OIL SPILLS

What is oil used for? And how much do we use?

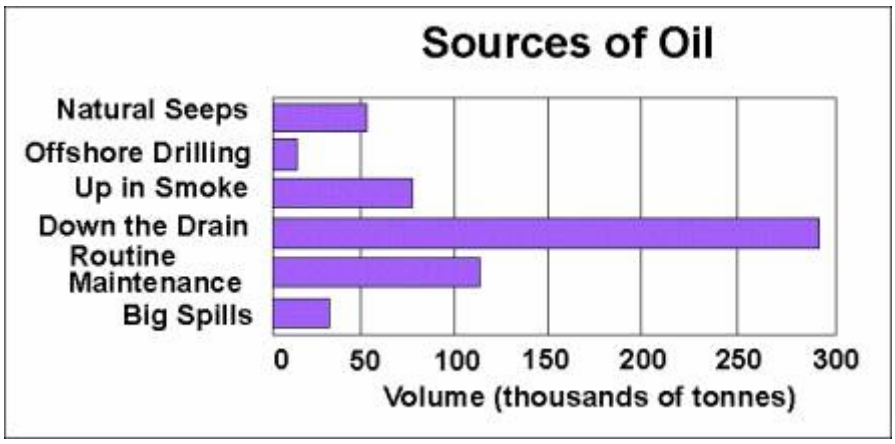
Each day, Canada uses more than 1.7 million barrels of oil. Oil is used to fuel vehicles and heat buildings, as well as lubricate machinery and bicycles, and make plastic, medicine, ink, fertilizer, paint, varnish and electricity. Oil is used in many processes, but not all oil is the same. Oil types can differ in viscosity (it's resistance to flow; molasses is highly viscous), volatility (how quickly it evaporates) and toxicity (how poisonous it is to humans and the environment). These three characteristics are very important when oil spills are being cleaned up, because the characteristics can influence the method of clean-up that will be used. The following chart summarizes the different types of oil and their characteristics.

Type	Example	Density	Volatility	Toxicity	Clean-up
1	Jet fuels, gasoline	Very light	Highly (evaporates in one to two days)	High concentration of toxic compounds that are water soluble	None possible
2	Diesel, no. 2 fuel oil, light crude oils	Light	Moderately (leaves a residue of up to one-third of the spilled volume after a few days)	Moderate (long-term contamination possible in intertidal regions)	Can be very effective
3	Most crude oils	Medium	Approximately one-third will evaporate within one day	Severe and long-term contamination in intertidal regions; impacting waterfowl and fur-bearing mammals	Most effective if conducted quickly
4	Heavy crude oils, no. 6 fuel oil, bunker C	Heavy	No evaporation or dissolution	Severe and long-term contamination in intertidal regions; severe impact to animals, which will be coated with and ingest oil; possible long-term contamination of sediments	Weathers slowly and difficult to clean under any conditions

Characteristics of Various Types of Oil;
http://response.restoration.noaa.gov/type_topic_entry.php?RECORD_KEY%28entry_topic_type%29=entry_id,topic_id,type_id&entry_id(entry_topic_type)=320&topic_id(entry_topic_type)=1&type_id(entry_topic_type)=2

Where does oil pollution come from?

Oil pollution does come from oil spills from large tankers, but there are other sources of oil pollution that, collectively, discharge more oil into water than the major oil spills do. The following graph shows the amount of oil pollution can come from various sources.



Sources of Oil Pollution;
http://www.informaction.org/cgi-bin/gPage.pl?menu=menua.txt&main=oil_causes.txt&s=Oil

The United States National Research Council (NRC) published a report in 2002 that said that, globally, approximately 1.3 million tonnes of oil are released into the sea each year. The exact amount of oil pollution varies each year, generally between 470,000 and 8.4 million tonnes, depending on the frequency and severity of oil spills. As well, estimates from credible organizations and scientists will vary greatly, because it is extremely difficult to measure the amount of oil pollution that comes from non-point sources, such as industrial and domestic runoff.

