INLAND OIL SPILL CONTROL COURSE

THE TEXAS A&M UNIVERSITY SYSTEM

TEXAS ENGINEERING EXTENSION SERVICE

OIL & HAZARDOUS MATERIAL
CONTROL TRAINING DIVISION

INLAND OIL SPILL CONTROL
COURSE

TEXAS ENGINEERING EXTENSION SERVICE

INLAND OIL SPILL CONTROL HANDBOOK

prepared by the

Oil and Hazardous Material Control Training Division
Texas Engineering Extension Service
The Texas A&M University System
College Station, Texas

TABLE OF CONTENTS

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Introduction

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INTRODUCTION

INTRODUCTION

The Inland Oil Spill Control Course has been developed to provide its participants with a basic knowledge of the effects of spilled oil and the equipment and strategies needed to effectively deal with these spills. A good way to begin to develop an awareness of the potential oil spill problem is to review statistics. In this way, one can gain a better understanding of the magnitude of the oil spill problem.

From 1977 through 1981 a total of 53,115 spills were reported in the United States (Table 1). About 74 percent of these incidents occurred in the Great Lakes and coastal regions. But, while almost three-fourths of the incidents occurred in large bodies of water, inland spills accounted for about 57 percent of the total spill oil volume. In fact, during the past few years, increasing volumes of spilled oil have come from inland sources (Table 2). For these inland sources, 64 percent of the volume was spilled in river areas, and 29 percent in non-navigable areas.

Another way of reviewing spills is by their cause. The United States Coast Guard lists 17 possible categories for spills (Table 3). The major causes of oil spillage by occurrence were tank overflow, pipeline rupture and leak, and hull and tank rupture and leak (Table 4). Similarly, the major causes for oil spills by volume were hull and tank rupture and pipeline rupture with leak (Table 5).

Products spilled most often include crude oil, diesel, and waste oil when judged by occurrence[1], with gasoline, other distillates, solvents, and asphalt spilled less often. Spilled products occurring in the greatest volume included crude oil, fuel oil, diesel, and gasoline.[1]

[1]Greater than 10 percent of total spillage.

These statistics indicate a need for oil spill control training, especially in inland areas.

Course Objectives

The purpose of this course is to provide the trainee with information and training necessary for handling an oil spill within the capabilities of manpower and equipment at a company facility. To achieve this goal, the instructional staff will provide classroom discussions and practical experiences designed to maximize the effectiveness of an oil spill supervisor under spill conditions, to permit him to work within the framework of the law, and to learn ways to minimize expense and liability to the company. It is the school's aim that when a trainee leaves at the end of the week he will be able to:

1. recognize potential spill situations,
2. modify existing contingency plans to make them more current and practicable and to include experiences learned from previous spills,
3. establish a supervisory team to execute a contingency plan,
4. organize, train, and direct a response team,
5. recommend and direct the use of proper oil spill equipment, such as skimmers, booms, sorbents, and other tools required to mount an effective spill cleanup,
6. preplan arrangements for additional support equipment and supplies not readily available,
7. establish plans for an effective communications system during a spill, which include radio, telephone, and public address systems,
8. meet legal requirements for properly reporting oil spills,and
9. effectively handle public relations aspects and be aware of the legal implications at a spill scene.

TABLE 1. OIL SPILL INCIDENT OCCURRENCE IN PERCENT

	1977	1978	1979	1980	1981
Atlantic Coast	21.2	23.2	24.9	22.0	22.8
Gulf Coast	34.8	30.4	35.3	24.4	20.0
Pacific Coast	17.3	18.7	14.7	15.2	12.7
Great Lakes	7.3	5.5	6.5	5.0	2.8
Inland	19.4	22.3	18.7	33.2	41.0
Other				0.2	0.7
Total	100%	100%	100%	100%	100%
Total Incidents	10,660	11,950	10,990	9,194	8,376

(From U.S. Coast Guard - "Polluting Incidents In and Around U.S. Waters, 1977 and 1978, 1978 and 1979, 1979 and 1980, and 1980 and 1981.")

TABLE 2. OIL SPILL VOLUME IN PERCENT

	1977	1978	1979	1980	1981
Atlantic Coast	38.3	54.4	17.6	12.3	3.5
Gulf Coast	30.1	19.2	31.4	8.7	2.5
Pacific Coast	5.3	1.8	8.3	12.2	1.1
Great Lakes	3.1	0.9	2.2	4.8	0.7
Inland	23.2	23.7	40.4	61.8	92.2
Other				0.2	
Total	100%	100%	100%	100%	100%
Total Volume (gallons)	8,979,381	14,343,996	10,500,344	10,171,050	17,668,622

(From U.S. Coast Guard - "Polluting Incidents In and Around U.S. Waters, 1977 and 1978, 1978 and 1979, 1979 and 1980, and 1980 and 1981.")

TABLE 3. LIST OF OIL SPILL CAUSES (U.S. COAST GUARD)

1. Hull/Tank Rupture
2. Transportation Pipeline Leak
3. Other Structural Failure
4. Pipeline Rupture/Leak
5. Other Rupture/Leak
6. Valve Failure
7. Pump Failure
8. Other Equipment Failure
9. Tank Overflow
10. Improper Equipment Operation
11. Other Personnel Error
12. Railroad/Highway/Air
13. Bilge Pumping
14. Ballast Pumping
15. Other Intentional
16. Natural/Chronic
17. Unknown

TABLE 4. TOP FIVE IDENTIFIED SPILL CAUSES BY INCIDENTS

	1977	1978	1979	1980	1981
1.	Tank Overflow	Tank Overflow	Tank Overflow	Tank Overflow	Tank Overflow
2.	Hull/Tank Rupture	Hull/Tank Rupture	Pipeline Rupture/Leak	Pipeline Rupture/Leak	Pipeline Rupture/Leak
3.	Other Equipment Failure	Pipeline Rupture/Leak	Hull/Tank Rupture	Hull/Tank Rupture	Hull/Tank Rupture
4.	Pipeline Rupture/Leak	Personnel Error	Other Equipment Failure	Other Equipment Failure	Other Equipment Failure
5.	Transportation Pipe./Leak	Other Personnel Error	Other Personnel Failure	Other Personnel Failure	Improper Equipment Operation

(From U.S. Coast Guard - "Polluting Incidents In and Around U.S. Waters, 1977 and 1978, 1978 and 1979, 1979 and 1980, and 1980 and 1981.")

TABLE 5. TOP FIVE IDENTIFIED SPILL CAUSES BY VOLUME

	1977	1978	1979	1980	1981
1.	Hull/Tank Rupture	Hull/Tank Rupture	Hull/Tank Rupture	Pipeline Rupture/Leak	Hull/Tank Rupture
2.	Pipeline Rupture/Leak	Other Structural Failure	Pipeline Rupture/Leak	Other Structural Failure	Pipeline Rupture/Leak
3.	Transportation Pipeline Leak	Pipeline Rupture/Leak	Transportation Pipeline Leak	Hull/Tank Rupture	Tank Overflow
4.	Other Equipment Failure	Tank Overflow	Other Structural Failure	Other Intentional	Other Personnel Error
5.	Railroad/ Highway/Air	Railroad/ Highway/Air	Other Equipment Failure	Tank Overflow	Other Intentional

(From U.S. Coast Guard - "Polluting Incidents In and Around U.S. Waters, 1977 and 1978, 1978 and 1979, 1979 and 1980, and 1980 and 1981.")

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Oil in the environment

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OIL IN THE ENVIRONMENT

OIL IN THE ENVIRONMENT

Our environment provides the basic needs of man: food, oxygen, and water. In addition it provides a challenge and creative stimuli for recreation, aesthetic beauty, and ideas. Biologists are concerned about plants and animals because living organisms form intricate and sometimes delicate associations that can be disturbed by an outside influence. A disturbance, such as an oil spill, can affect one or several organisms which can affect organisms used by man.

The effects from large ocean spills on chemical, physical, and biological processes have been well published and documented,[1, 2, 3] yet the effects from inland spills are not as well known. Although some experiments on inland organisms have demonstrated physiological stress induced by hydrocarbons, dynamic spill induced changes in organism populations are only beginning to be understood.

The most thoroughly studied organism affected by hydrocarbons is man. The way in which oil affects man will be similar to many of the effects oil might have on plants and other animals.

Effects On Humans

Crude oil may not be thought to be highly toxic to humans, but the major products within a crude oil can be harmful (gasoline, benzene, phenols, cresols). The harmful effects can vary from chronic to acute.[4] The problems arise from those hydrocarbons that are distilled from crude. A major problem with short carbon chained alkanes, such as those hydrocarbons which make up gasoline, is flammability, but these vapors can also exert a slight anesthetic and depressant effect on the central nervous system at concentrations from 5 to 10,000 parts per million (ppm) (up to 1 percent of air volume). Larger concentrations (up to 4 percent air volume) may induce narcosis and convulsions leading to death. At extremely high concentrations, these products can displace inhaled oxygen and cause anorexia and asphyxiation. A more common problem with alkanes is irritation of skin and mucous membranes. Carcinogenic, teratogenic, or mutagenic effects have not been found in humans or other mammals.

The aromatics are ringed hydrocarbons such as benzene, toluene, and xylene. Although benzene has been recognized as a toxic substance (as low a 0.7 percent air volume), lower concentrations can affect the central nervous system (respiratory paralysis, mucous membrane irritation with pulmonary edema, gastrointestinal irritation, skin blistering, and paraesthesia - loss of tactile sense). The effects of toluene and xylene are not as extreme. Toluene effects are documented by painters and "glue sniffers" habituation. Both chemicals can cause fatigue, mental confusion, loss of coordination, severe nervousness, and insomnia as well as skin and mucous membrane irritation. Although benzene can occur in crude and gasoline, toluene and xylene are not as common.

Other aromatics such as phenols and cresols occur in some crudes. Since phenolic compounds (phenols) are acidic, they can be corrosive to skin, eyes, and membranes. They can also induce nausea, vomiting, difficult breathing, pulmonary edema, headache, visual disturbance, convulsions, and partial paralysis. Many phenolic compounds are readily absorbed into the blood stream and have acted as carcinogens and co-carcinogens in animals. Cresols also cause skin and mucous membrane irritation and corrosive tissue burns, especially tissues of the kidney and liver. Their microbicidal effects have long been known, as cresol-treated posts resist the attack of bacteria and fungi.

Crude oils may contain metals which can be carcinogenic, mutagenic, or teratogenic. Lubricants usually contain metals. The effects vary from skin irritation, kidney or liver damage, and cumulative poisons to death.

Generally, the effects by hydrocarbons can be categorized into five (5) classes:

1. Direct Lethal Toxicity (death)
2. Sublethal Disruption of Physiological Activities (depression, nausea, narcosis, convulsions, fatigue, insomnia, pulmonary edema, gastrointestinal irritation, paraesthesia)
3. Direct Physical Coating (mucous membrane irritation, skin blistering, death)
4. Incorporation of Oil In Organisms' Body (carcinogenic, teratagenic, mutagenic, death)
5. Alteration of Habitat (acidity, heavy metals accumulation, death)

Studies of these effects during actual spills have been limited. Furthermore, many of the acute effects may require prolonged exposure or heavy doses. However, the chronic effects can bring about poor worker performance and/or damage claims. Therefore, personal and public safety should be a primary consideration.

Spills On Land

When oil is spilled on land, some oil will evaporate, some oil will stay on the surface, and some oil will penetrate into the soil. Oil that evaporates generally does little harm, as the vapors disperse below harmful limits. However, accumulated vapors in low lying areas (stream bottoms) or highly flammable products can ignite and cause thermal damage (burn scars, dehydration, and/or death) to both plants and animals.

Oil that stays on the land surface can coat plants and animals with varying effects. Total coating can smother an organism. The effects of partial coating will vary with the season. Generally, plants coated during the non-growing season (due to cold temperatures, extremely hot temperatures, or dry season) are affected less than during growing seasons. Plants coated with oil during the growing season (especially early in the growing season) may cease photosynthesis due to the oil limiting light from reaching the leaves. The complete or partial oil coating on plant leaves can also be toxic to the plants,[7] can reduce seed production,[8] or can reduce germination.[9]

Generally, plants that live only one year or less (annual plants) are not as tolerant of oiling as plants that live more than a year and that can regenerate from roots (perennial plants). This trend has been found in the tundra where mosses, lichens, and liverworts are affected more than dwarf and woody shrubs,[10] in grassland with annual and perennial grasses,[11], in forests with various trees,[12, 13] and in marshes with annual and perennial grasses.[14, 15]

When plants are not tolerant of oil, elimination of plant species can be as high as 90 percent during the first year after the spill. On the other hand, light oiling has been found to stimulate some plants.[5, 6] If the number of plants is reduced, the spill can contribute indirectly to soil erosion.

Oil that seeps into the ground can have direct effects on plants (Fig. 1) and other organisms that may affect plants or animals. Besides direct toxicity to roots, oil can decrease oxygen in soil by filling air-filled pores. Kerosene based jet fuels are particularly resistant to oxidation due to the addition of oxidation inhibitors. Generally, oil oxidation is highest for crude followed by leaded gasoline, kerosene, motor oils, and diesel fuel.

With an increase in oil, some decomposing micro-organisms can increase, which can decrease or stop plant growth. Oil can reduce nutrient availability and increase toxic elements to plants.[8, 9, 18] Oil has also been shown to interfere with root uptake of water.[19]

Changes in micro-organisms' numbers (bacteria and fungi) can occur after an oil spill (Fig. 2). Since bacteria and fungi are necessary for the breakdown of organic matter, including oil, and the recycling of nutrients, changes in their numbers can affect their ability to degrade organic matter and supply plants and other organisms with nutrients (Fig. 3). Oil can change the numbers of a species by death of micro-organisms[20] and/or by stimulating growth of other micro-organisms.[21] For example, a microrhizal fungus (root fungus) aids plants in acquiring nitrogen. Crude oil is known to decrease these fungi, thereby decreasing plant growth.[22]

Other problems may result from the fact that some species that degrade oil change an insoluble hydrocarbon into a more soluble hydrocarbon, such as naphthalene, xylene, or benzene, that can dissolve into the groundwater and cause pollution of potable waters;[25] also, some species of micro-organisms which may increase after a spill are known to be pathogenic.[23, 24]

The effects of land spills on animals generally are a problem more to small animals with little mobility than larger animals with greater mobility. Most mammals and birds will avoid oil contaminated land unless they are incapable of leaving. For example, two dead sheep were found after consuming oiled seaweed which was their main winter food source.[26] Small animals such as worms, spiders, and insects contacting oil can die from oil toxicity or from physical

