rivers several kilometres away.

## COMPOSITION OF SOIL

Most soils and rocks are composed of small fragments or pellets that are agglutinated and have little interstices or pores between them. If the pores are connected, the formation is said to be permeable; it lets fluids such as oil and water penetrate into it. For example, sand and gravel are permeable. Materials such as clay, silt, and schists, have very small, poorly interconnected pores; because they let little liquid through, they are said to be impermeable.

Soils and rocks are comprised of distinct layers, which were produced by successive deposits of vari-

ous materials. Very often, these layers are not parallel, but slant to one side or to the other. This slant, as well as the different porosity and permeability of each layer, are determining factors in how fluids, including oil, will flow underground. For ex-

ample, oil can flow into cracks and faults in a rock, which would otherwise be impermeable.

Another factor that has an important influence on the degree of soil absorption is quite simply whether the soil is wet or dry. It is clear that a

surface covered with dry sand will absorb fluids, oil included, much more rapidly than a surface covered with wet sand or already saturated with oil.

## TECHNICAL DEFINITIONS

**Density:** *The density of oil determines how easily it is dispersed in water. Most oils, with the exception of certain crude oils and heavy petroleum residues, float on water because their density is lower than 1.0. It should be noted that the density of oil mixtures increases over time as the volatile parts evaporate, and this can make the residual parts of the mixtures run.*

**Viscosity:** *This is the measure of the resistance a fluid has to flow; the weaker the viscosity, the higher the flow. At the time of cleanup operations, viscosity determines the speed at which the slick spreads, the stickiness of the deposit, its degree of penetration in the land and in the sediments on the beach, and the efficiency of the pumps that are recovering the oil.*

**Surface tension:** *This is the force of attraction between the surface molecules of a liquid. Together with viscosity, this property determines the speed at which a slick will spread on water or on land, or the speed of penetration, in the latter case. The weaker the surface tension, the faster will be the spread or the penetration. Light fuels and crude oils are characterized by low surface tension. As the temperature increases, surface tension decreases and, consequently, the spread is more rapid.*

**Pour point:** *This is the temperature at which an oil becomes a semi-solid or congeals and no longer flows because an internal microcrystalline structure has been formed. Pour point is one of oil's most significant properties; it determines the type of deposit on the shore and subsequent cleanup measures. Gasoline and other liquid oil's are usually found below their pour point, whereas semi-solids or bitumen are found above it and only flow when the ambient temperature is relatively high (15° to 25°C). The former, therefore, can rapidly penetrate most beach substrates, whereas the latter remain at the surface unless the substrate is coarse or the ambient temperature is high.*

**Flash point:** *This is the temperature at which oil vapors ignite when exposed to a heat source such as an open flame. It is a highly significant factor for ensuring safety of the workers during cleanup. Gasolines can ignite in most conditions as opposed to bunker oil or heavy fuels.*

**Solubility:** *This is the property of a substance that can dissolve in a given solvent. The weak solubility of oil in water is an advantage in protecting aquatic life.*

## PART THREE

# EMERGENCY OPERATIONS

*Emergency operations cover three stages that sometimes overlap and consist of stopping the leak, containing the spilled oil, and recovering it.*

## STOPPING THE LEAK

The person in charge of emergency operations must act as swiftly as possible to locate the source of the oil spill and stop, or at least dampen its flow. This is not always possible. Indeed, although it is relatively easy to close a faucet or a valve, it is clearly impossible to stop a gash in a reservoir. For this reason, it is important to implement containment measures immediately, giving priority to those that have the advantage of being safe.

## CONTAINMENT OF THE SPILL

There are two methods with corresponding techniques that can be used to contain an oil spill and prevent it from spreading further; they differ slightly if the spill is on land or on water.

## CONTAINMENT ON WATER

Quick containment of the oil slick is a sure way to limit damage and reduce cleanup costs. The main purpose of the equipment used is:

- 1) to surround the slick and prevent it from spreading while increasing its thickness in order to facilitate recovery;

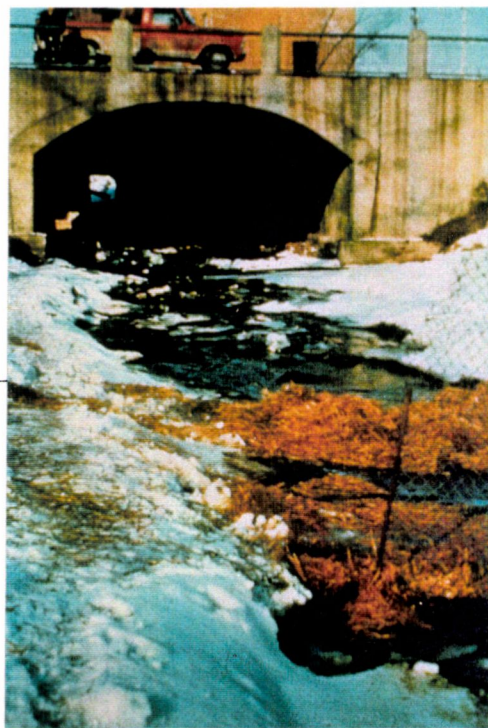
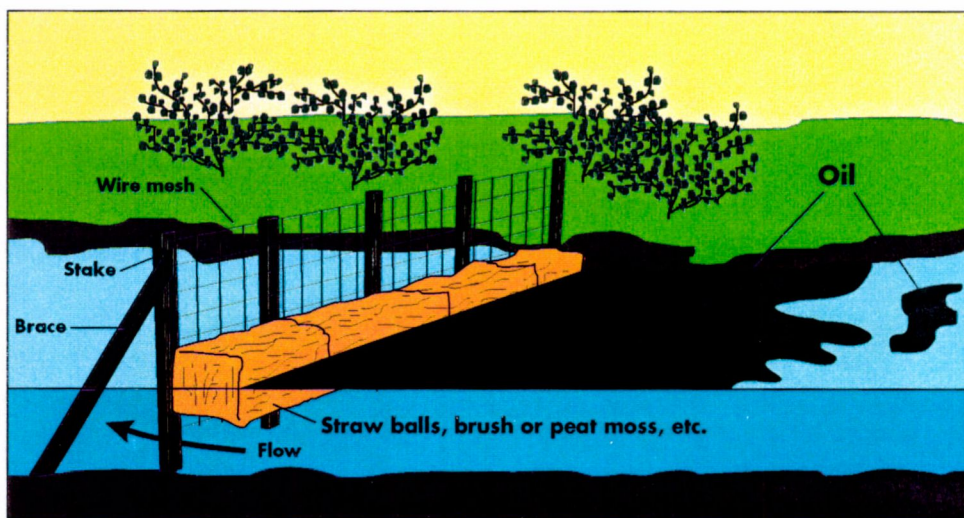
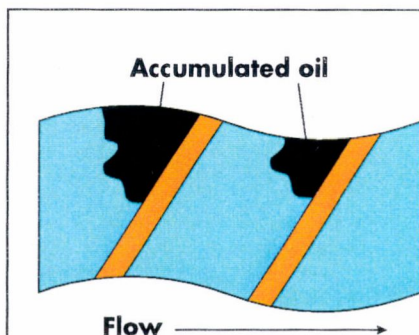
- 2) to channel the slick towards areas where the oil can be recovered;
- 3) to protect certain sensitive areas while the recovery plan is in progress.