Some oil pollution is actually natural; oil can seep from the bottom of the ocean and from eroding sedimentary rocks. Coal Oil Point, which is several kilometres off of the California coast, releases between 7,500 and 11,400 litres of crude oil each day! There have been about 200 natural underwater oil seeps identified around the world, including off the east coast of Canada, near Labrador and off the north coast of Baffin Island.

In the above diagram, "offshore drilling" refers to discharges and accidental spills from oil field operations. For more information about oil fields, including the impact that drilling has on nearby water sources, see the Oil Fields fact sheet.

In the above diagram, "up in smoke" refers to air pollution, mainly from vehicles and industries, which emit hundreds of tonnes of hydrocarbons. Hydrocarbons are also emitted when burning is used to clean up an oil spill. Hydrocarbons contain sulfur and nitrogen, which mix with water in the atmosphere and fall to the earth as acid rain. Acid rain can cause great damage to the environment, including water and plants, and it can even wear away buildings and statues. For more information about acid rain, see the Acid Rain fact sheet, or the "What is Acid Rain and how does it affect me?" lesson plan in the Operation Water Flow section.

In the above diagram, "down the drain" includes a number of domestic, municipal and industrial sources of oil pollution. Any oil that is spilled in industrial or domestic operations can be washed down storm drains; this includes spills in fuel depots, oil leaks in vehicles and lawnmowers, and non-accidental pouring of paint or oil down storm drains. Runoff carries a great deal of oil into water sources, especially from asphalt. It is estimated that a city of five million people will, through pavement runoff, discharge the same amount of oil into waters as a large oil tanker spill would. More than one-half of Americans change their own oil, but only about one-third of the used oil from do-it-yourself oil changes is collected and recycled. The average oil change uses

almost five litres of oil; this amount of oil can contaminate approximately 3.8 million litres of freshwater!

Transportation and transfers of oil increase the risk of oil spills; to transport oil from the source to the use, up to 15 transfers may be required between ocean tankers, pipelines, trains and tanker trucks. As the number of transfers increases, so does the risk of spilling the oil. The following chart shows the regions with the greatest number of oil spills greater than 34 tonnes since 1960. Typically, these areas have intense industrial operations and transportation of oil.

Region	Number of Spills Since 1960
Gulf of Mexico	267
Northeastern United States	140
Mediterranean Sea	127
Persian Gulf	108
Southern North Sea	75

Regions in the World With Most Oil Pollution;
http://response.restoration.noaa.gov/faq_topic.php?faq_topic_id=1#2

Routine maintenance includes bilge pumping and other ship operations. Bilge is a mixture of oil and water; each discharge is fairly small, but thousands of releases of bilge into the oceans add up to a large amount of oil pollution. This is one source of oil pollution that is difficult to measure; it is illegal for ships to release bilge into ocean waters, so there are likely many bilge releases that go unnoticed.

Big spills typically account for 5 to 12 percent of total oil pollution that enters the ocean, but oil spills are especially serious because of the heavy concentration of oil in one region. Because oil spills are localized, they can severely contaminate beaches and sediment, and cause serious harm to marine wildlife. Oil spills can suffocate fish, get caught in the feathers of birds and mammals and block light from photosynthetic plants in the water.

What happens when oil spills?

There are a number of processes that can occur when oil spills, depending on the water source and the type and amount of spilled oil.

1. The most common effect is the spreading of the oil over the surface of the water. Most oil is less dense than water, so when oil spills, it spreads across the water surface. Oil spreads very quickly, with lighter oils, like gasoline, spreading faster than heavy crude oils. Currents, wind and warm temperatures will cause the oil to spread faster. Typically, oil can spread as thin as a coat of paint very rapidly. For this reason, it is important for oil spills to be contained as quickly as possible.