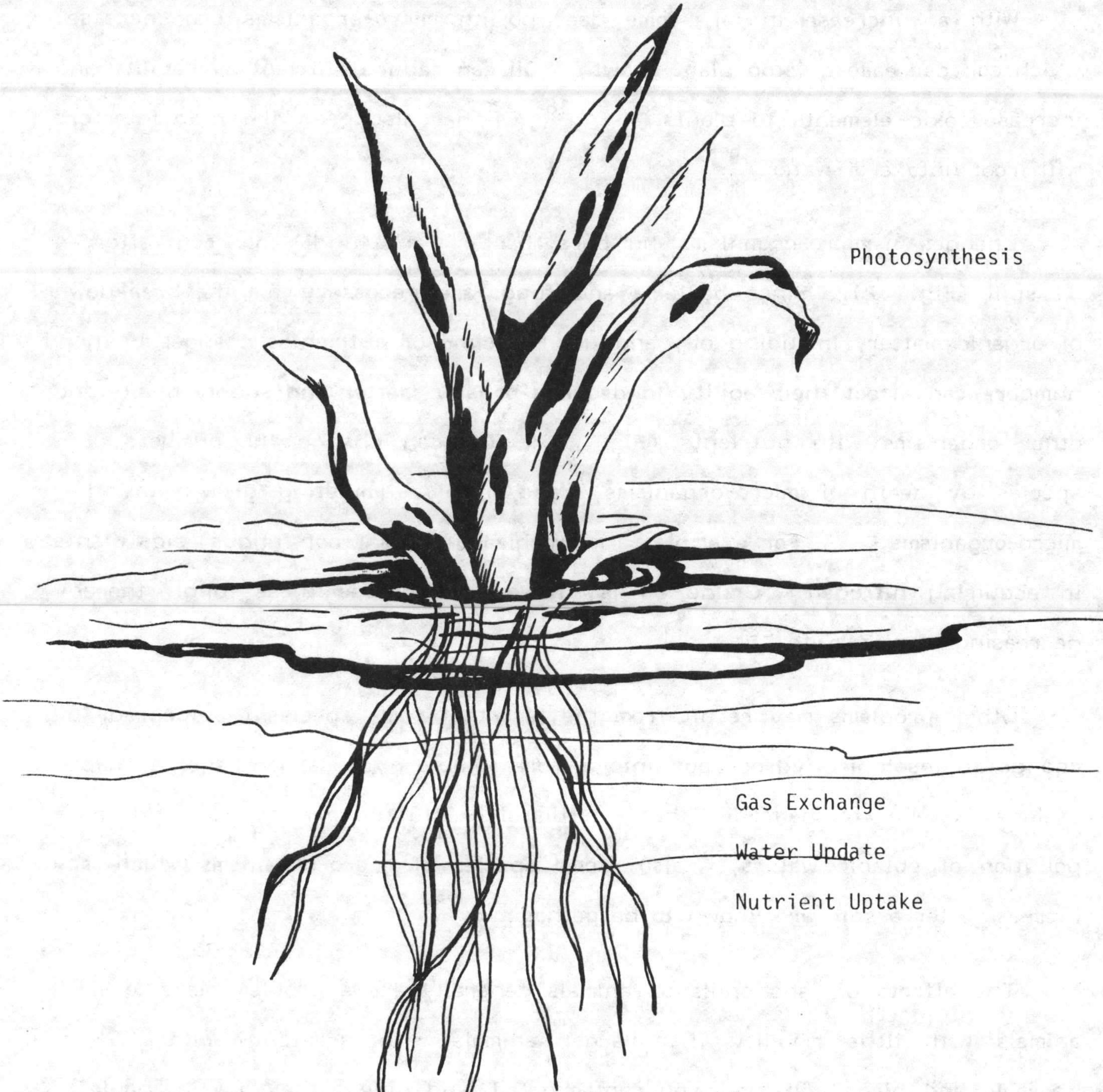

Figure 1. Oil Coating on Plants

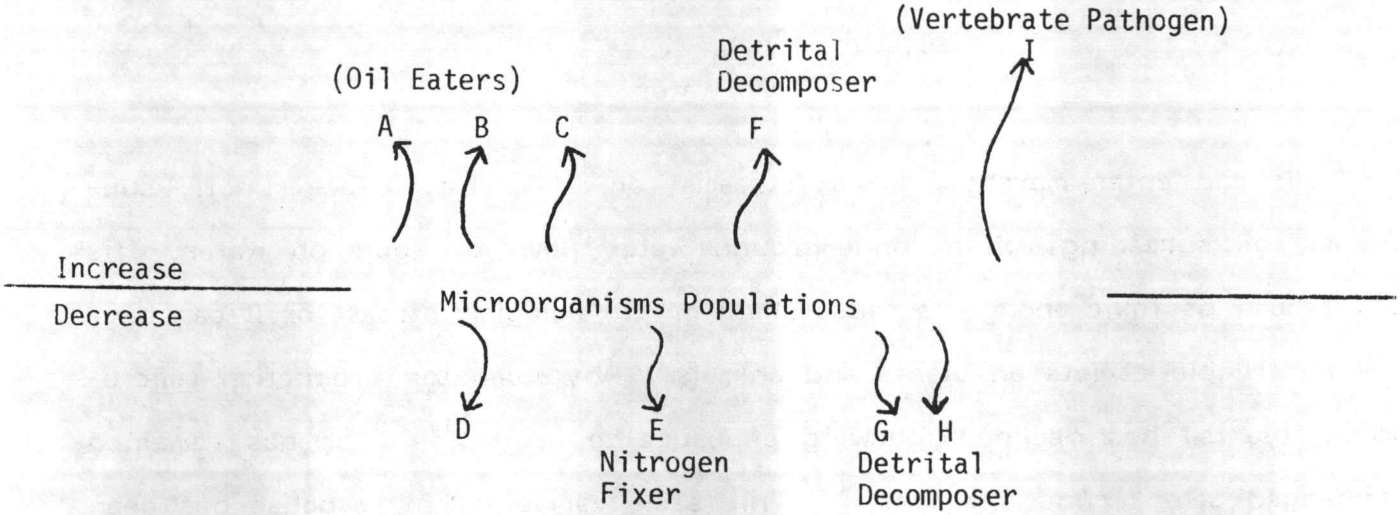

Figure 2. Effects of Oil on Bacteria

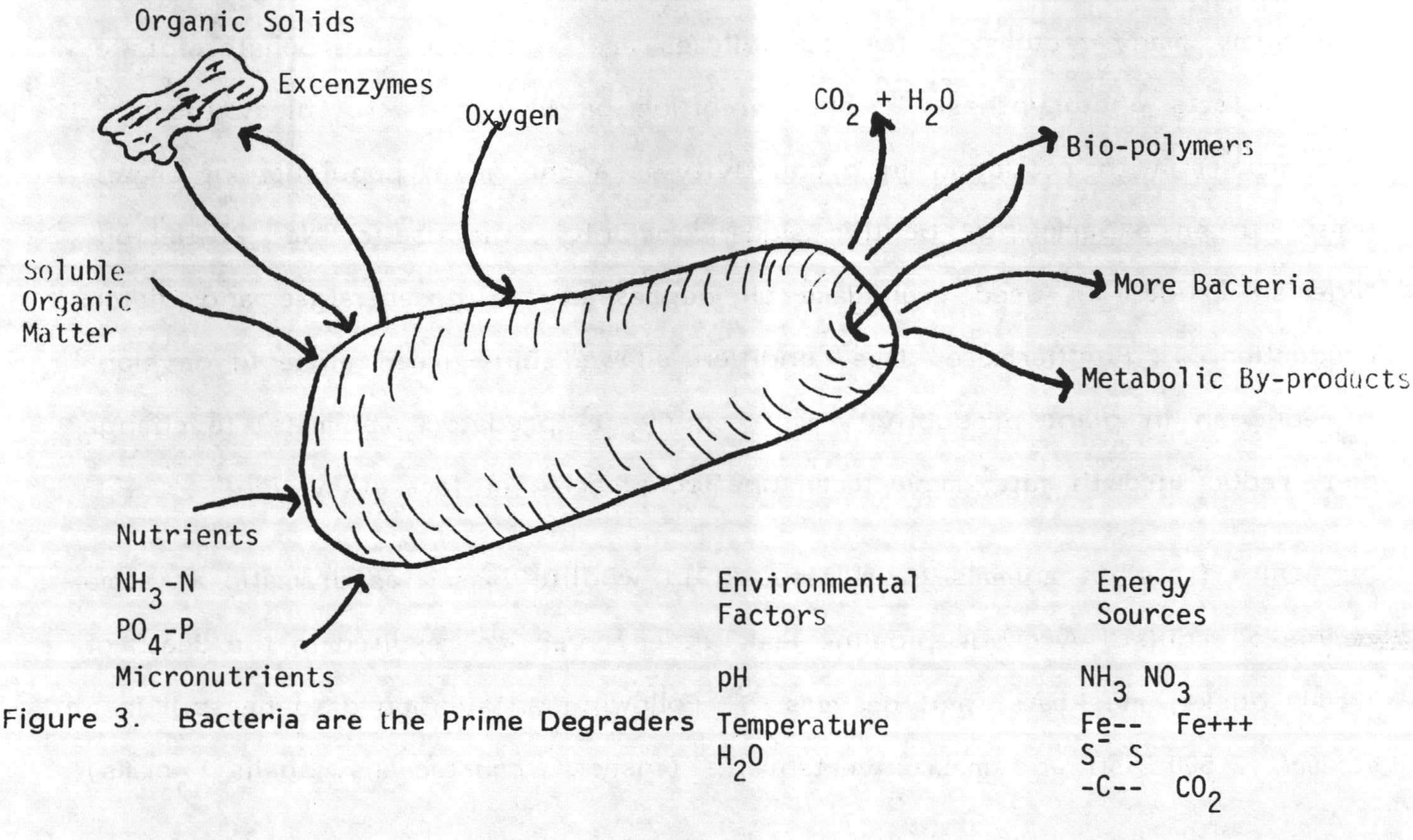

Figure 3. Bacteria are the Prime Degraders

restraint of highly viscous oils. For example, experimental populations of crickets were reduced by as much as 70 percent due to oil ingestion and integment absorbtion.[27]

Oils On Water

Oils can enter marshes, lakes, streams, or rivers by surface runoff, subsurface oil spreading, oil in underground water flow, or spills on water. Its effects can be toxic enough to cause death or physiological stress; or it can have few observable effects on plants and animals. Phytoplankton production (microscopic plants) has declined following exposure to crude[28, 29] or has remained unchanged after crude exposure.[30] This same variability in response has been found for algae[31] and marsh grasses.[7, 32] This variability may be caused by the type of oil, the amount of time an organism is exposed to oil, and the physiological condition of the organism. Although the reduction in productivity may be caused by many factors, a few possibilities are: reduced bicarbonate uptake, which affects photosynthesis,[33] and inhibition of DNA and RNA biosynthesis.[34] The problem with reduction in productivity is a change in population of organisms. In an experimental benthic algae community, the use of No. 2 fuel oil, Nigerian crude, or used crankcase oil depressed the green algae and diatom production.[35] Furthermore, this condition allowed blue-green algae to develop. A reduction in plant productivity will require its predators (animals) to change diet, reduce growth rate, move to an uneffected area, or face starvation.

Oil effects on animals have resulted in wildlife losses as dramatic as some marine oil spills. A crude pipeline leak under river ice resulted in the death of 10,000 ducks, muskrats, and beavers.[36] Following an aviation gasoline spill in a stream, 2,500 fish and macroinvertebrates (insects, crustaceans, snails, worms) died within the first two miles of the spill.[37] A diesel spill in a creek resulted in an estimated 90 percent fish loss and the death of many macroinvertebrates.[38] After a No. 2 fuel oil spill in a creek, 20 carp, a turtle, a beaver, and a wood duck died.[39] Runoff from a gasoline tank truck collision into a pond resulted in the death of three wood ducks and an undetermined number of snakes.[40]

One reason for spill related death to animals is hydrocarbon toxicity. Although freshwater organisms have not been as extensively studied as marine organisms, oil can cause death or physiological stress in an animal (Table 1). In marine environments, hydrocarbon toxicity can result in individual death, physiological stress in body organs, behavioral changes, and teratological effects.[41, 42] Physiological stress includes lesions in veins, intestines, gills, kidneys, and increased respiration rates. Behavioral changes include reduced chemotactic perception (antenna reception in invertebrates) which can affect food locating behavior, predator perception, sexual partners finding, aggression, and grooming. Teratological effects (especially in birds) include inhibition of gonadal development, reduced egg production, and embryo or young malformations (Table 2).

The chance of an organism being affected by a spill will depend on the type of oil (particularly those with soluble aromatics), time exposed to oil and the physiological condition of the organism. Generally, those organisms that live at the water's surface or frequently visit the water's surface (high concentration of oil) will be affected more than organisms deeper in the water column (low concentration of oil) (Fig. 4). However, shrimp, a water column species, have been shown to survive toxicity experiments; yet during spills massive dieoffs have occurred as shrimp obtain lethal doses by surfacing at night and contacting slicks.[60] The surfacing behavior is also known for zooplankton. Although after a spill zooplankton were not affected by oil, they contributed an estimated 20 percent or more of oil volume to the bottom fecal droppings.[61]

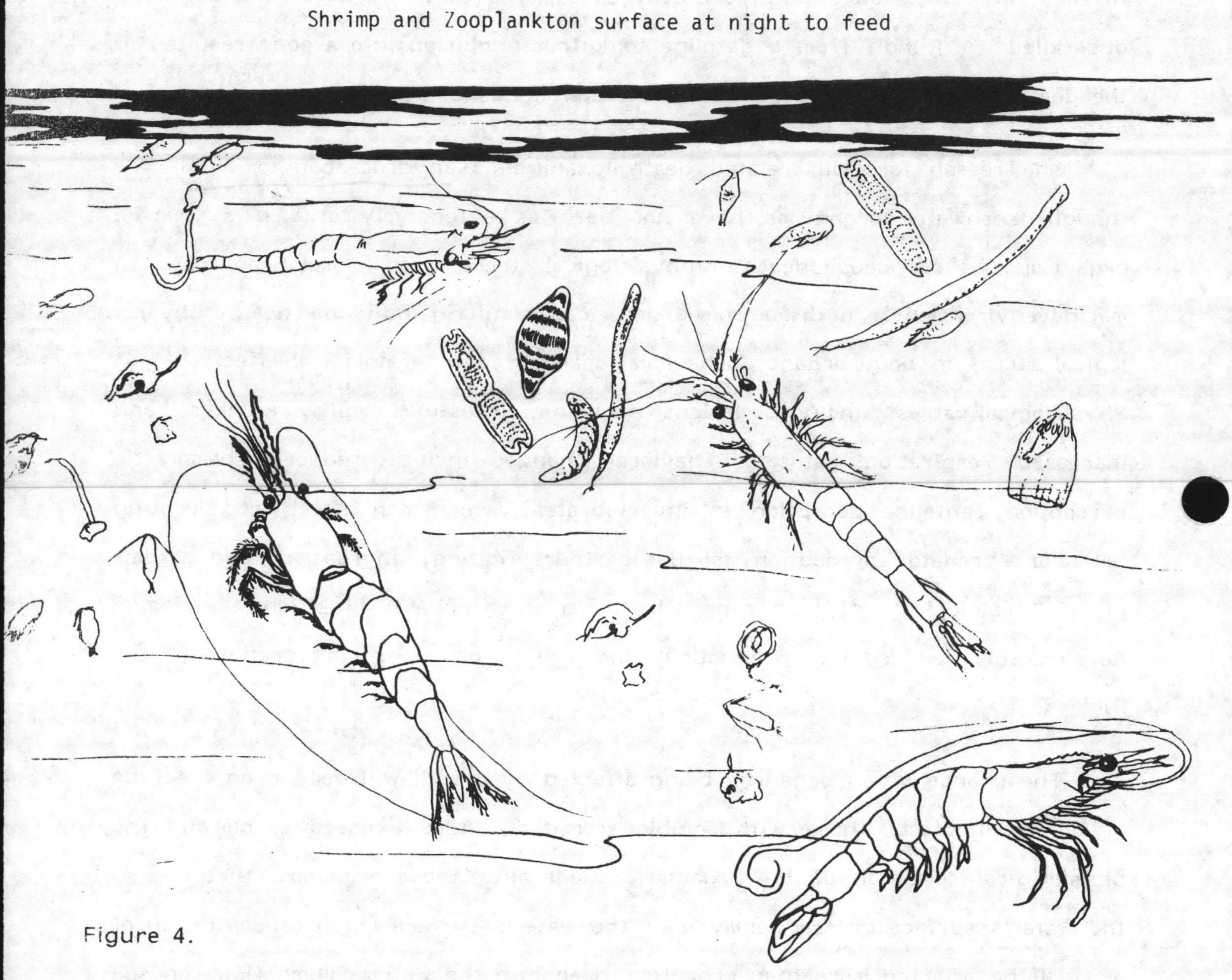

Figure 4.

TABLE 1. OIL TOXICITY ON FRESHWATER ORGANISMS

Organisms	Oil Type	Reported Toxicity	Remarks	Reference
Asplanchne Sieboldi (rotifer)	10 crude oils		Crude oils were toxic to rotifers. Stress in surviving rotifers showed reduced consumption and productivity rates. Oil had no effect on longevity.	43
Dapnicmagma (dapnia)	Napthalene	13.2 mg/l 24 hr LC_{50} 3.4 mg/l 48 hr LC_{50}	Dapnia showed sluggish behavior and decreased hemoglobin concentration.	44
Procambarus acutus P. clarkii (crayfish)	Water soluble fractions of No. 2 fuel oil		Crayfish took up napthalene upon exposure and excreted napthalene when placed in oil free environment.	45
Cipangopalundine chineasis (freshwater Mollusea)	Poly-nuclear aromatic hydrocarbons		Bioaccumulation concentrations were 15 to 200 times higher in mollusea than in sediments.	46
Jordanella floridae (American flagfish larvae)	Waste crank-case oil		Oil affected 30-day and 100-day old larvae survival due to metals in oil.	47
Salmotrutta (brown trout)	2, 4-dichlorophenol 2, 6-dichlorophenol 2, 3, 5-trichlorophenol 3 chloro-o-cresol 4 chloro-m-cresol	1.7 mg/l 4.0 0.8 2.0 1.3	24 hr LC_{50}	48
Lepomis macrochirus (bluegill sunfish)	Benzene Cyclohexone Phenol Toluene	22.49 mg/l 34.72 23.88 24.00	96 hr TL_m	49

Organisms	Oil Type	Reported Toxicity	Remarks	Reference
Carassius auratus (goldfish)	Benzene	34.42 mg/l		
	Cyclohexone	42.33		
	Phenol	44.49	96 hr TL_m	
	Toluene	57.68		
Lebistes reticulatus (guppies)	Benzene	36.60 mg/l		
	Cyclohexone	57.68		
	Phenol	39.19	96 hr TL_m	
	Toluene	59.30		
Pimephales promelas (fathead minnow)	Phenol	8.3 mg/l	48 hr LC_{50}	50
		29.0	96 hr LC_{50}	
		23.0	192 hr LC_{50}	
Lepomis macrochirus (blue gill sunfish)	Benzene	20 mg/l	24 hr TL_m	51
	Kerosene	2,990		
	Phenol	19		
Gambusia affinus (mosquito fish)	Cyclohexone	15,500 mg/l	24 hr TL_m	51
	Heptane	4,924		
	Napthalene	220		
	Cresol	24		
Xenopus lacuis (African clawed frog)	Napthalene	2.1 mg/l	96 hr LC_{50}	52
Rana catesbeiana (larval bullfrog)	Bunker C	0.13-10.0%	Within 7½ hrs. 72.8% of the number of frogs floated to the surface regardless of concentration compared to 4.9% of control group. Latter larval stages more susceptible to mortality, larvae had high accumulations of oil in buccal cavity and intestinal tract.	53

Organisms	Oil Type	Reported Toxicity	Remarks	Reference
BIRDS				
Anas platyrhyuchus (mallard)	Prudhoe Bay crude		Mallards tolerated large quantities of crude mixed in their diet.	54
Grus canadensis (sandhill crane)	Prudhoe Bay crude		Cranes tolerated high doses of oil in diet.	55
Falco spareurius (American kestrol)	Ixtoc I oil		Oil ingestion study showed crude possesses little hazard to free ranging kestrels.	56
Anas platyrhyuchus (mallard)	South Louisiana crude		Oil ingestion reduced egg production of hens, reduced growth in ducklings, biochemical lesions in ducklings' liver and kidneys.	57
Anas platyrhyuchus (mallard)	South Louisiana crude Kuwait crude No. 2 fuel oil		Oiled eggs: microliter applications of crude or refined oils on the surface of fertile eggs caused death to embryo or malformed chick.	
Somateria mallisima (common eider)	No. 2 fuel oil			
Larus marinus (great black backed gull)	No. 2 fuel oil			
Sterna sandivicensis (sandwich tern)	No. 2 fuel oil			
Larus ateirilla (laughing gulls)	No. 2 fuel oil			

Organisms	Oil Type	Reported Toxicity	Remarks	Reference
Hydranasse tricolor (Louisiana heron)	No. 2 fuel oil			
Hydranassa tricolor (Louisiana heron)	Weathered Libyan crude		Weathered oil applied to water-bird eggs caused embryo mortality.	58
Anas platyrhyuchus (mallard)	Weathered and unweathered aviation kerosene		No toxicity of kerosenes to eggs attributed to absence of high molecular weight aromatics in kerosene.	59

Another reason for spill related death is oil coating an organism. Although low viscosity oils (gasoline, diesel) are usually more toxic than highly viscous oils (bunker C, heavy crude, weathered crude), highly viscous oils usually cause more damage by coating organisms. The highly viscous oils can physically entrap insects, worms, and mollusks[62, 63] or reduce the insulation ability of mamal hair or of bird feathers.[64, 65, 66] Oiled birds and mammals would need to increase body heat 1.7 to 2.5 times greater than normal to maintain body warmth. This would require an increase in food intake and/or increase body fat metabolism. Failure to do so can result in pneumonia, starvation, and death (Table 2). Birds most often affected in inland waters are the following:

1. divers (loons, grebes, cormorants, pelicans)
2. waterfowl (ducks, geese, swans, merganzers)
3. waders (herons, egrets, sandpipers, plovers, gulls, and terns)
4. hawks (peregrine falcon, osprey, bald eagle)

Birds affected least are most land birds (quail, pheasant, jays, starlings, woodpeckers, and sparrows).