Efficiency of the barriers is greatly reduced when the current is greater than 0.5m/s. The barriers must therefore be placed in the part of the watercourse where the flow is the weakest. The ends of the

barriers must be attached to the shores in such a way that the oil that accumulates there cannot pass by. If no equipment is ready to contain an oil slick, barriers should be made with whatever is at hand. Nonetheless, it is practical and more efficient to use commercial barriers.

## IMPROVISED BARRIERS AND BOOMS

There is no perfect equipment for stopping an oil slick; there are advantages and disadvantages to each kind. Those who draw up the contingency plans must determine which apparatus is best suited to a particular place, in view of the circumstances.



## SNOW FENCES AND SORBENT BARRIERS

As a general rule, these barriers should only be used in watercourses that are 0.90m to 1.20m deep with soft beds into which stakes or T bars can be driven. It is recommended to angle the barrier 30° to shore, so that the oil can accumulate on the side, thus facilitating recovery operations. Chicken wire can be attached to the snow fence, and sorbent material (straw, hay, material) placed along the upriver side. Using a second chicken wire, the sorbent material is then "sandwiched" between the two. The sorbent material must be quite coarse so that it cannot pass through the mesh. A layer of sorbent material at least 30cm thick and 1.50m long is recommended for heavy oils; the layer must be even thicker for light oils. A second and even a third barrier can be put up as an extra precaution.

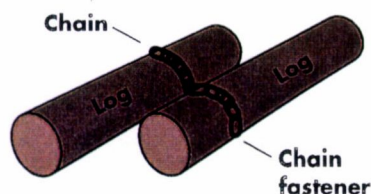
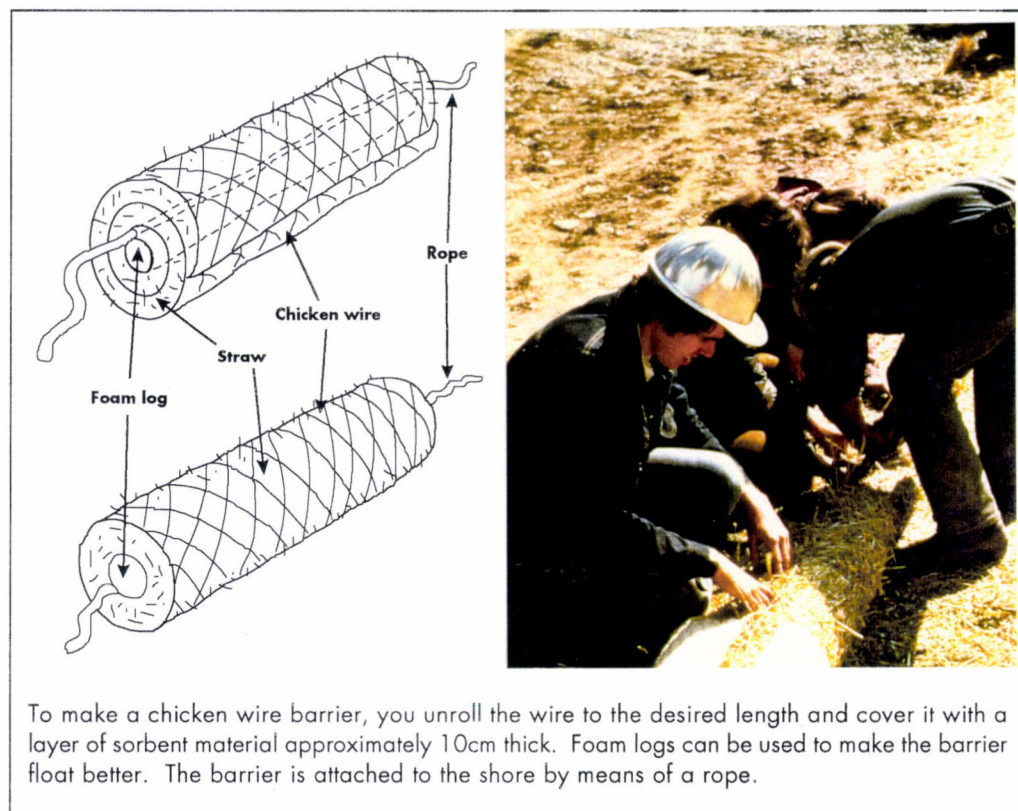
N.B. This type of barrier cannot be used to contain gasoline.

## CHICKEN WIRE AND SORBENT BARRIERS

The chicken wire and the sorbent material are rolled together, creating a barrier that somewhat resembles a log. In running water, these barriers must be placed at an angle so that the oil can accumulate on the side of the bank and therefore be easier to recover.

## Wooden barriers and booms

Wooden barriers (logs, telephone poles, 4x4's, trees) can be used to contain oil in protected areas or in stagnant water. Because of their rigidity, these barriers are not always efficient. Small



The wooden logs or available timber can be lashed together with chains or ropes. The adjoining ends of the logs are wrapped in a waterproof sealant (inner tubes, plastic material, etc.) to form a flexible, water-tight joint.



waves or ripples can cause splashover.