2. Oil can settle to the bottom of the water. While the density of oil ranges from 0.85 grams per cubic centimetre to 1.04 grams per cubic centimetre, most oil densities fall into the 0.90 to 0.98 grams per cubic centimetre range. Ocean water has a density between 1.02 and 1.03 grams per cubic centimetre, depending on the salt concentration. River water, however, has a density of 1.0 gram per cubic centimetre. This means that a heavy oil, with a density of 1.01 grams per cubic centimetre, would float in ocean water, but sink in a river.

3. The oil can be moved, with currents, tides and the wind. This can be a significant problem in rivers, because the currents can carry the oil a great distance from its origin. It can also cause substantial damage in oceans, because the tide can carry the oil to beaches and intertidal zones, which are especially sensitive to oil pollution.

4. Natural bacteria can digest the hydrocarbons and convert them to carbon dioxide and water. This is called biodegration, and is a natural process that can clean water and sediment after an oil spill.

5. Some oil will evaporate. Up to 50 percent of the volume of most oil spills can evaporate. Light fuels, such as gasoline, will almost entirely evaporate within one or two days.

6. Natural physical, chemical and biological processes can cause the oil to weather, changing the characteristics of the oil.

7. Oxidation is a chemical reaction that can occur between oxygen and hydrocarbons, and is a natural process that slowly breaks down the hydrocarbons.

8. Emulsification is the combination of two liquids, when one is suspended in the other. Between water and oil, the combination can be water-in-oil or oil-in-water; water-in-oil is a stable mixture and can persist for years. Water-in-oil often consists of 50 to 80 percent water, and the water appears reddish-brown and feels greasy, due to the presence of oil.

What kind of damage does oil pollution cause?

Oil pollution can damage ecosystems, including plants and animals, and contaminate water for drinking and other purposes. The feathers and fur of birds and marine animals can become coated in oil; when the animals are covered in oil, they can no longer insulate themselves against the cold water, and birds have difficulty flying. Furthermore, when the animals clean themselves, they ingest some of the oil. Most birds that are coated in oil would not survive, if it weren't for people cleaning them. In fact, to clean one bird requires a one hour examination from a veterinarian, two people, each working for two days to clean the bird, and then holding the bird in captivity for 20 to 40 days (which requires about two hours each day of work). So a lot of work goes into cleaning one bird. Fish can be suffocated by the thick sludge of oil on the water surface, and bottom-dwelling fish can develop liver disease, as well as reproductive and growth problems.

Bird Covered in Oil after *Exxon Valdez* Oil Spill;
http://sludge.wordpress.com/2006/08/25/remember-alaska-and-exxon-valdez/

Plants that grow in or near the water can be harmed by oil pollution. An oil spill can block the sunlight that plants need for photosynthesis, which kills plants growing in the water. Oil spills can result in closed beaches and harbours. Oil pollution affects fishing and hunting, which is especially detrimental for people who rely on hunting and fishing, such as many rural communities. Water sources that are intended to provide drinking water can become contaminated.

There are some areas that are more sensitive to oil pollution than others. For example, coral reefs, mangroves and marshes are more sensitive than sandy beaches and sea-grass beds. Currents and wind can sometimes carry the oil far from the spill location, causing damage to the vegetation, birds and marine animals along the way.

How is oil pollution cleaned up?

There are several clean-up methods that can be used, depending on the type and amount of spilled oil, the water location and local weather conditions. Following are a list of some clean-up methods that are commonly used to treat areas that have been affected by oil spills.

Recovery times can range from weeks to decades. Along bedrock shorelines, where there are high-energy waves, the region may recover within several weeks. Exposed beaches generally recover within a matter of months, but marshes and salt flats may take years or even decades to recover from an oil spill. Mangroves, which are coastal regions in the tropics and subtropics, can take around 50 years to recover.