Marine mammals generally have insulation of fat and hair which provides them protection from loss of body heat when coated with oil. Except for a few hair seals, marine mammals have few problems with spills other than eye irritation. However, freshwater mammals, many being small, can have problems. After the Sullom Voe oil spill,[13] otters (Lutra lutra) were dead apparently due to oil coating.[26] Other evidence from oil sludge pits, tar pits, and oilfield spillage pits demonstrates oil's ability to entrap wildlife, as shorebirds, numerous ducks, herons, mockingbirds, crows, hawks, owls, cottontails, rats, skunks, toads, grasshoppers, beetles, dragonflies, moths, and butterflies were found trapped in the oil.[67]

TABLE 2. SUMMARY OF OIL EFFECTS ON BIRDS

Oil on Birds

1. Pneumonia
2. Starvation
3. Death

Oil in Birds

1. Inhibition of Gonadal Development
2. Reduced Egg Production in Hens
3. Embryo Malformation
4. Chick Malformation
5. Reduced Growth Rate in Ducklings

Oil on Eggs

1. Embryo Death
2. Embryo Malformation

Deterring Wildlife

When wildlife (primarily birds and mammals) can be harmed by a spill, a natural consideration would be to keep the oil away from the wildlife or the wildlife away from the spill. Althoug deterring wildlife can be accomplished, a single technique will not work on all birds or mammals. Furthermore, deterrent devices may be useless where breeding wildlife have nests, dens, or young.

Deterrent techniques have been developed to encourage birds and mammals to stay away from airports, oil ponds, oil lagoons, and other areas.[68] They use sound stimulus, visual stimulus, or both stimuli to scare wildlife. Wildlife responses to a stimulus vary. Diving birds, such as loons, grebes, cormorants, and anhingas will usually dive in response to danger, while non-diving birds, such as dabbling ducks, gulls, and coots, will take flight in response to danger. Molting birds may be incapable of leaving an area. Wildlife will become habituated to a deterrent device with time. Therefore, deterrent devices should be used only where wildlife is threatened and should not be deployed due to its availability. Also, birds tend to contact oil more often at twilight and at night when cleanup operations are few. Many water birds roost in ponds, lakes, marshes, and rivers. Therefore, a good wildlife deterrent must be mobile, effective over a large area, effective for wildlife threatened, and effective at day and night.

Some examples of sound deterrent devices are distress calls, predator sounds, Av-Alarms, pyrotechnics, and gas exploders. Distress calls are recorded calls of a species that when broadcast cause the species and possibly closely related species to disperse. Although most species are slow to habituate to their own distress call, some species do not or rarely give a distress call. Predator sounds have been used in marine environments by using killer whale sounds to disperse seabirds and on land to remove flocks of birds from trees.[69] Their use in inland areas has not been tested thoroughly. The Av-Alarm is a proprietory device that produces loud sounds in the frequencies of the species to be dispersed. The sounds are thought to interfere with the communications of the flock, therefore creating stress in the species which causes them to disperse. The sounds from one of these devices are also effective on people. Pyrotechnique devices make a loud noise and/or light flash to scare wildlife, although the stimuli does not mimic any naturally occurring experience. Some examples are shell crackers, verey flares, rockets, mortar shells, and dynamite. Shell crackers are used in a shotgun usually to produce a loud pop or crack and a puff of smoke at a distance from the shotgun. Shell crackers are commonly used at airports with bird problems. Verey flares shot from a hand gun produce a trail of smoke, a flare, and a loud pop. When using pyrotechniques, oil flammability and operating aircraft should be considered as a pyrotechniques' usability. Gas exploders use propane or acetylene gas to ignite and produce a loud pop somewhat similar to a shotgun shell being fired. They have been widely used in agricultural areas to disperse seed eating birds and in grasslands to disperse coyotes.

Devices that use visual stimuli include scarecrows, dyes, lights, reflectors, hawks and falcons, and food lures. Scarecrows are generally of limited value because wildlife becomes habituated to the device and it only works during the daytime. However, human effigies in small boats that rock with wave action have shown some success.[70] Dyes producing colored water or colored oil could be quickly applied by aircraft but would be only effective during the day. The testing of eight colors has shown orange to be the best deterrent, with black being the worst deterrent.[71] Search lights and flashing lights have been successful at dispersing feeding and flying waterfowl at night. However, search lights may attract some birds, especially during rain, fog, or heavy cloud cover. This phenomenon is particularly noticeable at inland areas adjacent to the Gulf of Mexico from the end of March to the middle of May, when billions of small birds migrate across the Gulf and are attracted to light. In using strobe or flashing lights, the optimal color tends to be red with a flashing rate of 6 to 12 seconds. However, this rate can stimulate epileptic seizures in susceptible people. Reflectors such as aluminum pie tins have shown only limited success. However, their success has been increased by allowing tins to move. Aluminum tins work best on sunny days. Similarly, hawks and falcons work well on fair weather days. They require extensive care and training, and work best over inland areas. Food lures may attract birds away from a spill or may attract more than a normal number of birds to a spill area. Since a food lure would need to be placed near the spill to be effective, it may attract high numbers of birds upon continuous use for several days.

The use of aircraft and model aircraft use both sound and visual stimuli to scare wildlife. Although aircraft can quickly scare birds away from a large area, some water birds will dive from the stimuli. Also, many birds will be reluctant to leave wildlife sanctuaries, especially after the start of hunting season.

Saving Oiled Wildlife

When oiled birds or mammals are observed, one may be inclined to "rescue" the oiled animal. Before an animal is subjected to this stressful situation, a few questions should be answered.

1. Would the animal be better off without being cleaned?
2. Are there nearby facilities for cleaning the animal?

Generally, a light amount of oil may not hinder an animal's daily activity. If an animal is moderately or heavily coated the animal may be saved if cleaned. However, if cleaning cannot be initiated quickly (within one day of capture) the chances for the animal's survival diminish.

Another consideration is the legal aspect. Although it is illegal to capture and hold a migratory bird (includes ducks, geese, swans, cormorants, loons, grebes, herms, egrets, and pelicans) without the appropriate U.S. Fish and Wildlife Service and state permits, the law may be relaxed during an emergency. Also, a person cannot capture and hold migratory birds until after permits have been received.

If the animal would be more likely to survive after being cleaned, the first step is to capture the animal. Depending on the animal type, the rescuer should wear gloves, clothes to cover the body, including the arms, and goggles. These coverings will reduce personal injury from animals that scratch or birds that attack the eyes. Remember, animals can inflict painful injuries by biting or scratching. Some oiled animals can be easily caught with a long handled net. However, animals should not be chased until they collapse due to exhaustion. After an animal is captured, sometimes struggling can be reduced by covering its eyes with some object to shut out light. Each animal should be placed in a separate container for transportation. Boxes with lids work well for birds, and garbage cans with lids work well for small mammals.

Ideally, animals should be transported to a rehabilitation center within one hour. Therefore, it is imperative that rescue operations be preplanned. Even though publications can describe what needs to be done,[72, 73] without proper training, cleaning efforts can be futile. Trained personnel can be found through the state agency that issues bird handling permits, the fish and wildlife service, zoos, or other wildlife exhibiting organizations. Organizations that clean oiled animals are:

International Bird Rescue Research Center
Aquatic Park
Berkley, CA 94710

Wildlife Rehabilitation Center
84 Grove St.
Upton, MA 01568

Overall, capturing and rehabilitating wildlife should be a planned operation to minimize stress to the animals (Table 3). Cleaning wildlife can be successful.[74, 75] In some cases, oiled animals are more likely to survive without cleaning.

TABLE 3. OILED WILDLIFE RESCUE AND RECOVERY PLANNING GUIDE

1. Capture
2. Confinement
3. Transportation
4. Cleaning
5. Rehabilitation
6. Release

Summary

Oil in the environment can follow many pathways (Appendix 1 and 2). It may kill organisms, stimulate organisms, or hinder and stimulate different organisms. The major problems with oil are:

1. Direct lethal toxicity
2. Sublethal disruption of physiological activities
3. Direct physical coating
4. Incorporation of oil in an organism's body
5. Alteration of habitat

Although preventing oil from entering an area of high wildlife value is the best way to reduce the impact of a spill, wildlife deterrent devices can help reduce oil induced problems, particularly for birds and mammals. Multiple techniques are suggested for deterring wildlife. When wild animial rehabilitation is considered, an organized plan for capture, cleaning, and rehabilitation should be administered with trained personnel.

APPENDIX 1. BIOLOGICAL IMPACTS

BIOLOGICAL	Direct Kill	- Coating/asphyxiation of animals and organisms - Direct contact poisoning
	Delayed Kill	- Lethal dose of toxic soluble portion results in death at some other location - Food chain interference - Reduced resistance to subsequent infection - Possible incorporation of carcinogen into the affected species and human food chain
	Salability or Population Density	- Kill of sensitive young of the species - Food chain interference requiring migrations to less desirable areas - Tainting (taste/odor) to destroy food value - Degradation of breeding/feeding areas

APPENDIX 2. PHYSICAL IMPACTS

- PHYSICAL
  - Soiling
    - Crafts
      - pleasure
      - military
      - commercial
        - enjoyable-use diminution
    - Shorelines
      - beaches
      - estuaries
      - preserves
        - use diminution
        - productivity diminution
    - Structures
      - buildings
      - piers
      - bridges
      - roads
        - possible structural failure
        - use limitations
    - Animals & Plants
      - birds
      - kelp
        - toxic effects
        - tainting (taste/odor)
  - Fouling
    - Water Intake Structures/ Screens
  - Aesthetic Quality Degradation
    - Odor
    - Appearance
  - Hazard
    - Explosion
      - life
      - property
    - Ingestion
      - humans
        - illness
      - aquatic species
        - potential source of carcinogens
        - emulsified oil affects breathing & feeding mechanisms
        - direct & indirect kills
      - terrestrial species & birds
        - preening by oil soaked birds & direct kill potential
    - Skin/Eye Contact
      - irritation "burns"
    - Inhalation
      - humans
      - terrestrial animals
  - Interfering
    - Gas Transfer from Air to Water
      - affects oxygen regimen
    - Public/Private Land Use
      - private property
        - use diminution
        - value diminution
      - business property
        - piers
        - other
      - roads
        - commerce
        - pleasure
    - Other Water Uses
      - recreation
      - navigation
      - water supply
      - fish culture
  - Depositing in Bottom Sediment
    - smothers bottom species
    - may resurface & recreate spill condition
    - destroys biologically productive area

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DESCRIPTION:

Properties of oil that

affect Recovery

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PROPERTIES OF OIL THAT AFFECT RECOVERY

Knowledge of how oil reacts after it is spilled is essential for effective oil recovery. Crude oil and refined petroleum products are not made of one type of molecule, but are mixtures of different molecules. The types of molecules are similar in structures except for the number and position of carbon and hydrogen atoms in each molecule. During the refining step the molecules are sorted, altered, and reorganized to produce specific blends of molecular types that have been found to work best for the customer (Figs. 1 and 2).

Each blend will act slightly different because the properties of the molecules change as the chemical structures change. As an example, one factor that controls the oil spreading rate is the viscosity of the oil. The less viscous No. 2 oil, with shorter length molecules, will spread faster than the more viscous No. 6 oil which has much longer molecules.

Oil Spreading

Of the different ways oil may interact with the environment, the rate of spreading is perhaps the most important. As discussed above, spreading rate is a function of the viscosity of the oil. Viscosity is determined by the type of oil molecule and the temperature. In the winter, when the temperature is very low, oil spilled on the ground will not penetrate the soil as quickly or spread over the surface as rapidly as it would in the summer. If the ground is frozen, the oil will not penetrate at all. A second factor affecting spreading rate is the surface tension of the oil. Like viscosity, surface tension is also temperature dependent and tends to restrict spreading at low temperatures. Although the factors that affect spreading are known and spreading rates can be predicted under carefully