A weir can be set up on very small watercourses. To do so, one improvises at the site, using plywood sheets, boards or logs, which are

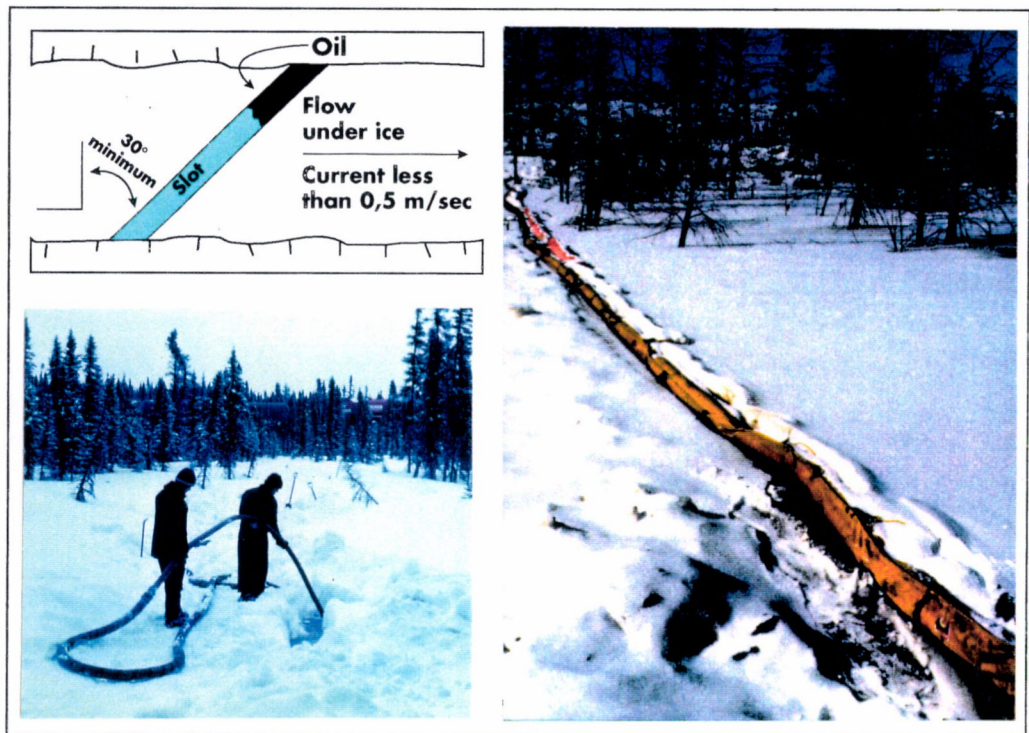
wedged vertically across the full width of the watercourse. Water flows under the weir but the oil is caught. If possible, it is preferable to place these weirs at an angle in relationship to the current so

that the oil accumulates on one of the two banks, thus facilitating its recovery. As an added security, several weirs can be installed parallel to each other.

## Ice slotting

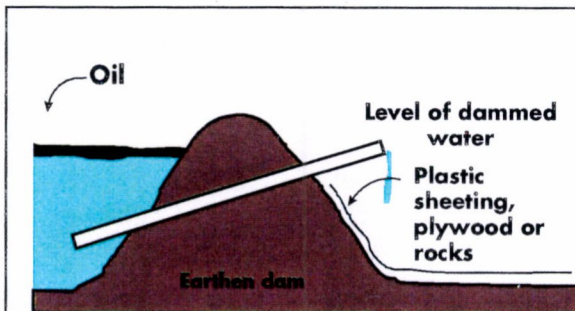
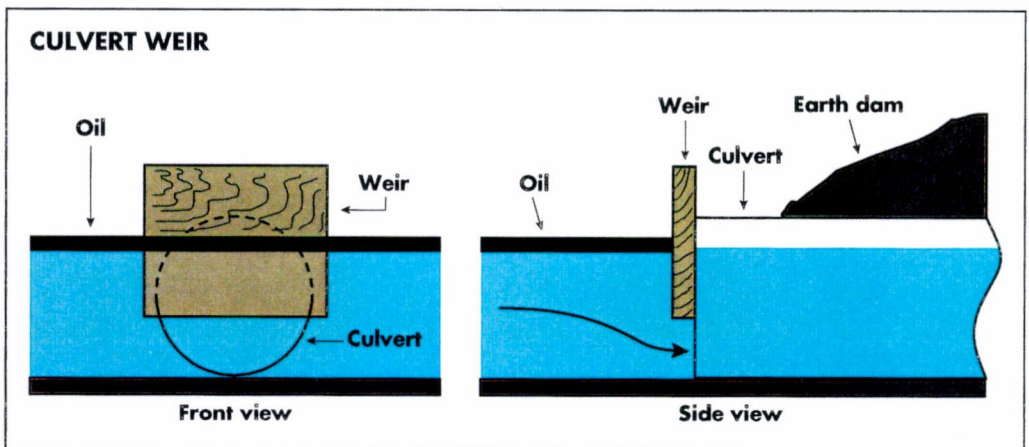
An oil slick under the ice can be contained by making trenches that are left to freeze over after plywood sheets have been inserted into them. This method is usually only applicable to deep water when the current flows at less than 0.5m/s and when the ice is thick enough to stand the weight of the crew and the necessary equipment. Several sheets of plywood can be juxtaposed.

The maximum size of the opening in the ice is one metre across. Oil that accumulates in the opening can then be removed. For such a system to be truly effective, the opening must be at an angle in relationship to the current.



## Dams

Sometimes an oil slick in a narrow and shallow watercourse can be contained by the use of dams; an advantage in this method is that earth or sandbags are readily available to build them. By building a dam, the water level rises and the strength of



Running water accumulates upstream from the dam and some water will have to be let through to prevent overflowing. To do so, a siphon pipe can be inserted in the dam. The siphon must protrude far enough beyond the dam downstream, to prevent erosion of the toe of the dam; plastic sheeting, plywood or rocks can be placed there to hold the pipe. When the siphon pipe is installed almost horizontally, a flexible barrier can be placed around the pipe inlet to prevent the oil from entering.



the current decreases: this makes it possible to contain the oil and remove it little by little.