Natural Methods: Bioremediation

The natural environment can effectively remove contaminants from the water and soil. There are microorganisms that are present in the environment that can break down many harmful chemicals, including gasoline and oil. To increase the rate at which the microorganisms work, nutrients, such as nitrogen or phosphorus, are often added. Bioremediation is a process that occurs, to some degree, after every oil spill. After the majority of the oil spill is cleaned up manually, biological processes break down the trace amounts that could not be removed. Or, in sensitive areas that would cause too much damage if people were to attempt to clean up the oil, these biological processes, together with evaporation, oxidation, weathering and other natural processes, will break down the oil and naturally clean up the environment.

Booms

Because oil spreads very quickly, the most important primary step is to contain the spill to as small of an area as possible. Booms are one of the most commonly used tools, because they can contain the oil to keep it from spreading. There are three main types of booms. A hard boom, like the first picture below, is a piece of plastic with a cylindrical float at the top and a weighted bottom, so that it floats on the surface with an underwater "skirt."

Sorbent booms, like the one shown in the second picture below, are made from materials that can absorb oil, and are most effective on thin, light oil slicks. Great caution must be taken when removing sorbent booms, so that the oil is not squeezed back into the water. Booms can also be used to prevent oil from running into storm drains when oil spills on pavement.

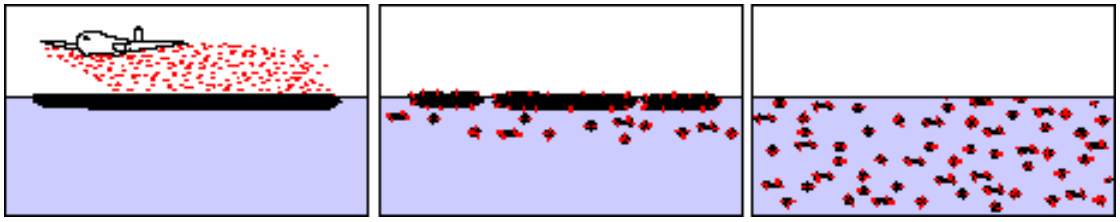
Hard Boom;
http://www.piersystem.com/go/doc/586/124985

Sorbent Boom;
http://www.slickbar.com/slickbar/oil%5Fbooms/mk%5F8%5Fpermanent%5Fboom/

Fire booms are the third type of boom, but are not used as much as hard and sorbent booms. A fire boom is very similar to a hard boom, but is made of metal, so that it is fire resistant. Fire booms are used to contain oil spills until they can be lit on fire.

Chemical Dispersants

Chemical dispersants can be successful in cleaning up oil spills. Dispersants are chemicals that are applied to the surface of the water, usually by a low-flying plane. Oil can eventually break down naturally, and chemical dispersants act to speed up the natural process. The oil binds to the dispersant, and is able to move further down the water column, meaning that the oil disperses into the water. The water dilutes the oil to a concentration that is less harmful to aquatic life in the region. The following diagram illustrates how chemical dispersants can be applied to an oil spill. The red substances are the chemicals that are applied to the region with a low-flying plane; the black substance is the oil that binds to the dispersants and becomes suspended and diluted in the water.



Application of Chemical Dispersants to an Oil Spill;
http://www.itopf.com/dispersa.html

Dish detergent is a common household item that can illustrate how chemical dispersants work, because grease and oil bind to dish detergent and are washed away. However, chemical dispersants are not applied to shallow water near shores, marshes, near coral reefs, or other sensitive areas.

Skimmers

Skimmers are boats that can skim oil from the water surface. An advantage of using a skimmer to remove oil from water is that it doesn't change the physical or chemical properties of the oil, as methods such as using chemical dispersants do. Skimmers often have attached settling tanks, so that the oil and water can be separated in the tank. If the oil is relatively fresh, it can be refined. In other instances, the oil is burned. The success of skimming depends on the type and thickness of the oil spill, the amount of debris in the water, the location and the weather conditions (skimming works best in calm weather).