MOLECULAR SIZE

FIGURE 1

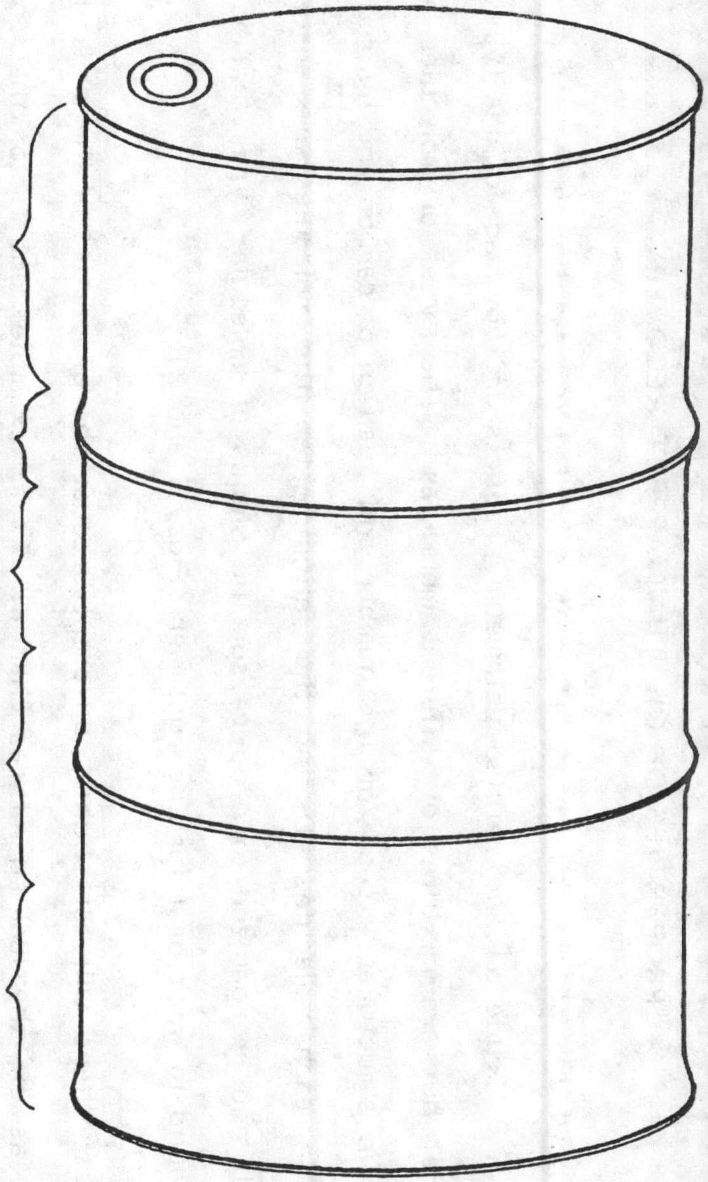
GASOLINE (C_5–C_{10}) 30%

KEROSENE (C_{10}–C_{12}) 10%

LIGHT DISTILLATE OIL (C_{12}–C_{20}) 15%

HEAVY DISTILLATE OIL (C_{20}–C_{40}) 25%

RESIDUUM OIL ($>C_{40}$) 20%



"AVERAGE" CRUDE OIL

MOLECULAR TYPE

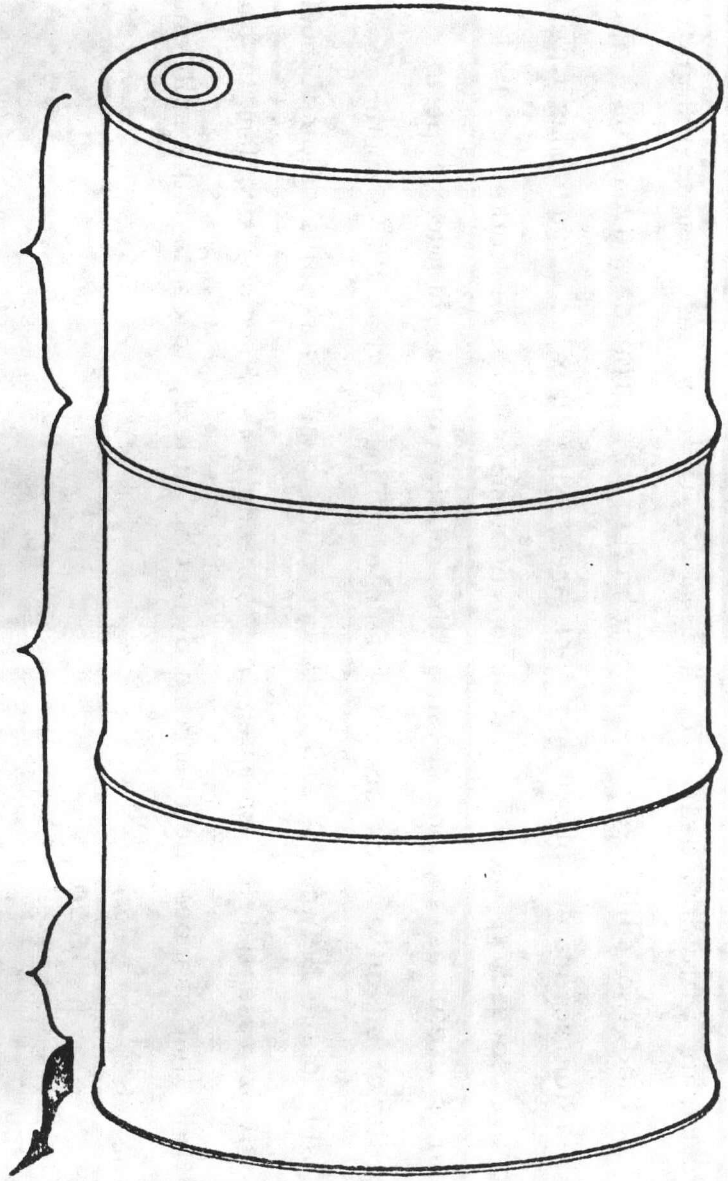
FIGURE 2

PARAFFIN
HYDROCARBONS
(ALKANES) 30%

NAPHTHENE
HYDROCARBONS
(CYCLOALKANES) 50%

AROMATIC
HYDROCARBONS 15%

NITROGEN, SULFUR, AND OXYGEN CONTAINING COMPOUNDS (NSO) 5%



controlled laboratory conditions, spreading rates for actual spills are very difficult to calculate with any degree of accuracy. Outdoor test results using two types of oil and two spill sizes are shown in Fig. 3. The data from the figure is not valid for accurately predicting slick areas with time for a particular future spill because spreading rate is a function of temperature and other variables. The graph is useful as a guide to show the relative effects of time, type of oil, and quantity of oil on a slick area. A rule of thumb is that the diameter of an oil slick will double between 4 and 12 hours after a spill for spills of up to 5000 barrels. It is essential to remember that spreading is a serious problem to the cleanup crew that can best be overcome by acting quickly to contain the spill and remove the oil.

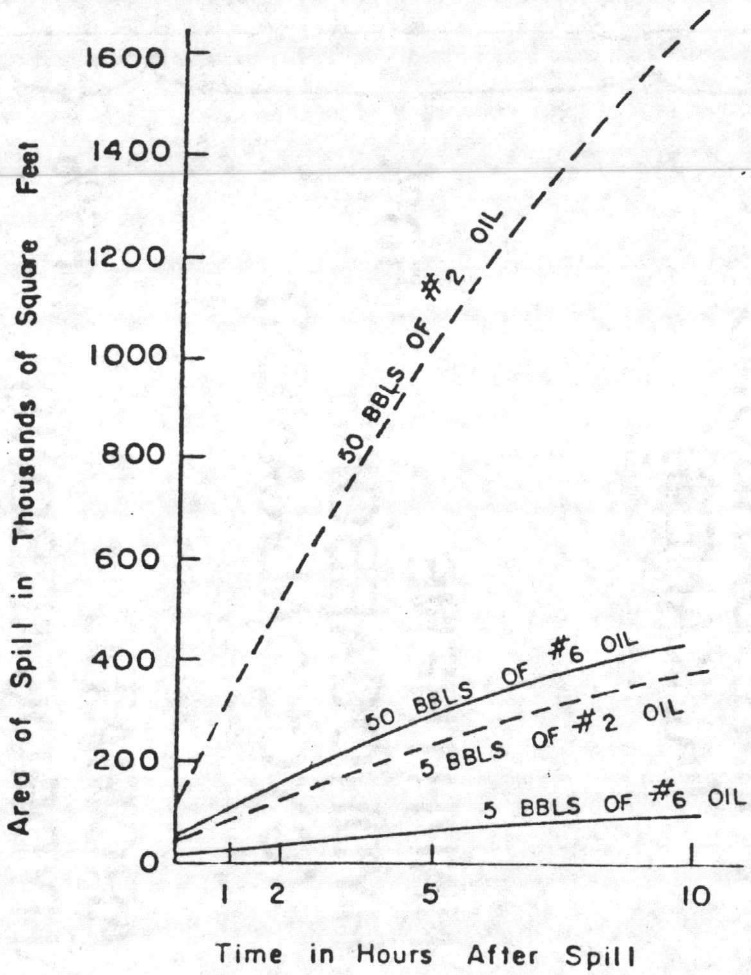


Figure 3. Relationship of Spill Area, Volume of Spill, and Type of Oil with Time

Viscosity affects cleanup efforts with regard to pumping recovered oil. The more viscous the oil, due to oil type and temperature, the more difficult it will be to pump. It is therefore important to match pumps and hoses to the pumping conditions. It is also important to know the oil's pour point, which indicates the temperature at which the oil can no longer be pumped. The pour point temperature will be a function of the makeup of the oil. A waxy crude oil will have a high pour point. Number 2 oil has a pour point of about 20°F. Number 6 oil has a pour point greater than 100°F and therefore must be heated prior to pumping.

Oil Evaporation

Volatility is an important characteristic because it governs the rate of evaporation of spilled oil and will determine combustion properties. The flash point and the lower flammable limit are two terms describing volatility. The flash point is the minimum temperature at which sufficient liquid is vaporized to create a mixture of fuel and air capable of being ignited. For example, the flash point of gasoline is -45°F (-43°C) and that of No. 2 diesel is 125°F (52.7°C). Therefore gasoline is likely to ignite in most spill situations. On the other hand, diesel's flash point is above normal temperatures at most spill events. This does not mean that diesel will not ignite. An ignition source can provide the temperature necessary for ignition and the initial combustion can provide the temperature needed for continued combustion.

Combustion is possible when the ratio of fuel to air lies between certain limits. A mixture with not enough fuel (too lean) or not enough air (too rich) will not support combustion. Since it is unlikely that a too rich situation will occur during a spill, the too lean mixture is of primary interest. The minimum volume of fuel (vapor) that will support combustion is called the lower flammable (explosion) limit. For gasoline, this volume can be as low as 1.4 to 1.7% of the air volume. A preferred way to check for combustibility is with a combustible gas detector. Remember that the combustible gas detector test is only good where taken, and this information cannot be generalized for the entire spill area. Furthermore, hydrocarbon products form a layer along the ground which will, in time, mix with the air. The vapors are apt to settle in low places.

Most oils will emit combustible vapors, especially light oils such as gasoline and aviation fuels (Fig. 4). Combustion is likely where oil is concentrated at spill sources, behind booms, or on the shoreline. Since three things are required for combustion to take place [fuel, oxygen (air), and an ignition source], the removal of any one requirement will prevent combustion. Therefore, fuel on land can be covered with a foam blanket or dirt to remove the air. Ignition sources can be removed. Some common sources are: flames (matches, cigarettes), electric sparks (pumps, motors), static sparks, and hot surfaces (mufflers, catalytic converters, pumps).

A complex mixture such as crude oil will initially lose light fractions by evaporation followed by successively higher boiling fractions (Fig. 5). The evaporation rate will be increased by high winds (Fig. 6). Rough weather conditions also increase evaporation by exposing more surfaces of the oil at wave crests and as sprays. Because evaporation is enhanced by increased surface area, more evaporation will occur as the oil spreads.

Heavier components of crude oil will evaporate slowly and form a residue on the water surface. The residue will have a higher specific gravity, a higher viscosity, and contain greater concentrations of sulphur, metals, and wax than the original crude. Evaporation will result in losing a significant portion of the

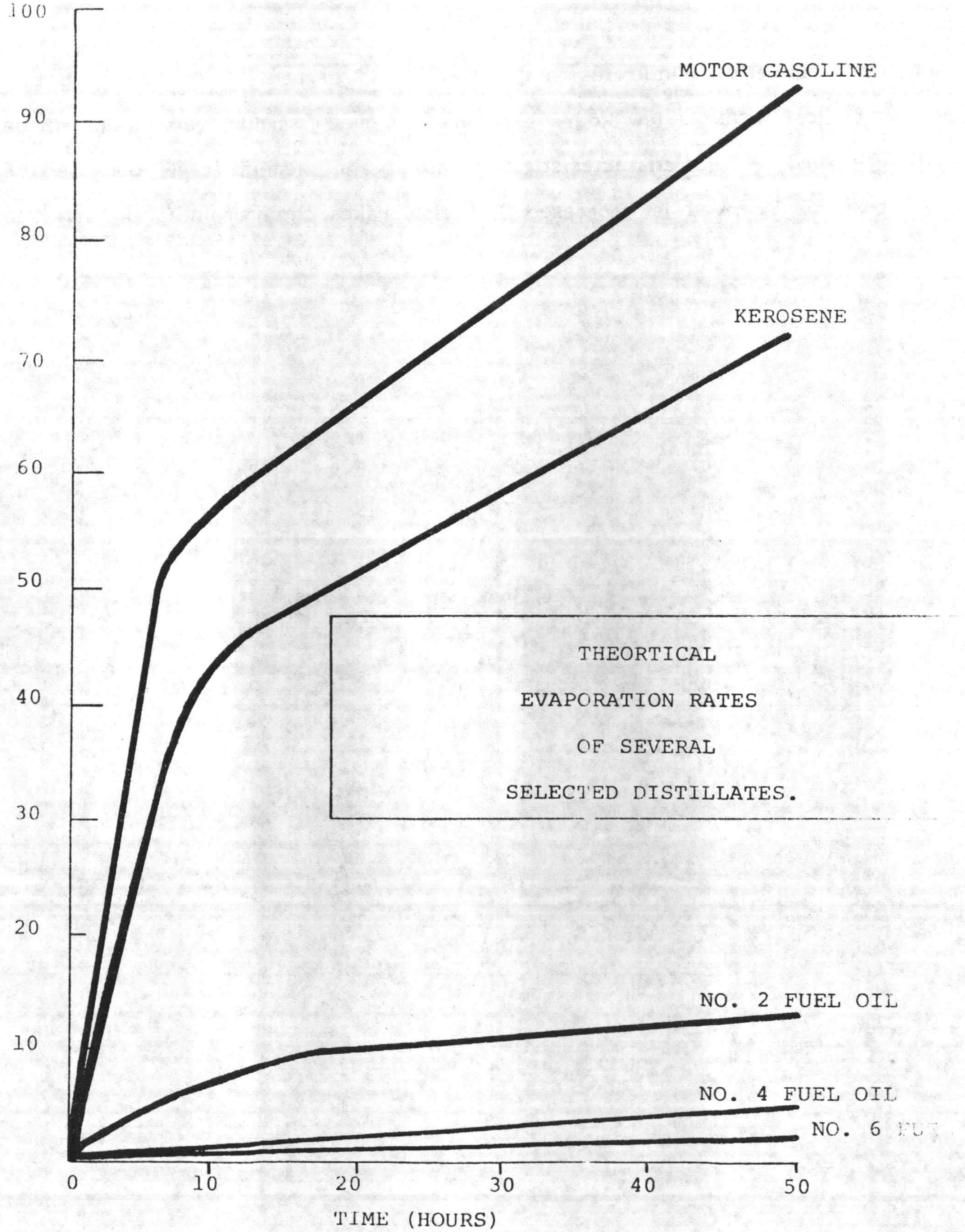


Figure 4. Relative Evaporation Rates of Hydrocarbon Fuels

spilled oil. Experience indicates that as much as 20 percent of the total weight of oil can be lost within a few hours exposure. A much smaller percentage will be lost afterward. This characteristic will assist the cleanup crew because the amount to be removed is decreased. It also makes the remaining oil safer to handle.

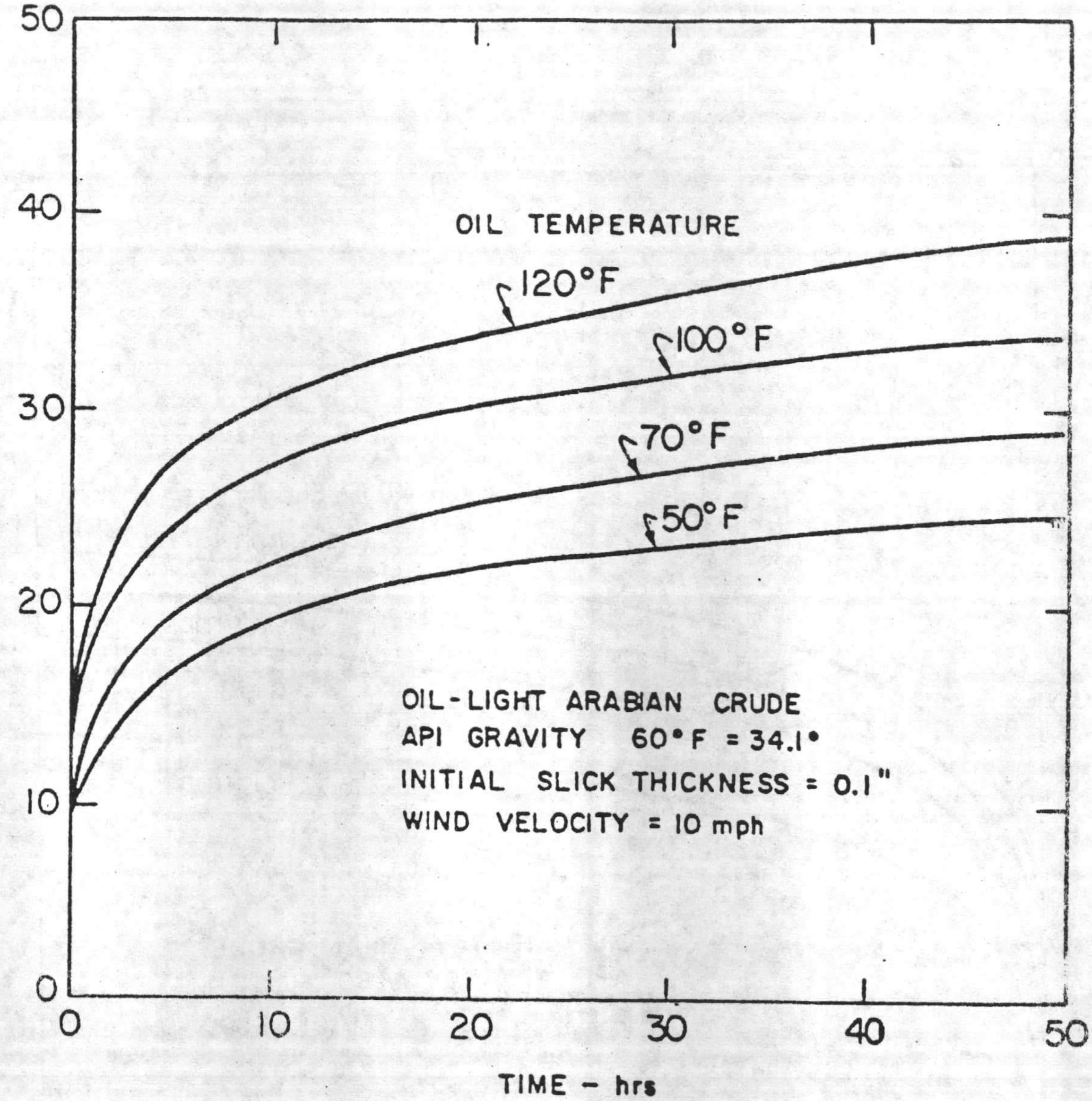
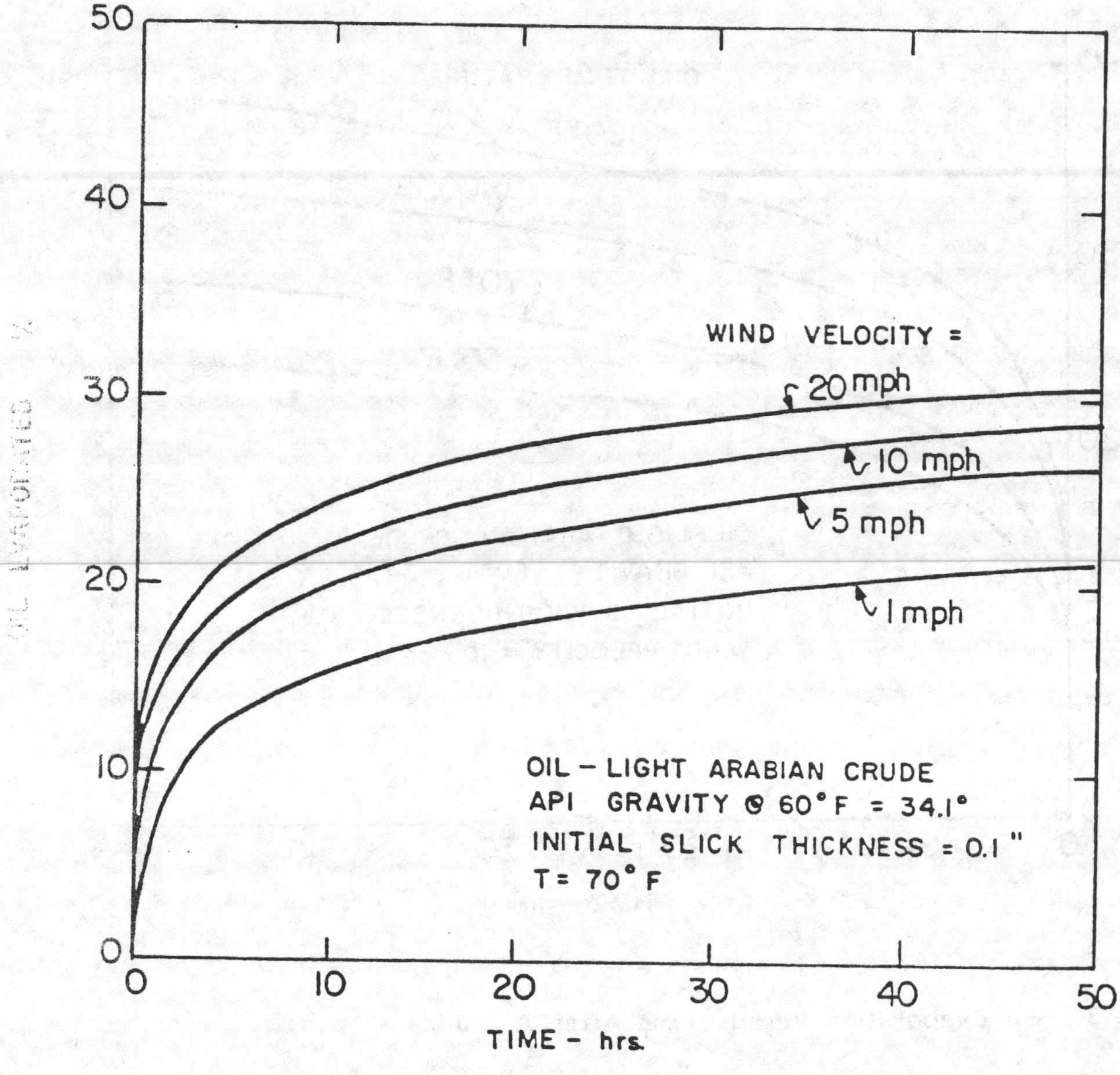