### Blockage of open drains

Open drains containing water can be blocked with an earthen dam or a weir. The necessary flow of water can be maintained by the use of siphon pipes. Alternately, the drain can be re-directed to a suitable collection area. Once the slick has been contained, the oil must be collected as soon as possible.

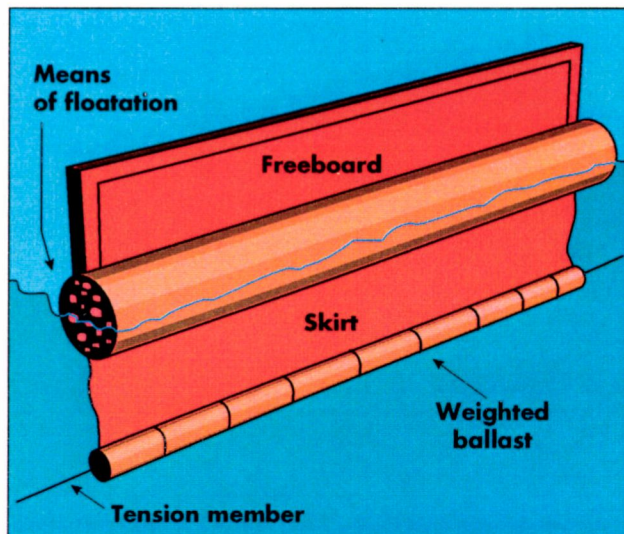
### COMMERCIAL OIL SPILL BARRIERS (Floating booms)

All commercial barriers consist of four parts:

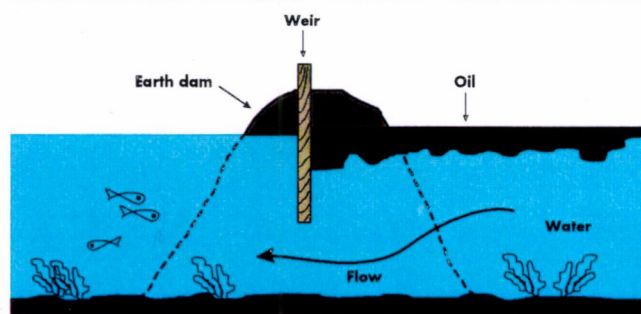
- a foam log for flotation;
- a freeboard to prevent waves from washing the slick over the top of the barrier;
- a skirt to prevent the slick from sliding under the log;
- a tension member to carry the load imposed on the barrier by wind, wave and current forces.

Furthermore, some barriers are ballasted, so as not to list.

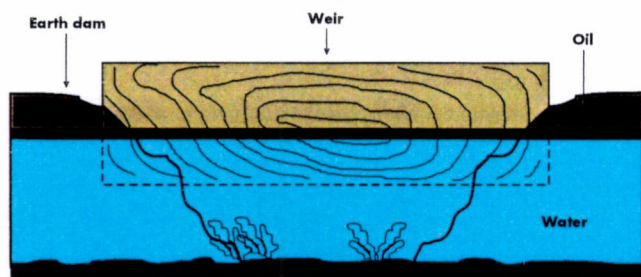
### BASIC COMPONENTS OF A FLOTATION BOOM