Sorbents

In addition to using sorbent materials as booms, to contain and soak up oil spills, sorbents can also be applied to the water surface as powders. Sorbents are often the final step of clean-up, because they can absorb trace amounts of oil that could not be skimmed off. Commonly used sorbents include natural organic materials, such as peat moss and sawdust, or synthetic organic materials, such as polypropylene, polyester foam or polystyrene. Sorbents are generally applied by hand, and recovered with the use of nets and rakes.

Burning

Burning is a method that is often used to remove oil from the surface of the water. Oil may also be burned after skimmers remove the oil from the water surface. The burning of oil releases nitrogen and sulphur, which in turn causes acid rain. While burning can remove the oil from the water surface quickly and efficiently, it causes additional pollution. Thus, there are some ways of cleaning up after oil spills that are more beneficial than others.

Burning an Oil Spill;
http://www.mms.gov/tarprojectcategories/insitu.htm

Beach Clean-up

Areas near shore that are contaminated with heavy concentrations of thick oil are often cleaned up manually, using shovels and trucks. Manual recovery can also be used to pick up oiled beach sand and gravel, to remove it from the beach and transport it to alternate locations for treatment. Vacuum trucks can vacuum the oil up, right off of the beach. Pressurized hoses can also be used to wash oil off of beaches, into the water, where it will be dispersed and diluted in the water.

Case Study: The Exxon Valdez

The largest oil spill in American history occurred in March 1989. An oil tanker called the *Exxon Valdez* struck a reef in Prince William Sound, Alaska, spilling more than 41.6 million litres of oil. Though this oil spill was the largest in American history, it was only the 18th largest oil spill in the world; in fact, according to Oilspills.org, a larger oil spill occurred off of the Newfoundland coast, less than one year before the *Exxon Valdez*. The largest oil spill on record occurred in the Arabian Gulf in 1991, when the Iraqi army destroyed tankers and oil terminals and wells in Kuwait. In fact, the Arabian Gulf oil spill released more than 37 times more oil into the environment than the *Exxon Valdez* did.

Because the large spill occurred in a remote location, accessible only by helicopter and boat, and a number of clean-up methods were unsuccessful, this spill illustrates the difficulty of cleaning up after an oil spill. The cost of cleaning the region was estimated at over $2 billion, and required more than 11,000 people, 1,400 vessels and 85 aircraft to clean the contaminated land and water.

The map below shows how far the oil spread along the coastline of Alaska.

Location of *Exxon Valdez* Oil Spill;
http://www.pwsrcac.org/about/history.html

After consultation between several experts, one of the first attempts was to burn the oil. Ships moved fire booms into place to keep the oil contained. The trial burn was the only burn, however, because burning requires calm waters and wind, and the weather was not cooperative in this case.

Meanwhile, as booms were put into place, skimmers began removing the oil from the surface of the water. However, the oil was thick and filled with debris, which damaged the equipment and was time-consuming. Skimming also works most effectively in calm weather, so this method was not producing optimal results.

A third attempt to clean up the oil was the application of dispersants to the surface. Applying dispersants is controversial, because long-term health and environmental effects are not known. A certain amount of wave action is required for the dispersants to work to their full potential, and the wave action at the oil spill was not sufficient, so dispersant application was halted.

Throughout this entire process, special attention was given to sensitive areas, including seal pupping locations, fish hatcheries and shorelines. However, many birds and marine animals died. Shoreline clean-up occurred during the summer months of 1989 to 1991, with monitoring throughout the year; the area is still being monitored to make sure that the environment can recover.

Bioremediation processes were considered for treating the oil contamination on shorelines, and it was found that, with the addition of nutrients, enough microorganisms existed naturally in the region for successful recovery through natural methods. In some sensitive areas, clean-up can cause more damage than it removes, because the pressure on the ground from people walking can drive the oil deeper into the ground. It is estimated that approximately 50 percent of the spilled oil degraded by natural processes on beaches, in the water and in tidal sediment. Some regions and wildlife, such as sea otters, are still recovering from the extensive damage that the