Figure 5. Oil Evaporation Versus Time After A Spill



...re 6. Effect of Wind Velocity on Slick Evaporation

Biological Degradation

When oil is spilled in the environment, microorganisms that inhabit the spill area will begin to degrade the oil by using it for food. The rate of degradation will depend on temperature, type of oil, availability of nutrients, and presence of oxygen. It has been suggested that bacteria be added to oil slicks to permit the organisms to degrade the oil at a faster rate. However, the process is more complicated than merely adding organisms because of the requirement of oxygen and nutrients needed for rapid degradation. The relative effect of biological degradation is significant depending on the location of the spill. For example, there would be very little degradation in arctic waters, but considerable oil degradation would occur in tropical waters. Compared to evaporation, however, biological degradation is usually a small factor over a short period of time.

Other Factors

Most oils can be easily seen on top of the water with the exception of light oils such as No. 2 fuel oil. Although No. 2 fuel oil floats, it is almost transparent and very difficult to see when a worker is viewing the spill a few feet above water. This is why it is helpful to use helicopters to find spills. Spilled oil is usually much lighter than water and will alsmost without exception float, although some heavy oils have been reported to sink. Kuwait crude residue has a specific gravity of 1.023, and Franion Heavy has a specific gravity of 1.027. However, it is not likely that these residues will sink if spilled in sea water, which has an average specific gravity of 1.025. It is believed that a light emulsion forms under the spill and acts to float the oil.

A small amount of the oil will dissolve and emulsify in the water, depending on the amount of light fractions and degree of mixing caused by currents, waves, and vessel traffic. Light fractions will dissolve in water up to a maximum of about 1000 parts per million. Table 1 lists some hydrocarbon solubilities in distilled water.

Generally, oil density will tend to affect the ease of dispersion of the oil through the water column (Table 1). Light fractions will dissolve in water up to a maximum of about 10,000 parts per million. The problems with oil dissolving in the water are toxicity to aquatic life, odor in drinking water, flavor change in drinking water, reduced cooling efficiency in cooling waters (power plants), explosion hazard in industrial water supplies, and contamination of food or chemical products from receiving waters. If an emulsion occurs, a thin combination of oil, water, and air (sometimes sand) can develop. Under certain conditions a highly viscous emulsion called "chocolate mousse" can develop which is difficult to recover and persistent in the environment. After the Amoco Cadiz and Metula oil spills, chocolate mousse persisted on the shoreline for years.[2, 3, 4] The longer oil persists in the water, the more water will combine with the oil to form an emulsion (Fig. 7), and the thicker or more viscous the emulsion will become (Fig. 8). This will affect pumpability. Heavy oils and crude oils are most subject to mousse formation. Although emulsion formation does not significantly slow down the evaporation process, biodegradation is reduced due to the lack of available oxygen inside the mousse.

TABLE 1. DENSITY AND SOLUBILITY OF OIL COMPOUNDS[5]

Compound	Density	Solubility In Water
PARAFFINS		
Pentane	.62	360 ppm
Hexane	.66	138 ppm
Heptane	.68	52 ppm
Octane	.70	65 ppm
Nonane	.72	c. 10 ppm
Decane	.73	c. 3 ppm
NAPTHENES		
Cyclopentane	.75	"slight"
Methyl Cyclopentane	.75	
Cyclohexane	.78	
Ethylcyclohexane	.79	
AROMATICS		
Benzene	.88	820 ppm
Toluene	.87	470 ppm
Ethylbenzene	.87	140 ppm
Xylene	.88	c. 80 ppm
Napthalene	1.15	c. 20 ppm

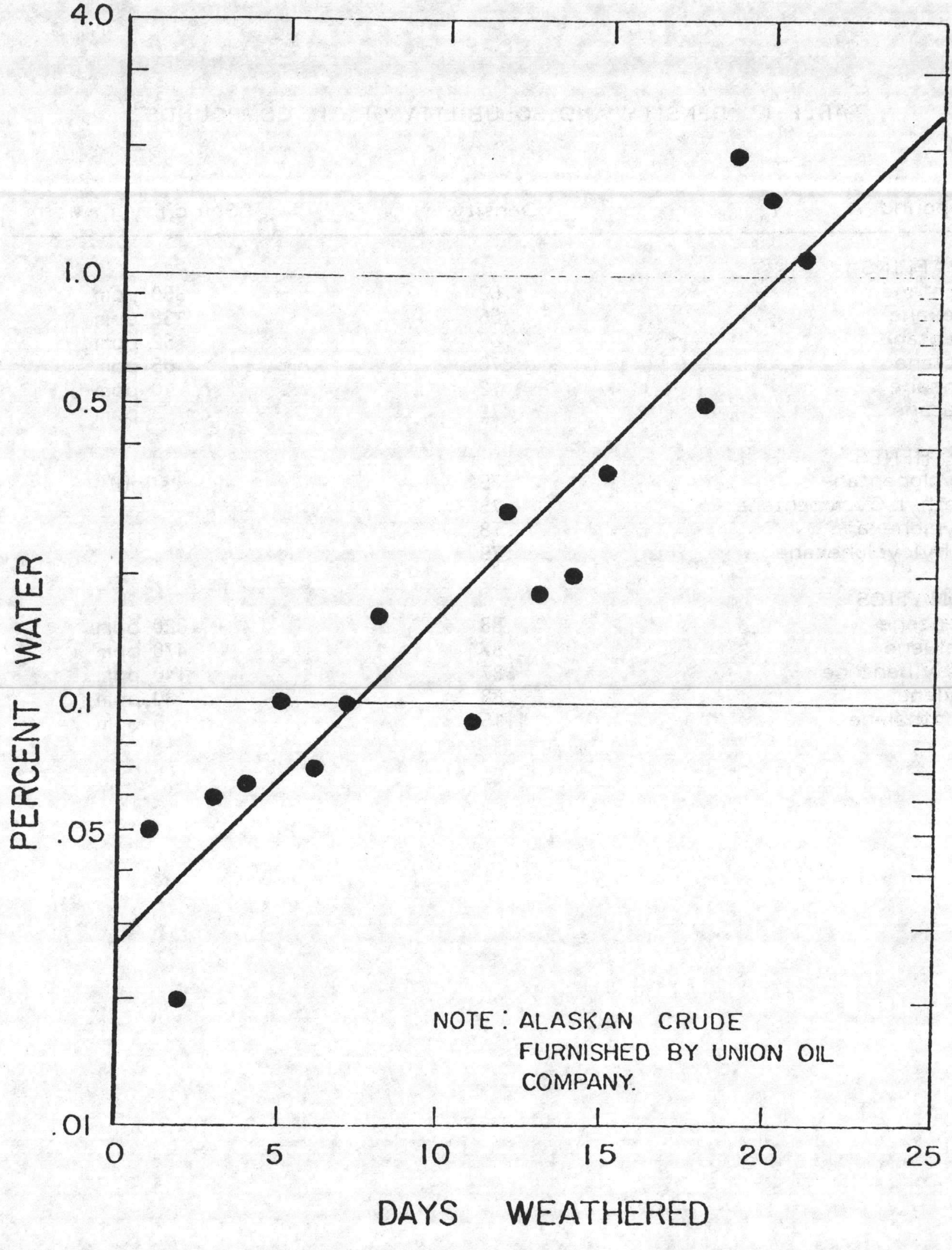


Figure 7. Water Incorporation Into Crude With Time[6]

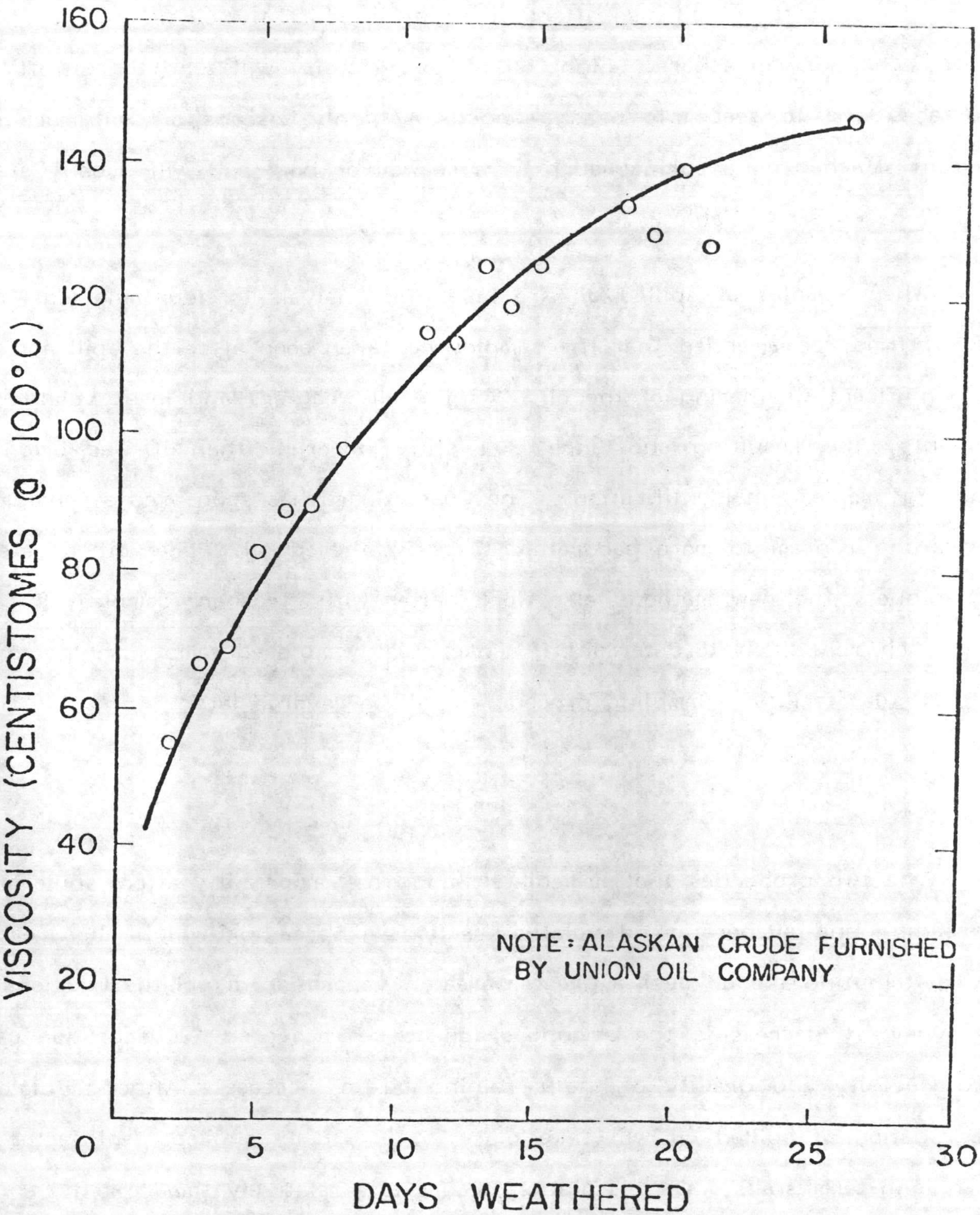


Figure 8. Viscosity of Crude With Time

The viscosity of oil also affects the way in which the oil will interact with a beach when driven ashore. Light oil of low viscosity will tend to run off rocky surfaces and to seep into beach sands. A highly viscous oil will more likely remain attached on a surface such as a seawall or boat and will usually stay on top of beach sand (Table 2).

When samples of spilled oil are taken for analysis to determine legal questions, it is recommended that the samples be taken soon after the spill and prior to significant weathering of the oil. As the oil weathers and loses volatile components, the resulting substance is slightly different than it was originally, causing problems in identification. The Coast Guard has sponsored a considerable research program to more accurately trace weathered oil. Like other detection techniques, the new methods also work better with "fresher" samples, but they are much more likely to determine if a particular weathered sample originated from a particular facility. Sampling procedures will be covered later.

Summary

The two properties that immediately and most importantly affect spills are oil spreading and evaporation of volatile fractions. Spreading will hamper recovery by distributing the oil over a greater area. Evaporation of volatile fractions aids recovery by decreasing the amount of oil to be recovered. Evaporation causes the viscosity and gravity of the remaining oil to increase. Although biological degradation of spilled oil will take place, it is usually an important factor only with long-term spills. Oil dissolution occurs to a relatively small extent, and the emulsification of oil depends on the properties of the oil and mixing energy. As oil weathers it becomes difficult to compare with unweathered oils. Therefore, the sampling program should begin soon after the cleanup program is implemented.

TABLE 2. PROPERTIES OF PETROLEUM PRODUCTS WHICH AFFECT THEIR SPILL BEHAVIOR[1]

Performance Critical Property	Descriptive Property	Gasoline	JP-4	Auto Diesel	Marine Diesel	Fuel Oils No. 2	Fuel Oils No. 6	Lube Oil	Relationship of Performance Property to Spill
Viscosity (centistoke at 100°F)	Resistance to flow	LOW	LOW	LOW (≈1.4)	LOW (≈3.0)	LOW (≈2.0)	HIGH (>75)	MOD - HIGH	Low viscosity materials spread easily over surface
Surface Tension	Resistance to spread over another liquid	LOW	LOW	MOD	MOD	MOD	MOD	MOD	Low surface tension materials will spread more readily
Volatility	Tendency to evaporate	HIGH	HIGH	LOW	LOW	LOW	VERY LOW	VERY LOW	High volatility favors evaporation--if combined with low flash point, present explosion hazard
Relative Solubility	Tendency for all or portion of spill to dissolve in water	VERY LOW	VERY LOW	VERY LOW	VERY LOW	VERY LOW	VERY LOW	Emulsifies	Soluble Components of spill (including additives) may be toxic to aquatic organisms
Density (specific gravity) approx	Mass per unit volume--tendency to sink in water	LOW (≈.73)	LOW	LOW (≈.85)	LOW	LOW (≈.82)	HIGH (.9 - 1.0)	MOD (.85)	Materials heavier than water (Sp Gr = 1.0) generally will sink--smother bottom organisms--affects shellfish
Emulsibility	Tendency to form stable suspension with water	VERY LOW	VERY LOW	LOW	LOW	LOW	HIGH	HIGH	High emulsibility spreads oil throughout water column, extends possible contamination range. Affects free swimming species (fish)
Pour Point	Lowest temperature at which oil will pour	LOW	LOW	LOW	LOW (20°F)	LOW (20°F)	HIGH (60°F)	LOW (10°F)	As pour point is approached, spill spread decreases
Flash Point (min)	Tendency to ignite	VERY LOW (-40°F)	VERY LOW (-20°F)	LOW (≈104° F)	MOD (140°F)	LOW (100° F)	MOD (150° F)	VERY HIGH (350°F)	Low flash point combined with high volatility = explosion hazard

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INITIAL RESPONSE ACTIONS

When an oil spill occurs, a multitude of questions arise as to what procedures to use to safely handle the event. Although the first company representative may not be in charge of all oil spill control operations, his decisions are crucial in controlling the spill at the spill scene.