### BLOCKAGE OF DRAINS OR SMALL WATERCOURSES



Side view

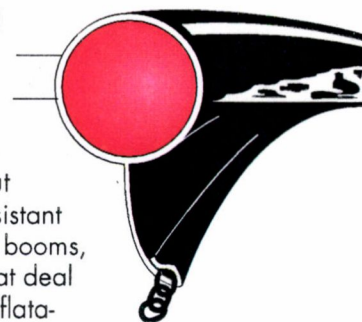


Front view

### THERE ARE BASICALLY TWO TYPES OF COMMERCIAL BARRIERS:

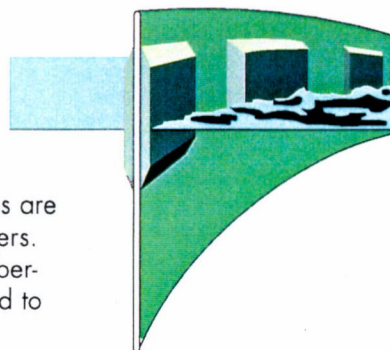
#### Flotation boom with skirt

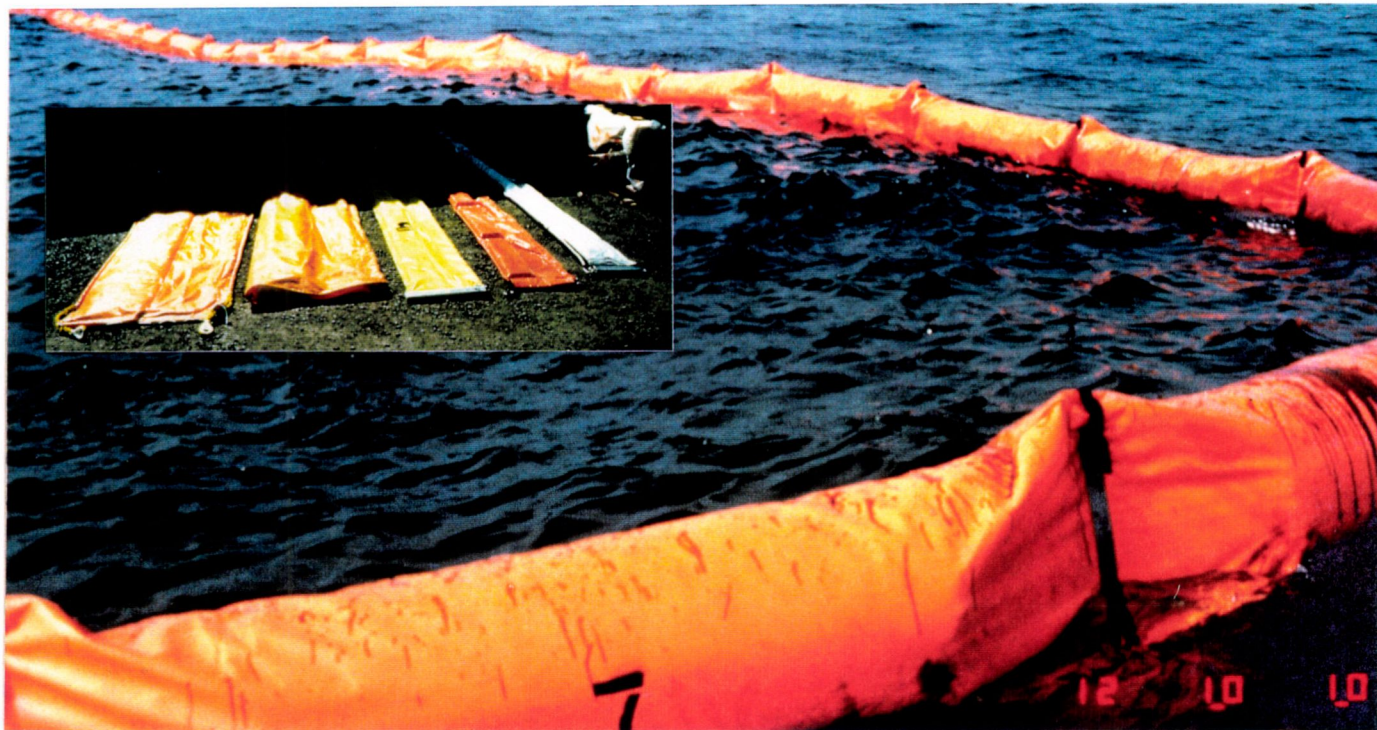
They have an underwater skirt or a flexible screen which is usually held up by a solid or inflatable cylindrical floaters. Inflatable booms are less cumbersome to set up but they are also less resistant than the solid-floater booms, which take up a great deal of storage space. Inflatable booms ride the water well and are quite easy to clean.



#### Freeboard flotation boom

These have a flat section that is kept in a vertical position in the water by exterior or interior floaters, that are generally solid. These booms are good for calm waters. They are very cumbersome and also hard to clean.





The most significant property of a boom is its containment capacity, which can be determined by evaluating its behaviour in a swell. The boom must be flexible enough to ride with the wave but also be rigid enough to

have an acceptable containment capacity.

No barrier can function properly if it is not correctly installed nor if weather conditions are too poor. For example, it will be impossible to contain oil slicks if the

current is swifter than 0.5 m/s. The boom should not be placed at a right angle in relationship to the current. The optimal drift angle must be found for the slick.

When installing the boom, it is important to moor it with

a floating anchor so it can drift with the wind. The slick will therefore be progressively concentrated in a relatively thick layer behind the U or V shape where it can be easily collected.

	IMPROVISED BARRIERS	COMMERCIAL BARRIERS
ADVANTAGES	<ul style="list-style-type: none"> <li>• Abundance of basic material is available</li> <li>• Work very well in shallow, calm water</li> <li>• Generally, cleanup crews need no specialized training</li> <li>• Low cost</li> <li>• Useful for small spills</li> <li>• Several booms can be installed rapidly</li> </ul>	<ul style="list-style-type: none"> <li>• Availability on the market is assured</li> <li>• Installation fluctuates with water movement</li> <li>• Very strong</li> <li>• Moderate price</li> <li>• Great reliability</li> <li>• Useful for larger spills</li> <li>• Work well in rough water (to 0.5m/s)</li> </ul>
DISADVANTAGES	<ul style="list-style-type: none"> <li>• The installation does not always adjust to water levels changes</li> <li>• Has to be used together with another method to increase the amount of product collected</li> <li>• Requires regular monitoring</li> <li>• Temporary installation</li> <li>• Danger of absorbing more water than oil</li> <li>• Difficult handling and disposal of saturated sorbents</li> </ul>	<ul style="list-style-type: none"> <li>• Need for storage and upkeep</li> <li>• Large storage areas are sometimes needed (for solid floaters)</li> <li>• Problems in coupling</li> <li>• Trained crew required to unroll booms</li> <li>• Longer installation time required (often a boat is needed)</li> </ul>

## CONTAINMENT ON LAND

Once on land, the spill spreads out. Different means can be used to prevent the slick from spreading over impermeable soil or from penetrating deeply into permeable soils where there is a risk that it may reach underground water (the watertable). Swift, efficient response makes it possible to limit the damage and, consequently, reduce cleanup costs.

### Blockage of sewers

Once approval has been granted from municipal

authorities, it is sometimes possible to block the sewers by means of a pneumatically or mechanically operated sewer stopper or by using a watertight canvas. It is important to make sure that there is no backup of oil or sewage into homes or other facilities. The vapors of light petroleum products such as gasoline, which are trapped in this manner, could cause a fire or an explosion.

When oil is spilled on the road, penetration of the product into open drains can be prevented by blocking the drains either above or below their cover. In either case, one must:

- cover the drain with a waterproof sheet whose diameter is one and a half times that of the drain cap;
- place sand, gravel, earth, snow or any heavy object around the edges of the sheet, to prevent the spill from entering the manhole.

### Construction of earthen dams

In the case of minor spills it is particularly effective to construct short, semi-circular dams. A series of them can be erected to contain the spill. It should be noted that the purpose is to contain the oil, not to absorb it.

The quantity of liquid spilled, together with the physical characteristics of the spill site, will determine the number of dams to be built. The dam technique is useful for a spill on a cement or asphalt road. On a dirt or gravel road, however, it might be preferable to dig trenches rather than to build dams.

Containment dams can be built with earth, sand, snow or any sorbent material readily available in sufficient amounts near the site of the spill.

The natural slope of the land should always be taken into consideration in order to use it to one's advantage.

Dams prevent the oil slick from spreading and protect sewer or drain openings. In the case of light petroleum slicks, like gasoline, the damming material must not let the product penetrate it. It is important to monitor the dams frequently to make sure they are holding up well.

### The three dam technique

The "three dam" technique is particularly effective when a vacuum truck has overturned.