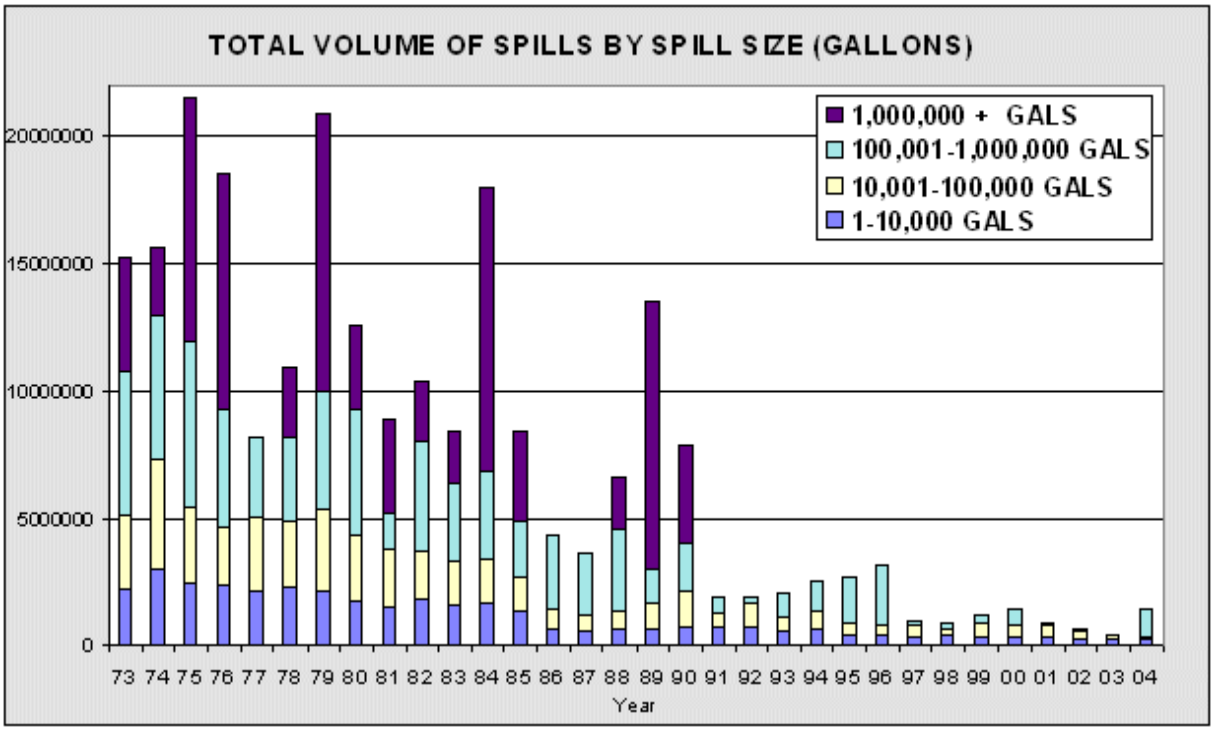
oil spill created. At least 87 percent of herring spawning grounds were heavily oiled and the fishing season for many varieties of marine life were cut short or completely cancelled.

Beach Clean-Up After *Exxon Valdez* Oil Spill

A significant result of the *Exxon Valdez* oil spill was the implementation of the Oil Pollution Act of 1990, which the United States passed to strengthen regulations on oil tank vessels, oil tank owners and operators.