Is the Product Flammable?

If the product is flammable, removing ignition sources (hot automobile engines and mufflers, cigarettes, etc.) will reduce the fire hazard. If flammability is questionable, hydrocarbon monitoring devices can be used to determine this possibility (Appendix 1). Since continued hydrocarbon sensation upon olfactory senses dulls the sense of smell, smell is not a dependable tool to locate hydrocarbons. To reduce the fire hazard of flammable products, firefighting foams can be used to cover the spill and lower the evaporation rate. Water fog can also be used for vapor control, but runoff will be increased.

Are People In Danger?

Once the site has been inspected, people should be protected. First, the response crew should stay upwind and the police and fire department should be contacted. If someone is found unconscious (tank truck driver, vapor victim, or other person), rescue should be initiated only by personnel using proper safety procedures and equipment. This may include full protective clothing, self-contained breathing apparatus, and safety lines. If product flammability or toxicity are potential problems, evacuation should be considered in downwind areas. Local police, firemen, etc. should be used in evacuations due to their familiarity with the area, knowledge of the people, and availability. The Department of Transportation has recommended evacuating people from an area at least 2,000 feet from the spill perimeter. Heat from hydrocarbon fires can be intense, explosions can generate sudden winds by pulling air towards the flames, and explosions can throw parts of metal containers in any direction. Determining the extent of further evacuation can be aided with hydrocarbon monitoring devices.

To keep crowds from forming, traffic should be diverted to alternative roadways. Remember, vehicles close to the spill scene should not be started until it is safe. For spills in waterways, boat traffic should be stopped from entering hazardous areas. To prevent and/or control crowds, security guards or policemen can be used to direct bystanders out of the area. Further warning notices, tape, flagging, rope barriers, and wood barricades can be set up to delineate a hazardous boundary.

Product evaporation can be reduced by using foams (see Physical and Chemical Agent section), soil burial, water flooding, and water fog. The use of sorbents, dispersants on thin water layers, and sumping and trenching techniques have proven only slightly effective at reducing evaporation.

Can The Product Be Safely Contained?

First, the leakage of the containers should be stopped or slowed. Depending on the situation, a pump station or valve can be closed shut, a drum can be rolled with hole up, or a leaking tank can be plugged. Next, spill containment can be initiated. On roadways, sewers and drains can be blocked to prevent explosion risk and sewage disposal contamination. On land, dams can be constructed in ditches, dry creeks, or other low places to stop spill flow on the surface. Dikes or trenches can be constructed around the spill site to guide oil to a collection site. Further, water can be added behind dams or dikes to reduce spill penetration into the soil.

On water, underflow dams can contain oil while allowing water to flow through. The main problem with underflow dams is vortex or whirlpool formation on the upstream side. The vortex will cause oil to escape from containment. A vortex can be eliminated by lowering the upstream end of the pipe in the dam or raising the pipe end in front of the dam. This allows a greater water depth between the pipe end behind the dam and the water surface. Another way to minimize vortex formation is by placing a floating board over the vortex. This action will prevent the vortex from obtaining its maximum size. Another device is the culvert wier. A board, plank, or capable material can be placed in the water on the inflowing end of the culvert. The culvert wier will stop or slow the oil on the water's surface, yet allow water to flow underneath the weir. Although this device is easy to construct, it can be difficult to maintain if the water flow varies during the spill event. The same principle can be used in ditches and small streams by placing a long board across the water to contain a spill. Containment and collection of material can be accomplished with the addition of a sorbent behind the board which is called a filter fence. The basic design is to have a fence material (board, poultry fence, chain-link fence, etc.) that will keep the sorbent from flowing downstream.

For larger bodies of water, beams should be used. (See Containment of Oil on Water section.) Furthermore, spills in larger bodies of water can be controlled faster with the use of aircraft. Through the use of aircraft the supervisor can get to the spill quickly, locate the oil, and determine the extent of the spill much better than by boat or on foot. Sometimes aircraft are the only method of adequately following a spill. For example, a light oil such as No. 2 fuel oil is all but invisible to an observer stationed near the level of the water. From a viewpoint above the water, an observer is capable of following the spill. In observing a spill, many phenomenon that appear as oil may require surface confirmation. Cloud shadows, underwater plant growth (seagrasses), and suspended sand particles near shorelines may all appear to be oil from an aerial view.

When surveying the spill site with aircraft, a camera or video recorder should be taken to obtain photographic evidence of the work. A battery operated tape recorder should be used to record the progress of the work and to provide a statement for each photograph taken. A two-way radio should also be taken so the supervisor will have contact with the ground operation. The aircraft will have one or more radios but the frequencies will not be compatible with those used in the cleanup work.

When a spill is in the containment and cleanup stage, the cleanup supervisor should survey the area daily by air to assess the progress of the work. Small pockets of oil can be located by air that may be missed by other methods only to get away at a later time and recontaminate the cleaned area. Streaks of oil can be located better from an aircraft. The effectiveness of booms can be determined by watching for oil coming under the boom and surfacing downstream. Oiled water fowl are easily located from the air and aircraft are sometimes used to scare birds away from an area.

Usually helicopters or airplanes are used in aerial surveillance. The one used may depend on availability, but there are advantages and disadvantages of each (Appendix 2).

Because of the valuable assistance of surveying a spill from the air, the use of aircraft should be included in the contingency plan. Daily flights over the spill area will permit documentation of cleanup progress using a camera and tape recorder.

When aircraft are not available or viewing conditions are poor (night or fog), oil movement can be estimated by knowing wind and current conditions. The wind effect is calculated by:

Average or mean wind speed X .034 = wind effect.

For example, a 12 mile/hour wind results in

12 mph X .034 = 0.4 mph wind effect

If both wind and current are present, vectors for each effect will estimate slick movement. See Appendix 3 for vector calculations. In knowing the spreading rate and changes in wind or current directions a spill's movement can be estimated (Fig. 1).

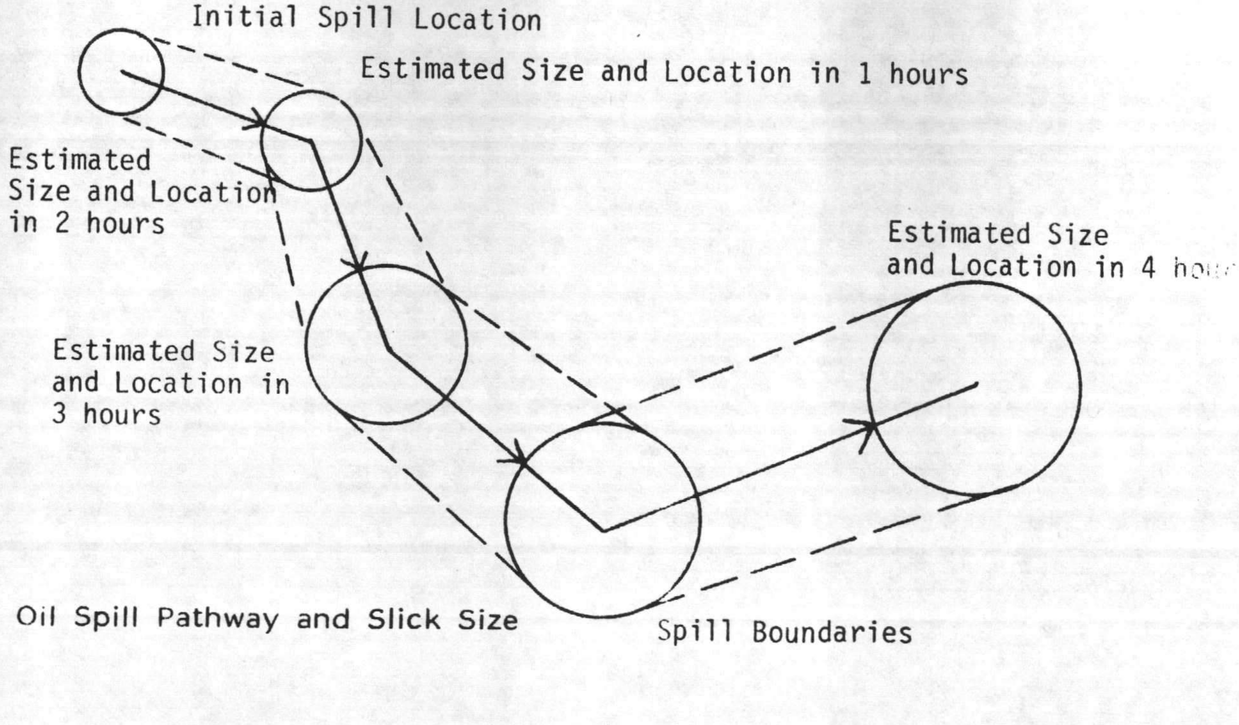


Figure 1. Oil Spill Pathway and Slick Size

Summary

Response to a spill should follow a logical sequence such as:

1. Is the product flammable? (Am I in danger?)
2. Are people in danger?
3. What is the problem magnitude?
4. Can the product be safely contained?

Once the hazard has been removed or reduced to an acceptable level, clean-up activities can be initiated.

APPENDIX 1. MONITORING EQUIPMENT

Monitoring equipment can be categorized into oxygen monitors, combustible gas indicators, and toxicity indicators (for carbon monoxide). Some monitors come with more than one capability.

Oxygen monitors measure the percentage of oxygen in the air. In the atmosphere about 20.9 percent of the air is oxygen. Man can live in as low a concentration of 19.5 percent oxygen (OSHA standard). Ratings below this point indicate an oxygen deficient area. Readings above 19.5 percent oxygen generally indicate a liveable area. However, high CO (carbon monoxide) or H_2S (hydrogen sulfide) conditions could exist with a "liveable" oxygen reading, which could be fatal.

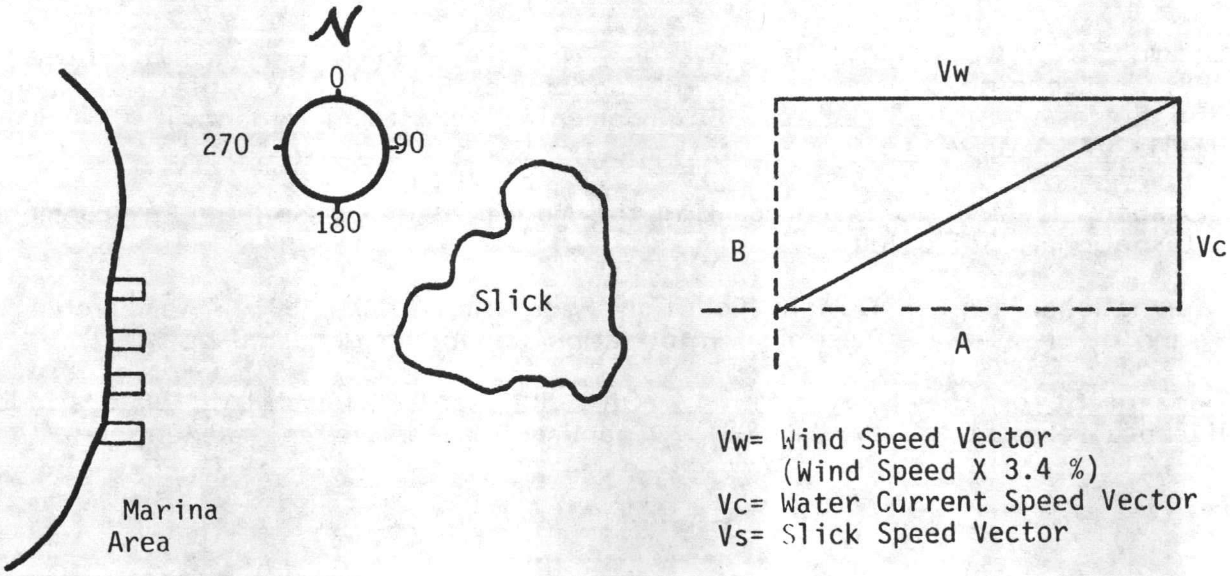
Combustible gas indicators generally measure the ability of an air sample to ignite. Two types are the MOS (Metallic Oxide Semiconductor) and the Hot Wire. Both can be affected by leaded gasoline and other substances. Generally they measure the percent of a gas or gases in the air. As with the oxygen monitor, combustible gas indicators do not measure H_2S or CO concentrations.

Toxicity indicators generally measure the part per million concentration of a gas, such as H_2S or CO. The selection of a monitoring device(s) should include: simple to operate, reliable, portable, fast response time, used under a wide range of weather conditions, rugged, and corrosion resistant.

APPENDIX 2. AIRCRAFT CHOICE

	AIRPLANE	HELICOPTER
Minimum Altitude		
Urban	1000 feet	Pilot does not create hazard to persons or property
Rural	500 feet	
Minimum visibility	1 mile must avoid clouds	Pilot can avoid obstructions
Landing	Usually needs airport (therefore, you drive to plant)	Open area (therefore, helicopter comes to you)
Other	Avoid planes with wings below windows	Usually more expensive
	Avoid helicopters with obstructions in windows (vents, scratches, discolored windows)	Avoid helicopters with obstructions in wondows (vents, scratches, discolored windows)
	Greater flying time	
	Greater flying distance	

APPENDIX 3. VECTOR ADDITION[4]



Vw= Wind Speed Vector
(Wind Speed X 3.4 %)
Vc= Water Current Speed Vector
Vs= Slick Speed Vector

Procedure:

1. Lay out wind speed and water current speed vectors from known compass headings. Use same scale (in/mph or knots) for both vector lengths.

   Example: Oil slick is in an area where wind is 30 mph west and current is 0.5 mph south. (0.34 x wind speed = 1.0 mph). A ratio can be set so that 1.00 mph = 2" and 0.5 mph = 1". The wind speed vector is drawn 2" in length to the west and the current speed vector is drawn 1" in length to the south.

2. Draw line parallel to Vw at tip of Vc (line A) and line parallel to Vc at tip of Vw (line B)

3. Draw line connecting intersection of lines A and B with O (line Vs).

4. Measure length of Vs in inches and determine mph from scale set in Step 1.

5. Take compass heading of Vs and speed of slick from Step 4. Estimate time of arrival at sensitive areas. Deploy personnel and equipment as required.

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SURFACE AND SUBSURFACE OIL CLEANUP

Damage Due to Land Spills of Oil

While oil spills occurring on the water are visible and frequently receive much publicity, underground leaks or tank truck accidents that allow the product to penetrate the soil often receive less notoriety. Within the oil industry, however, the problems associated with hydrocarbon contamination of both the soil and groundwater are well known. Spills from pipelines and tanks have been numerous, contaminating soil, streams, and groundwater. Some spills can be very unpredictable. Underground spills can lie hidden for decades, in some cases surfacing to pose cleanup problems years later.

Even small quantities of hydrocarbons spilled on barren ground may cause difficulties. Attendant problems include polluting water wells, damaging crop lands, and causing general damage to the ecosystems. In some instances, surface waters miles away from the original spill site may be contaminated by hydrocarbons transported through underground water systems. Another problem involves volatile petroleum products seeping into basements, sewer lines, and telephone conduits.

The varied effects of hydrocarbon spills on land are due in part to the physical and chemical properties of both the spilled product and the soil itself. Since the geology of a region may determine to a large extent how a spill will behave, it should be carefully considered before attempts are made to respond to an oil spill on land. Obviously, most oil spill cleanup on land will involve soils of unknown characteristics. However, in areas where the potential for an oil spill is great, a knowledge of the soil types and oil penetration depths into those solids will allow personnel in charge of cleanup to determine the most economically feasible cleanup methods. Major land spills often require geological experts to assess the situation and suggest cleanup procedures.

Sources of information concerning how oil acts on soil are varied. Actual prespill field studies conducted at high spill risk areas, i.e., a storage facility, yield perhaps the best estimates. In the absence of prespill information, rough estimates of oil penetration in soil may be made post-spill by referring to county soil maps to determine soil type, followed by calculations based on the type of product spilled.

Oil Penetration of Soil

Types of Soil

If the soil is relatively homogenous in structure and its texture is known, a reasonable estimate of petroleum penetration rates may be calculated. Texture, for purpose of this discussion, refers to the percent by weight of three mineral fractions: sand, silt, and clay. The sand fraction may be further classified according to particle size. The U.S. Department of Agriculture classification scheme is illustrated in Table 1.

TABLE 1. SIZE LIMITS OF SOIL SEPARATES[1]

Fraction	Soil Separate	Size (millimeters)
Sand	Very coarse sand	2 - 1
	Coarse sand	1 - 0.5
	Medium sand	0.5 - 0.25
	Fine sand	0.25 - 0.1
	Very fine sand	0.1 - 0.05
Silt	Silt	0.05 - 0.002
Clay	Clay	below 0.002

The percentage of each of the three main fractions is used to name the soil texture (Fig. 1).