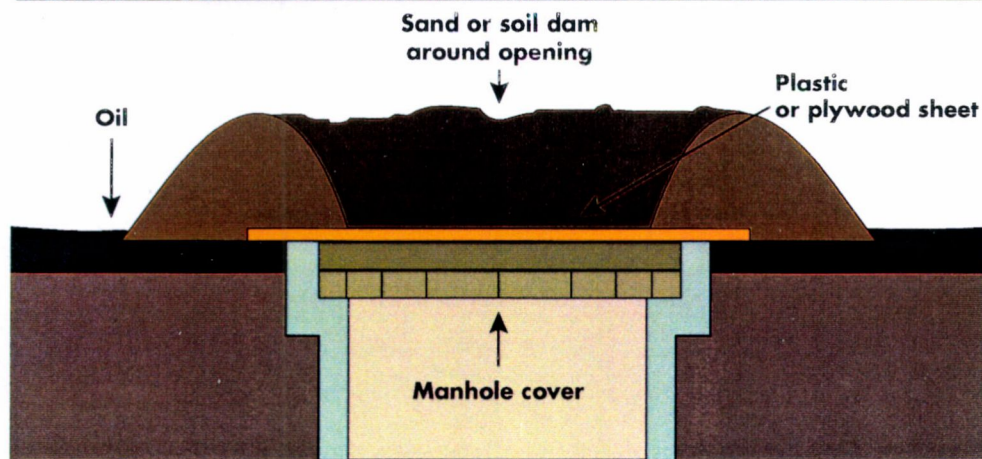
*The first dam* is used to retain the oil and confine it to the spill site.

*The second dam* serves as an overflow for the first. The liquid can be safely collected here at an appropriate distance from the spill site and still limit the size of the contaminated area.

The location of the second dam depends on certain factors, in particular:

- a) size of the spill
- b) type of road
- c) slope of the land

**BLOCKAGE OF SEWERS**



### Preparation of sump holes



In sandy soil, the sides of the sump holes that have been prepared to receive the petroleum product are often crumbly and unstable. They must be filled with gravel after perforated drain pipes have been placed in them vertically. The petroleum products that collect there over several months can then be directly sucked out of the pipes.

Where it is possible, sump holes are dug parallel to irrigation ditches. The irrigation ditch can be blocked by a dam; the water level will then rise until the gasoline overflows into the sump holes. Narrow boards can be used to control the amount of gasoline to be skimmed off.

Once it is in the sump hole, the gasoline can be removed by a vacuum truck. Pumps are used to suck up the water the gasoline is floating on, and the water is then redirected towards the sump hole.



#### d) type of petroleum product spilled

The *third dam* serves to receive the overflow from the basin formed by the second dam, in case the second dam is full. Paradoxically, therefore, the third dam is not intended for use.

### Preparation of sump holes

Sump holes are ditches or trenches arranged downstream from a spill to collect petroleum products. They are placed just below the level of the underground water so that oil floating to its surface can run into the holes. They are the most appropriate choice if the underground water runs near the surface, and if the soil above the water is permeable.

### Preparation of trenches

Trenches can be dug to contain and direct the flow of spilled liquid, or natural ditches can be used as trenches when they are near a spill. (In the case of a derailed train or of an overturned truck, for example).



## OIL RECOVERY

Once oil has been contained, recovery techniques are the same on land or on water.

After surrounding the slick (either on land or on water), barriers or dams must be used to remove the oil as quickly as possible. Recovery can take place manually or with mechanical devices. When the barriers are equipped with sorbent material, recovery is often carried out at the same time as the containment operation.

## VACUUM SKIMMERS

Skimmers are machines capable of removing the slick from the water without significantly altering the physical and chemical properties of the petroleum product. Most of these machines work best when the slick is relatively thick and, for this reason, they are used together with barriers that increase the thickness of the slick. Debris and ice interfere considerably with the work of the skimmers and often even block the machines. Heavy oils and very viscous petroleum products make them inoperable, especially in cold waters. Therefore, they must therefore be cleaned regularly.

Every skimmer contains a recovery system, a flotation system, a support module, as well as a pump to transfer the recovered products to a storage unit.

There are two basic skimming systems: suction and adhesion.

*Vacuum skimmers with a weir skimmer head* recover oil directly from the water by means of a single floater. They collect a great deal of water that has to be treated in a large capacity oil-water

### Weir skimmer with vortex (Weir with Archimedes' pump)

A vortex produced by a fixed-pitch propeller concentrates oil in its center by centrifugal force. The oil and water separate. The former rises to the upper part of the vortex and is driven off towards a storage bin, while the higher density water is driven back below the pump.



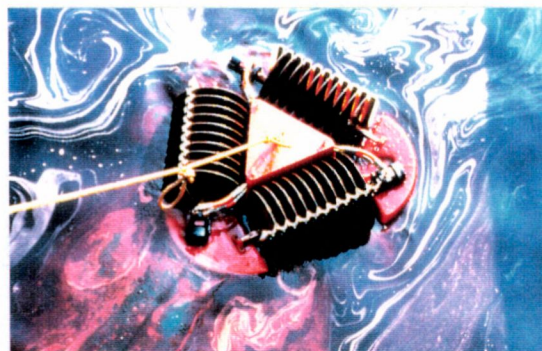
### Oleophilic rope skimmer

A rope with a central tension member composed of oleophilic ropes, forms a type of mop. It is activated by a pulley. Wringers squeeze out the saturated ropes, and the oil falls into a storage reservoir.



### Disk skimmer

The disks work on the water-oil interface. The oil adheres to the surface of the disks from which it is removed by scrapers. Once recovered, the oil falls into a tank and is pumped to storage reservoirs.



### Belt skimmer

Oil adheres to a belt that moves upwards, carrying it either towards scrapers or towards wringers. It falls into a storage tank. Inversely, as the belt moves downwards, it submerges the oil that has risen to the surface because its density is lighter than that of water. The oil adheres to the belt, which continues to turn, and again moves upwards. The oil is recovered.



### Vacuum skimmer with weir skimmer head

There are two basic versions: a vacuum system and a pneumatic system. Both have special skimmer heads that can be attached to flexible hoses. It is possible to recover more viscous products by increasing the water content of the oils recovered.



separation unit. A gravitational separator with a decantation tank is often sufficient.