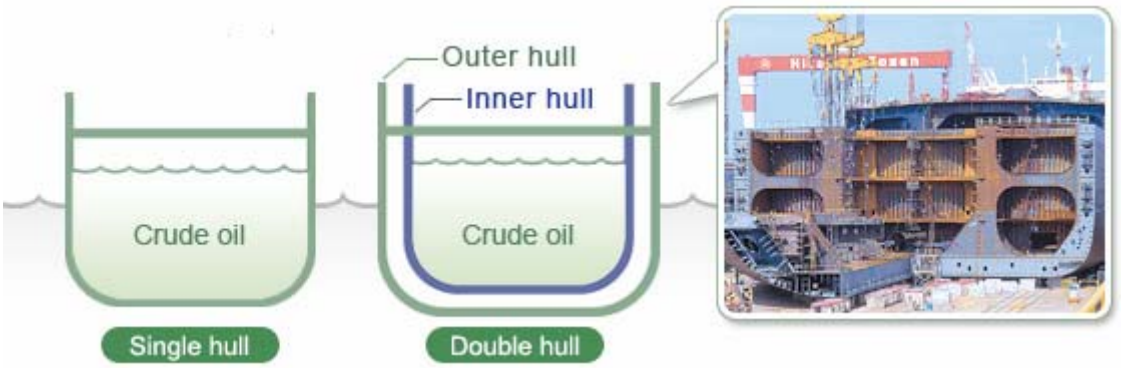
What can be done to reduce the amount of oil that pollutes water sources?

Globally, substantial process has been made to reduce oil pollution. The following graph shows the volume of spills in the United States since 1973, and illustrates the general decline in the total amount of oil spilled each year.



Total Volume of Oil Spills in the United States Per Year;
http://www.uscg.mil/hq/g-m/nmc/response/stats/summary.htm

In 1983, the United Nations treaty called the Convention for the Prevention of Pollution from Ships (also known as MARPOL: MARine POLlution) came into effect. MARPOL requires tankers and ships to use oil-pollution prevention equipment, such as double hulls on ships and reliable navigation and communication equipment. A double hull, as shown in the diagram below, requires ships to have two hulls, which adds another protective barrier to a ship.



Double Hull Ship

As well, individual tanks within ships are limited in size, so that the damage caused by a leak in one compartment can be minimized. MARPOL also prohibits discharges within certain distances of land. MARPOL was responsible for a large reduction in oil spills during the 1980s. While MARPOL came into effect in 1983, a significant reduction in oil spills in the United States did not occur until the early 1990s.

However, as noteworthy as the reduction of oil pollution is, there is still a lot of progress that still needs to be made. Many people do not realize how important it is to dispose of oil, paint and hazardous chemicals properly. Anything that goes down storm drains will end up in oceans, rivers and lakes, often without any further treatment to remove harmful contaminants! For more information about what individuals can do to reduce water pollution, see the Water Pollution fact sheet.

The Safe Drinking Water Foundation has educational programs that can supplement the information found in this fact sheet. Operation Water Drop looks at the chemical contaminants that are found in water; it is designed for a science class. Operation Water Flow looks at how water is used, where it comes from and how much it costs; it has lessons that are designed for Social Studies, Math, Biology, Chemistry and Science classes. Operation Water Spirit presents a First Nations perspective of water and the surrounding issues; it is designed for Native Studies or Social Studies classes. Operation Water Health looks at common health issues surrounding drinking water in Canada and around the world and is designed for a Health, Science and Social Studies collaboration. Operation Water Pollution focuses on how water pollution occurs and how it is cleaned up and has been designed for a Science and Social Studies collaboration. To access more information on these and other educational activities, as well as additional fact sheets, visit the Safe Drinking Water Foundation website at www.safewater.org.

Resources:

Environment Canada. 1994. Environmental Emergencies: Oil, Water and Chocolate Mousse. http://www.ec.gc.ca/ee-ue/default.asp?lang=En&n=7C882684-1&offset=3&toc=show.

National Oceanic & Atmospheric Administration: Office of Response and Restoration. July 2007. FAQs: Oil and Chemical Spills. http://response.restoration.noaa.gov/faq_topic.php?faq_topic_id=1.

Ocean Planet. 1995. Oil Pollution. http://seawifs.gsfc.nasa.gov/OCEAN_PLANET/HTML/peril_oil_pollution.html.

The Water Pollution Guide. 2007. Oil Pollution. http://www.water-pollution.org.uk/oilpollution.html.

United States Environmental Protection Agency. March 2006. Exxon Valdez. http://www.epa.gov/history/topics/valdez/.