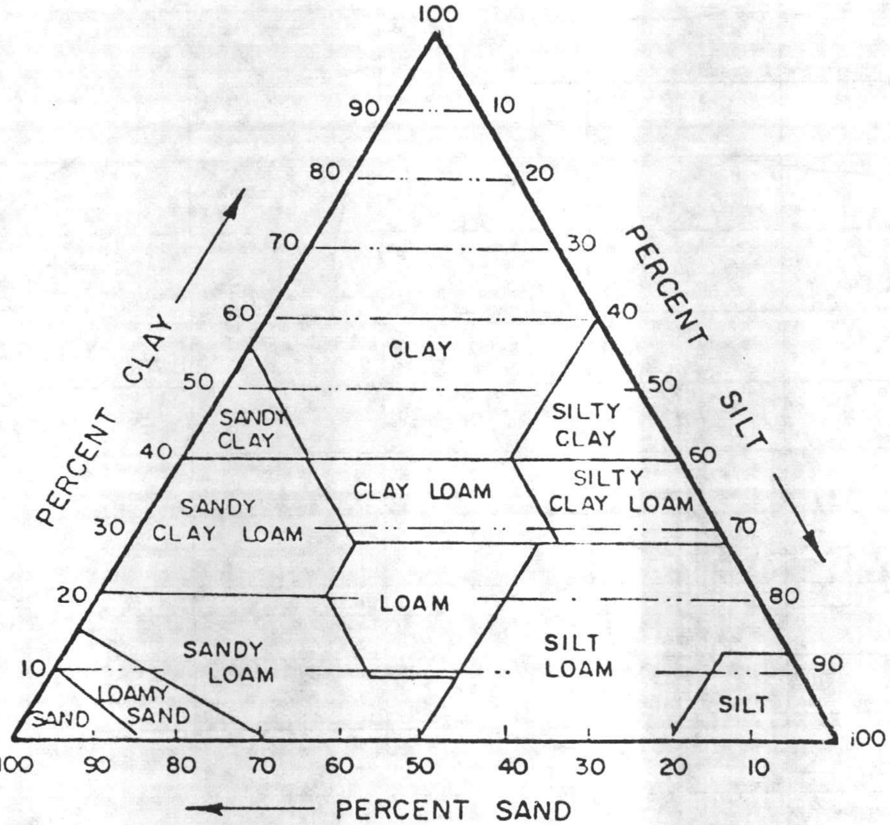

Figure 1. Soil Texture Profiles

A knowledge of these soil texture types may be used in conjunction with county soil maps in order to approximate how petroleum may penetrate the soil in any particular area. Generally, sandy soils are more easily penetrated by liquids than the clay-type soils (Fig. 2). However, plant roots, rotting roots, and cracks in soil can allow faster and deeper fluid penetration. The presence of pipelines, buried cables, telephone poles, and other ground modifying structures can allow for oil movement along their routes.

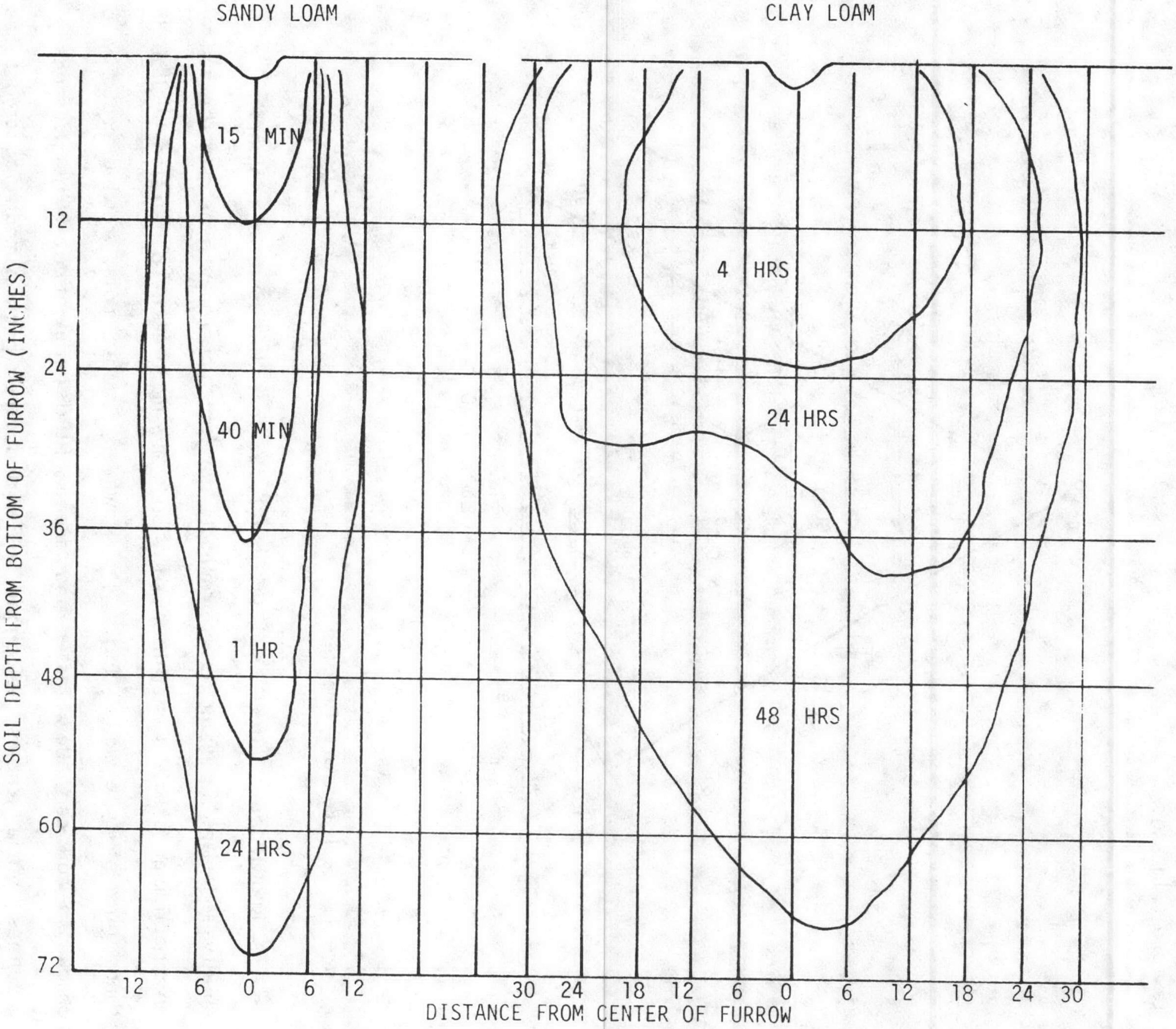

Figure 2. Comparison of Water Penetration and Soil Types[2]

When a large volume of oil is spilled onto the soil, the oil may spread across the soil surface and, depending upon its viscosity and the soil characteristics, may penetrate the soil (Fig. 3). If oil reaches the water table, the oil may depress the water table, forming a thick, lens-shaped mass that spreads throughout the funicular zone above the groundwater table and is subject to the influence of the groundwater flow (Fig. 4).[3] The funicular zone is that region above and approximately equal in thickness to the capillary zone.

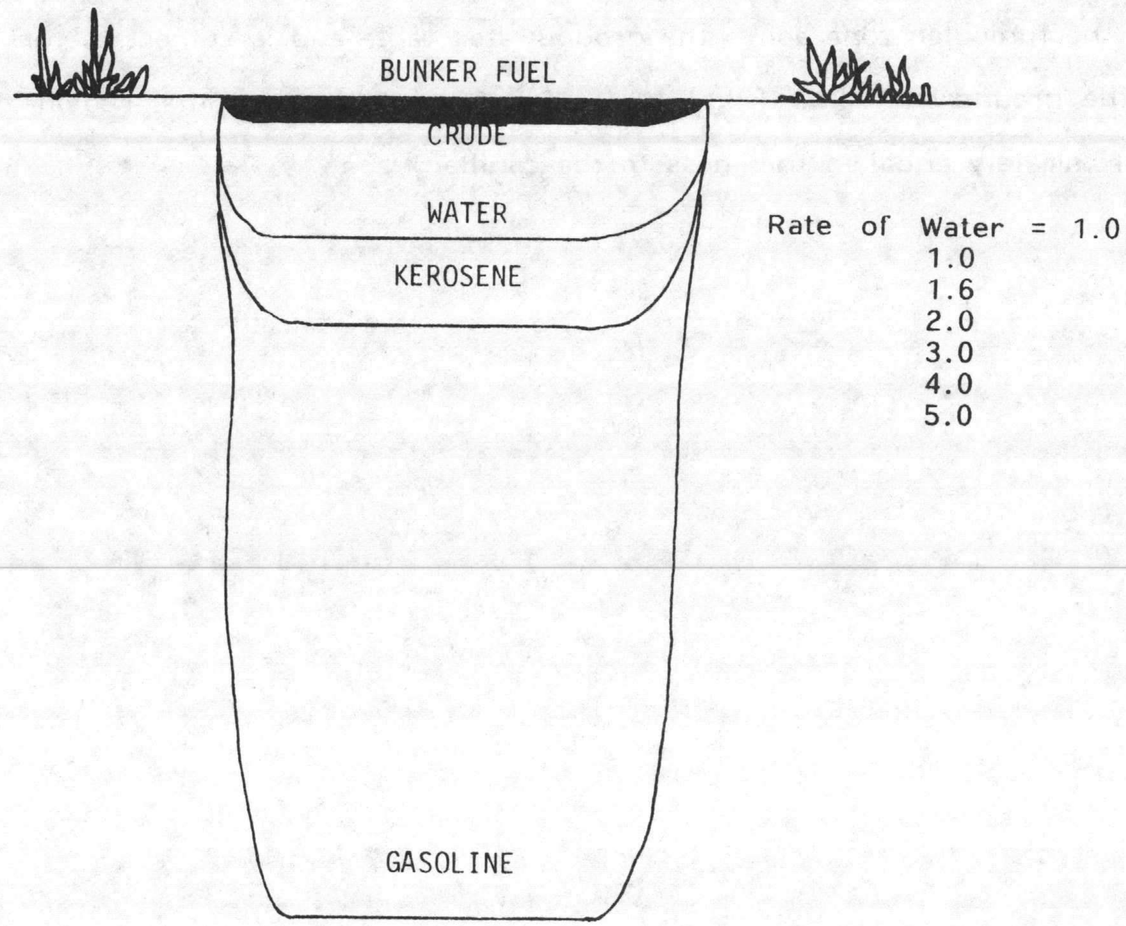

Figure 3. Relative Permeability of Various Liquids

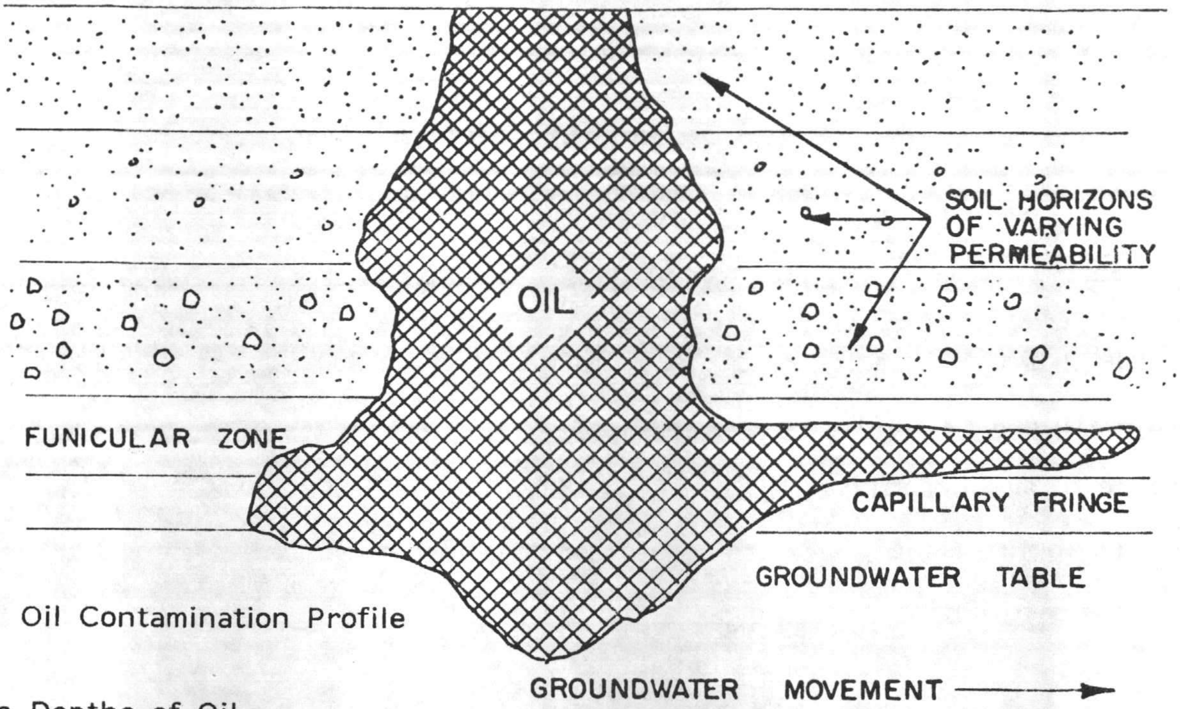

Figure 4. Oil Contamination Profile

Penetration Depths of Oil

A calculation of how much soil the oil will contaminate or whether or not the oil will reach the groundwater may be made if the soil properties are well known. The following formula has been found to be of value in many cases.[4]

Formula 1

$$D = \frac{K \cdot V}{A}$$

D = maximum depth of penetration in meters (m)

V = volume of infiltrating oil in m^3

A = area of infiltration in m^2

K = a constant, depending upon the retention capacity of the soil and the viscosity of the oil (Table 2)

The accuracy of the calculations will be limited by the accuracy of the "K" values. Again, the truest K values are those determined by individual prespill field studies. "K" values given in Table 2 are the estimates of one author for dry soil (worst cases) conditions. Obviously, values for wet soils would differ greatly from those given. Thus, rainfall as a factor must also be considered.

TABLE 2. TYPICAL VALUES FOR K

Soil	K		
	Gasoline	Kerosene	Light Fuel Oil
Coarse gravel	400	200	100
Gravel to coarse sand	250	125	62
Coarse to medium sand	130	66	33
Medium to fine sand	80	40	20
Fine sand to silt	50	25	12

For example, suppose a tank truck spills 14 cubic meters of light fuel oil on a medium to fine sand. The spill diameter is 10 meters.

$$A = \pi r^2 = (3.1316)\ (5m)^2 = 78.54\ m^2$$

$K \simeq 20$ (from Table 2)

$V = 14\ m^3$

$$D = \frac{K \cdot V}{A} = \frac{(20)\ (14m^3)}{78.54\ m^2} \simeq 3.6\ m$$

If the groundwater lies at a depth greater than 3.6 meters, then the assumption could be made that the soil would sorb the fuel oil before it could reach the water table.

The table and calculations are practical only for light products. Since the flow rate of an oil is inversely proportional to its viscosity, only those hydrocarbons of relatively low viscosity (high flow rate) are likely to cause substantial migration problems in most soils. Because heavy crudes have a low flow rate, a determination of their penetration rates is usually unnecessary.[5] Much of the information concerning groundwater depth and resulting water table gradient can be obtained inexpensively by consulting a local well driller.

Cleanup Techniques

Methods of cleaning up spills on land are varied to suit the following situations:

1. oil moving horizontally on land, and
2. oil sorbed by the soil above the water table.

In the case of oil moving horizontally on land, the problem can be further divided into three main situations. If oil is spilled onland around a tank farm or loading facility, prior planning should dictate the course of action. According to guidelines for Spill Prevention Control and Countermeasure (SPCC) Plans published in the Federal Register of December 11, 1973, entitled "Oil Pollution Prevention," section 112.7, subsections b and c state:

> (b) Where experience indicates a reasonable potential for equipment failure such as tank overflow, rupture, or leakage, the plan should include a prediction of the direction, rate of flow, and total quantity of oil which could be discharged from the facility as a result of each major type of failure.
>
> (c) Appropriate containment and/or diversionary structures or equipment to prevent discharged oil from reaching a navigable water course should be provided. One of the following preventive systems or its equivalent should be used as a minimum:
>
> (1) Onshore facilities
>
> (i) dikes, berms, or retaining walls sufficiently impervious to contain spilled oil
> (ii) curbing
> (iii) gutters or other drainage systems
> (iv) weirs, booms, or other barriers
> (v) spill diversion ponds
> (vi) retention ponds
> (vii) materials

When hydrocarbon spills occur on city streets as from a tank truck accident, the first agency to respond is usually the fire department. Unfortunately, the first response of many fire departments may be to hose the product into nearby storm sewers or roadside ditches. The fact that the fire department initiates this action does not relieve the company of liability for damages caused by the spill. In some cases, hosing the spill into a sewer system may actually increase the spill damages. In cities where the potential for a tank truck accident is high, a map of the storm sewer system should be obtained from the city. Prior knowledge of information such as flow rates and directions, access points, and high fire hazard areas in the system will allow a quick and positive response to a spill that enters the sewer. Proper training and equipment for removing a volatile hydrocarbon in such a special situation are essential. Perhaps one of the better general response procedures, especially appropriate if the product is highly toxic or soluble, is to keep the product out of the sewers. This may be done by constructing simple dikes of any readily available material that is impervious to oil. If soil is used, it should be relatively impermeable. Also, several types of commercially available quick-setting foam may be used to construct dikes. Collapsible storage bladders may be used for emergency containment of spilled product. These sausage-like devices also allow a leaking or damaged tank truck to be unloaded quickly at the scene of the accident. In deciding whether to contain hydrocarbons on land or flush them into sewers, consideration should be given to minimizing fire and explosion hazards. If the product presents no immediate fire or explosion hazard, the best response may be to keep it out of the sewers and remove it from the land surface. Oil on roadways can be pushed to collection sumps, trenches, or vacuum devices. Loose sorbents can be worked on top of pavement to remove residual oil.