*Oleophilic surface skimmers* have oleophilic parts (belts, drums, disks or ropes made from synthetic material). They yield good results in situations where oils of medium viscosity like light crude oil and medium crude oil are being recovered.

Automated skimmers are used to counter the negative effect of currents on oil recovery. They also collect floating debris, which accumulates behind a wire mesh so as not to clog the pumps. It must be cleaned regularly. This type of skimmer is well suited to ports where there are many tankers, or to refineries where there is a permanent danger of pollution.

The most important factors to consider when choosing a skimmer, are the viscosity and adhesive properties of the product that needs to be recovered. There is a danger for pumps to lose their prime when dealing with increasing viscosity of oils. This problem can be partially surmounted by pumping small quantities of oil with water and air, which serve as transporting agents. The use of demulsifiers also makes it possible to reduce the forma-



tion of oil-water emulsions, which increase viscosity.

### VACUUM TRUCKS WITH PUMPS

Vacuum trucks are quite easy to find in both urban and rural areas. They can be used as temporary reservoirs as well as for transportation of the spilled products. The 7 to 10cm hoses carried on the truck can be used to suck up oil from soil or from water without having to have special skimming heads. The valve system that is found in



### VACUUM SKIMMER TABLE

	WITH VORTEX	OLEOPHILIC ROPE SKIMMER	DISK SKIMMER	BELT SKIMMER	VACUUM SKIMMER
ADVANTAGES	Quite resistant to debris because of its filters	Good recovery of moderately viscous oil	Effective for medium viscosity oils	Useful for heavy oils	Simple machine, recovers oil of all viscosities
DISADVANTAGES	Works poorly in heavy currents	Debris can damage the wringers	Optimal rotation speed to be monitored	Can only be used in moderate currents	Easily plugged up, sensitive pumps

the trucks makes it possible to separate the oil from the water while the trucks are being filled. The water, which falls to the bottom of the tank, is progressively discharged at the spill site. Care must be taken so that this water is discharged upstream from the oil retention barriers, so that any oil that was poured out inadvertently from the truck can be recovered.

## SORBENTS

Sorbent products are used to facilitate recovery of oil spilled on water or on land. These products can absorb a large quantity of oil. They come in different shapes and are made of a variety of materials.

The use of commercial sorbents made out of synthetics (rubber, polyester foam, polystyrene, polyurethane) is recommended. They are more absorbent per unit volume and can generally be used over again. Commercial sorbents are especially recommended for viscous oils.

Sorbents made up durable synthetic yarn (they resemble mops) are effective in recovering very viscous oil like bunker oil.

Improvised sorbents made up of organic material (hay, straw, wood chips, etc.) are hard to handle and less effective, but they are often the only sorbent immediately at hand. They have a tendency to become water-logged and sink. They must be replaced frequently. Furthermore, they can complicate oil recovery by jamming the skimmers or the pumps.

Lastly, earth, sand and snow are excellent sorbents;

they are extremely useful for spills on a road or on a hard surface. However, depending

upon the degree of oil saturation, they may be dangerous and must be disposed of

according to government norms.



Sorbents that come in sheets or shaped like pillows are appropriate for collecting oil with low or medium viscosity. They have the advantage of being reusable.



## MANUAL RECOVERY METHODS

Manual recovery with pails, barrels and shovels is frequent, especially in the case of viscous oils. This method is also used when the terrain is unsuitable for heavy machinery or when the equipment would cause greater damage to the environment than manual recovery. It is important to have large containers available into which the oil can be poured: Port-a-Tank, for example. However, this method is very labor-intensive.

Well holes can be used as improvised storage containers. If the soil is porous, the bottom of the well can be lined with a plastic sheet, to make it waterproof. When the oil and water have separated, the water can be pumped out and the oil that remains at the bottom can be recovered.

## TECHNIQUES TO USE WITH CAUTION

*Tilling or soil aeration* are techniques used to break up the surface of the soil and aerate it. However, incorporating oil in the soil by tilling it tends to slow down natural degradation because, once it has been pressed down again, the soil becomes anaerobic.

The use of *chemical products*: it should be noted that the use of these products is regulated by government agencies. This is the case of surfactants, which can increase oil absorption by the soil and can even contribute to underwater contamination.

*On-site Burning* is sometimes used as a technique to treat oil spills on land. However, it is important to be aware of the fact that this technique may be harmful to

soil rehabilitation. Heat can have a negative effect on soil properties, harm the roots that are in it, and form a hard crust of residual material that prevents plant growth and modifies soil humidity. In some instances, flooding the soil before burning can minimize the harmful effects from the heat. Lastly, eliminating the debris after burning can prevent crust formation. The use of burning as a technique is subject to approval by the appropriate government authorities.



The Port-a-Tank consists of a collapsible metal frame with a liner and an outlet at the bottom to drain water off once it has been separated from the oil.



Manual recovery with pails, barrels and shovels is frequent, especially in the case of viscous oils.



## RECOVERY AND PUMPING TECHNIQUES IN THE WATERTABLE

When the watertable has been affected, attempts are made to drive oil out of the ground by circulating water through the contaminated layers. In all cases, a borehole is sunk below the watertable and a large volume of water is left to filter through the contaminated layers. This process drives the oil out of the pores of the soil and brings it to the surface of the watertable where it can be pumped from the borehole to a recovery yard at the surface.

Recovery wells are often used for underground spills.



*On-site Burning* is sometimes used as a technique to treat oil spills on land. However, it is important to be aware of the fact that this technique may be harmful to soil rehabilitation. The use of burning as a technique is subject to approval by the appropriate government authorities.

A well is dug down to the watertable. The oil at the surface is then removed by a pump or by a skimmer. Wells must be installed by experts who know the geo-

logical features of the site very well. Indeed, those who direct the cleanup operations must also be very familiar with the site in order to locate where the oil is probably

trapped. Catch holes are dug; they make cone-like depressions into which the oil runs and remains trapped.



Recovery wells are often used for underground spills. A well is dug down to the watertable. The oil at the surface is then removed by a pump or by a skimmer.

## PART FOUR

# CLEANUP AND RESTORATION

*Despite efforts to contain the oil slick on water, it often spreads to the shore. Then, the stricken area must be cleaned and restored to its original condition. The black tide covers everything: sandy beaches, cobble beaches, rocky beaches, wharves, jetties and docks of little commercial ports or marinas.*

In well-populated areas, this cleanup is an urgent undertaking; such is not the case in sparsely populated areas nor in areas where the ecosystems are not very sensitive.

### **Avoid further damage to polluted areas**

It is important to underline the fact that all cleanup and restoration techniques run the risk of changing the sites where they are applied. Since there is no perfect cleanup method, we are dealing with the *most acceptable methods*. In other words, cleanup operations must be chosen with a view to keeping any additional environmental disturbance to a minimum.

The most common methods are: the use of high pressure water, steam cleaning or sandblasting, excavation techniques, the use of sorbents, manual cleanup and, quite simply, natural assimilation.

### **High and low pressure water**

High pressure water is used to clean rocks, coarse sediments and man-made structures (piers, jetties, docks). When applied to rocky beaches, it often wreaks total destruction on



Water used to dislodge oil is shot from hoses at a rate of 10 to 20 litres per minute, with pressure ranging from 80 to 140 bars. Pressure hot water or steam cleaning are appropriate for use on man-made structures: piers, jetties, docks.

Sandblasting



Example of heavy machinery used for mechanical cleanup.

## RESTAURATION METHODS

	Chemical* dispersants	Hydraulic high-pressure	Hydraulic low-pressure	Steam cleaning	Sandblasting	Mixing	Mechanical removal	Manual elimination	Sorbents	Burning	Cropping
<b>Rock surfaces</b>	+	+	✓	+	+	○	○	✓	+	○	+
<b>Man-made structures</b>	+	✓	✓	✓	✓	○	○	✓	+	○	○
<b>Unresistant or unconsolidated cliffs</b>	○	x	x	x	x	○	x	x	x	○	○
<b>Coarse sediments beaches</b>	+	+	+	x	x	+	+	✓	+	x	○
<b>Sand beaches</b>	+	x	x	x	x	+	✓	✓	✓	x	○
<b>Marshes</b>	x	x	✓	x	x	x	x	✓	x	+	+

\* Chemical dispersants are only used in low sensitivity environments and require approval of appropriate government agencies

✓ Recommended  
+ Useful in some instance  
x Not recommended  
○ Not applicable

the fauna and flora.

Low pressure water is preferred because it causes less environmental damage.

Oil dislodged from the rocks by hydraulic dispersion (high or low pressure) is contained by barriers placed parallel to the banks. It is then recovered by skimmers or by vacuum trucks.

The use of pressure water should be avoided on cobble or sandy beaches because the pressure fosters oil penetration.

### Steam cleaning and sandblasting

These techniques are generally reserved for man-made structures (piers, jetties, docks). They are effective in loosening layers of hardened oil on rocks. Steam cleaning and sandblasting cause serious damage to the environment.

### Mechanical cleanup and excavation

On banks, large quantities of oil that have come to the surface can be removed by mechanical graders and elevating scrapers. This is a particularly good method when oil penetration is less than 2.5 cm. When penetration exceeds 25 cm, the only way to remove contaminated matter is by excavation and transporting it

### SORBENTS

Sorbents are used to contain spills both on land and on water (see p.18); however, they can also be used for cleanup. In this instance, synthetic sorbents will be used if possible because they are somewhat easier to collect than sorbents made from natural materials (hay, peat moss, etc.). Sheet sorbents are the most commonly used of all different types of sorbents for cleanup operations.



with front-end loaders.

In areas where there are cobbles or pebbles, the contaminated substrate is removed by bulldozers. Afterwards identical substrate is distributed in its place.

### Manual methods and natural cleanup

Manual disposal of contaminated material is usually necessary to complete the mechanical cleanup of most sites. It requires many workers but is often the only way to reach areas that are inaccessible to machines. Debris and contaminated material are put in plastic bags like those used for fertilizer.

On land where most of the oil has been eliminated and which can be considered "lightly" contaminated, turning over surface

## SOIL RESTORATION METHODS

Product type in soil type	Hydraulic measures	Interceptor trench	Soil venting	Soil excavation	Recovery wells
Gasoline in sand or mixed till	✓	+	✓	+	+
Gasoline in loam or clay	+	+	○	+	✓
Diesel fuel in sand or mixed till	✓	+	○	+	+
Diesel in loam or clay	+	+	○	+	✓
Light crude fuel in sand or mixed till	✓	+	+	+	+
Light crude in loam or clay	+	+	○	+	+
Heavier oils in sand or mixed till	+	+	○	+	○
Heavier oils in loam or clay	+	+	○	+	○

✓ Acceptable or recommended method

+ Method can be used under certain circumstances

x Should not be used

○ Only marginally applicable technique

sediment with rakes and harrows accelerates evaporation and other weathering processes by exposing the oil to greater oxidation in the air.

Finally, it is important to be aware that oil can be degraded naturally by the action of micro-organisms. The process can be helped by tilling the contaminated area and using fertilizers to improve the soil and accelerate natural microbial degradation. However, it must be established that oil penetration has not exceeded 15cm and that there is no danger of polluting the underground water nor of harming arable land. This measure can only be undertaken with the authorization of appropriate government agencies.

Natural assimilation can also occur in the case of spills on the water: heat,

wind and waves accelerate oil degradation. Thus, lack of intervention is sometimes the best manner of avoiding further damage to a polluted site.



Manual cleanup demands a horde of workers and great patience, but it is sometimes the only effective way to restore a site.



### NOTES ON THE NECESSITY OF EVALUATING AN EMERGENCY OPERATION

It is useful for the person in charge of the operation to write a report on the sequence of events so as to be able to learn from them and make future response strategies even more successful. This report should include eye-witness accounts, as well as articles from local newspapers. Basic information will be recorded: the circumstances surrounding the oil spill (time, date) the emergency measures that were planned and executed, and an analysis of their success. This information will be made available to other parties who will be able to benefit from the experience and knowledge that have been gained from it.