Land spills in remote areas pose special problems. Leaks from surface pipelines, tank truck accidents in rural areas, and oil field spills are common sources. Planning the response to such spills is difficult, but many workers in the industry have found that topographic maps of the areas along pipelines and around production fields help in figuring the direction of oil moving along the surface.

Before a spill occurs, a list of earthmoving contractors and equipment should be made (for types see Appendices). A telephone call to one of these agents is sometimes the quickest way to get a retaining dike built. Some companies have special spill kits for remote areas which include equipment for confining moving surface oil. Crude oils and heavy fuel oils on the soil can be floated with water in ditches, trenches, or behind dikes to limit oil penetration into the soil.

Hydrocarbons that are sorbed by the soil above the water table may be treated in several ways, depending upon the nature of the soil and product. If the spill area is shallow with a clay or water seal along the bottom, flushing with water will, with limited effectiveness, float the oil from the soil. Although rarely employed, natural sorbents, such as sawdust, hay, or ground corncobs, mulched into contaminated soil have been used where other cleanup methods have proven ineffective. After having been mixed into the soil, the sorbents are removed by a water stream, collected, and disposed of properly (Fig. 5). In frozen soils, high pressure water to dissolve oil or steam cleaning to lower oil viscosity is used to float oil with only minor damage to plants. These tools also work well on roadways, walls, and other man-made structures.

A common method of treating soil contaminated with hydrocarbons is simply allowing the oil to biodegrade. The success of this method depends on the oil

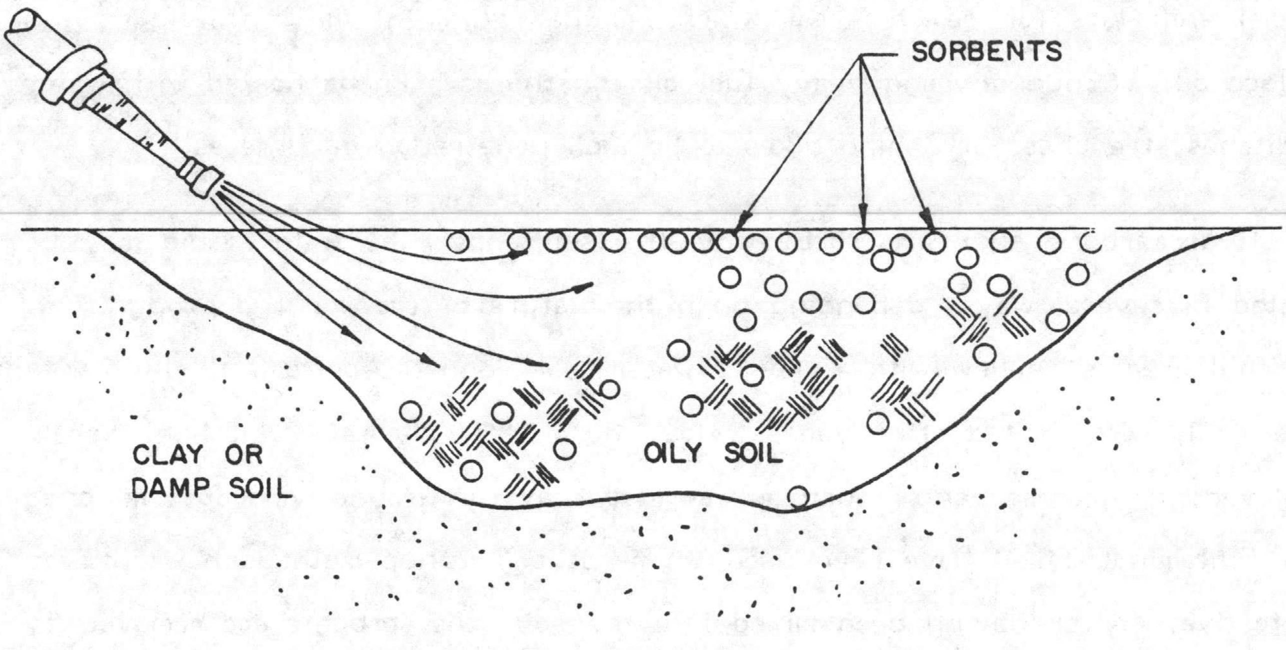

Figure 5. Sorbent/Hydraulic Removal of Oil

toxicity, available nutrients, available water, ambient temperature, and oxygen availability. Also, different oils respond to various species of organisms. Biodegradation of alkane hydrocarbons proceeds readily by naturally occurring microorganisms such as yeast, bacteria, mycobacteria, and mold fungi. More complex hydrocarbons such as aromatics biodegrade more slowly.

Before initiating any response, volatile hydrocarbons should be allowed to evaporate. Later, various techniques can be used to increase the biodegradation rate. The techniques include:

1. Tilling
2. Adding fertilizer
3. Adding lime
4. Adding bacteria
5. Temporary drainage
6. Aeration

If the oil depth is shallow, discing and adding fertilizer can add oxygen and nutrients which will cause rapid conversion of oil to carbon dioxide and water by bacteria. Repeated treatments will usually be necessary. Tillage should not be used on dry soils that may be blown away upon disturbance. Some workers have found that plowing organic matter such as sewage treatment plant sludge into the oily soil can increase the biodegradation rate. However, others suggest that it does not. For example, sawdust added to arctic soils has only added more organic matter to the soil which increases the biological oxygen demand.

Other additives such as lime may be considered for corrosive oils on acidic soils to neutralize the added acidity. Special bacteria cultures may be added to innoculate a site. Hoewever, it has been debated whether the cultures are more effective than naturally occurring bacteria. They have shown some success on very acidic soils.

To add air into the soil, temporary drainage with tilling and fertilization may help wet forest sites. Entry of air into the soil will facilitate oil volitilation and degradation. However, drainage without soil mixing can do more harm than good. Excessive drainage can cause soil problems such as soil subsidence.

Oil deeper in the ground, below the aerobic bacteria zone, may be degraded by air pumped into the ground. For small spill areas, soil aeration by pumping air through buried perforated pipe or drilled holes can oxidize volatile hydrocarbons and hydrogen sulfide and increase aerobic bacteria degradation. Recent research has experimented with hydrogen peroxide injection into soil layers to oxidize volatiles. However, this technique may sterilize the soil. Other research using surfactants can increase oil leaching, yet surfactants may clog soil. Before applying any land modifying technique, consultation with soil scientists and local government personnel is suggested.

Other cleanup techniques are burning, soil removal, and water infiltration. Burning is often thought of as a final cleanup process. However, more work is usually needed. Burning can remove large amounts of oil or the last traces of oil remaining after oil removal operations. It will also oxidize volatile hydrocarbons. Burning can leave an oil film or crust which may prevent seedling shoot penetration, can spread oil further than unburned spill boundaries, can kill plants which may contribute to erosions, and or can produce products more toxic than the original oil product. Therefore, if burning is used, biodegradation techniques should be used to help eliminate oil.

Soil removal is possible for shallow contaminated soils and spills of small area. The amount of oil contaminated can be tremendous even for heavy fuel oils (Fig. 6). Contaminated soil does not mean the soil is sterile. Soil should not be removed in most cases unless absolutely necessary.

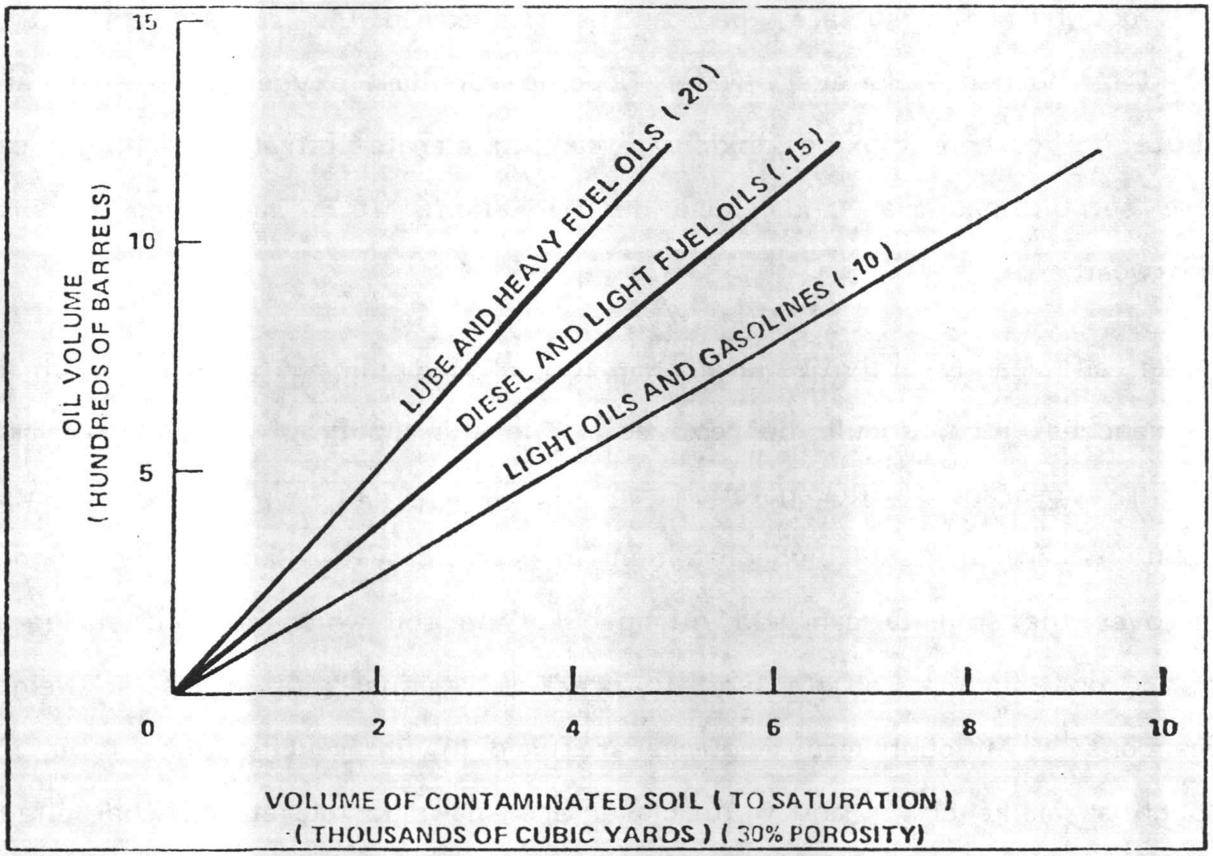

Figure 6. Relation of Spill Size to Volume of Soil Contaminated to Point of Saturation (Spill Immobilization)[8]

Problems associated with soil removal are contact with buried structures (pipelines, cables), damage to building foundations, explosion hazard in pits when working with volatile products, and equipment breaking through impermeable layers in the subsoil which would allow greater product penetration.

Water infiltration has proven to be impractical during most spills to float oil to the surface. In gravel or sandy soils where the groundwater table is less than a foot from the surface, oil can be flooded to the surface and either recovered or burned. However, water flooding can limit oxygen in the soil and contribute to carbon dioxide toxicity, can accelerate nitrate leaching, can decrease aerobic bacteria, and cause denitrification. It is impractical in sub-freezing weather.

After all cleanup activities are complete, any containment devices such as dikes, trenches, etc., should be removed. The site topography should resemble a prespill appearance. Revegetation or restoration can now be considered. Revegetation can increase biodegradation in some cases. Planting leguminous species over the spillsite can add nitrogen to the soil which can aid biodegradation. Crops such as alfalfa tend to breakup residual high molecular weight hydrocarbons.[8] Although many legumes are used in site revegetation (Table 3), some such as alsike clover and white clover are known to tolerate oil while alfalfa has a low tolerance of oil. Grasses may also be used for revegetation (Table 4). Some such as brome grass and reed canary grass are known to have high oil tolerances. Which specie is chosen will depend on the time of year planted, soil characteristics, and amount of oil in the soil. Once again, consultation with local soil scientists is advised.

TABLE 3. LEGUMES COMMONLY USED FOR REVEGETATION[9]

Variety	Best Seeding Time	Seed Density* seeds/ft^2	Important Characteristics	Areas/Conditions of Adaptation
Alfalfa (many varieties)	Late summer	5.2	Good on alkaline loam, requires good management	Widely adapted
Birdsfoot trefoil	Spring	9.6	Good on infertile soils, tolerant to acid soils	Moist, temperate U.S.
Sweet clover	Spring	6.0	Good pioneer on non-acid soils	Widely adapted
Red clover	Early spring	6.3	Not drought resistant, tolerant to acid soils	Cool, moist areas
Alsike clover	Early spring	16.0	Similar to red clover	Cool, moist areas
Korean lespedeza	Early spring	5.2	Annual, widely adapted	Southern, U.S.
Sericea lespedeza	Early spring	8.0	Perennial, tall erect plant, widely adapted	Southern, U.S.
Hairy vetch	Fall	0.5	Winter annual, survives below 0°F, widely adapted	All of U.S.
White clover	Early fall	18.0	World-wide, many varieties, does well on moist, acid soils	All of U.S.
Crownvetch	Early fall	2.7	Perennial, creeping stems and rhizomes, acid tolerant	Northern U.S.

*Number of seeds per square foot when applied at 1 lb/acre.

TABLE 4. GRASSES COMMONLY USED FOR REVEGETATION[9]

Variety	Best Seeding Time	Seed Density* seeds/ft^2	Important Characteristics	Areas/Conditions of Adaptation
Redtop bentgrass	Fall	14.0	Strong, rhizomatous roots, perennial	Wet, acid soils, warm season
Smooth bromegrass	Spring	2.9	Long-lived perennial	Damp, cool summers, drought resistant
Field bromegrass	Spring	6.4	Annual, fibrous roots, winter rapid growth	Cornbelt eastward
Kentucky bluegrass	Fall	50.0	Alkaline soils, rapid grower, perennial	North, humid, U.S. south to Tennessee
Tall fescue	Fall	5.5	Slow to establish, long-lived perennial, good seeder	Widely adapted, damp soils
Meadow fescue	Fall	5.3	Smaller than tall, susceptible to leaf rust	Cool to warm regions, wodely adapted
Orchard grass	Spring	12.0	More heat tolerant but less cold resistant than smooth bromegrass or Kentucky bluegrass	Temperate U.S.
Annual ryegrass	Fall	5.6	Hot winter hardy, poor dry land grass	Moist southern U.S.
Timothy	Fall	30.0	Shallow roots, bunch grass	Northern U.S., cool humid areas
Reed canarygrass	Late summer	13.0	Tall, coarse, sod former, perennial, resists flooding and drought	Northern U.S., wet cool areas

*Number of seeds per square foot when applied at 1 lb/acre.

Summary

Movement of oil on top and into the soil will depend on topography, soil permeability, and structures below the surface. Oil penetration into the soil can be predicted.

Oil on hard surfaces can be pushed into collection devices or sucked into vacuum devices. Final cleaning can use sorbents or water. Oil on other surfaces may use heavy equipment to remove oil and contaminated soil, water flooding within dikes to float oil, sorbents and water flooding to recover oil, or burning to remove oil.

Oil below the surface can be removed by aeration and biodegradation. Tilling, fertilizing, liming, adding bacteria, and draining soil may increase aeration and biodegradation. Soil removal and water infiltration require special consideration of the effects of the techniques.

Final cleanup involves site restoration. Containment devices should be removed and sites revegetated where needed. Techniques should be used that facilitate site restoration as quickly as possible.

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Further Reading

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CONTAINMENT AND RECOVERY OF OIL ON GROUNDWATER

CONTAINMENT AND RECOVERY OF OIL ON GROUNDWATER

Although spilled oil may adhere to soil particles, roots, and rocks, or may become blocked by faults to keep the oil from flowing into groundwater, changes in land geology or water regimes can cause trapped oil to enter groundwater. In other cases, spilled oil easily penetrates the soil to contaminate groundwater. Since oil on groundwater weathers and degrades slowly, if at all, oil can affect potability and its use in industrial processes for decades or centuries. This is important since about one-half of the population of the United States depends on groundwater (primarily the small to medium sized communities and farms).[1]

Many large groundwater spills have been well publicized. For example, a refinery in Brooklyn, New York apparently had tanks, pipeline, or valves leaking for years. Approximately 20 million gallons of petroleum distillate was estimated to be under 70 acres of industrial and residential property.[2] During the first year of cleanup 95,000 gallons were recovered. Oil recovery will take years. An estimated $3 to 4 million will be spent on recovery and cleanup.[3]

Small spills can also influence groundwater use until the oil product has been removed. This section will discuss groundwater oil movement, groundwater monitoring, oil containment, and oil recovery techniques.

Oil On Groundwater

When oil penetrates the subsoil to the groundwater or aquifer, the oil can move the groundwater by spreading and by groundwater flow. The water table is that level of the water observed in wells. However, in soils, water can rise above the water table due to capillary action. Just as the liquid level will appear higher in a straw, or the corner of a towel will transport water into a towel, water will fill spaces in the soil above the water table. Oil entering this water will spread and move on the capillary fringe (Fig. 1). The capillary fringe can vary from 1 to 18 inches, depending on soil permeability. Permeability indicates a soil's ability to allow fluids to pass from one space in the soil to other spaces in the soil. Larger spaces due to large soil particle size have higher permeability, therefore low permeability may be one-half inch per year and high permeability several feet per year.

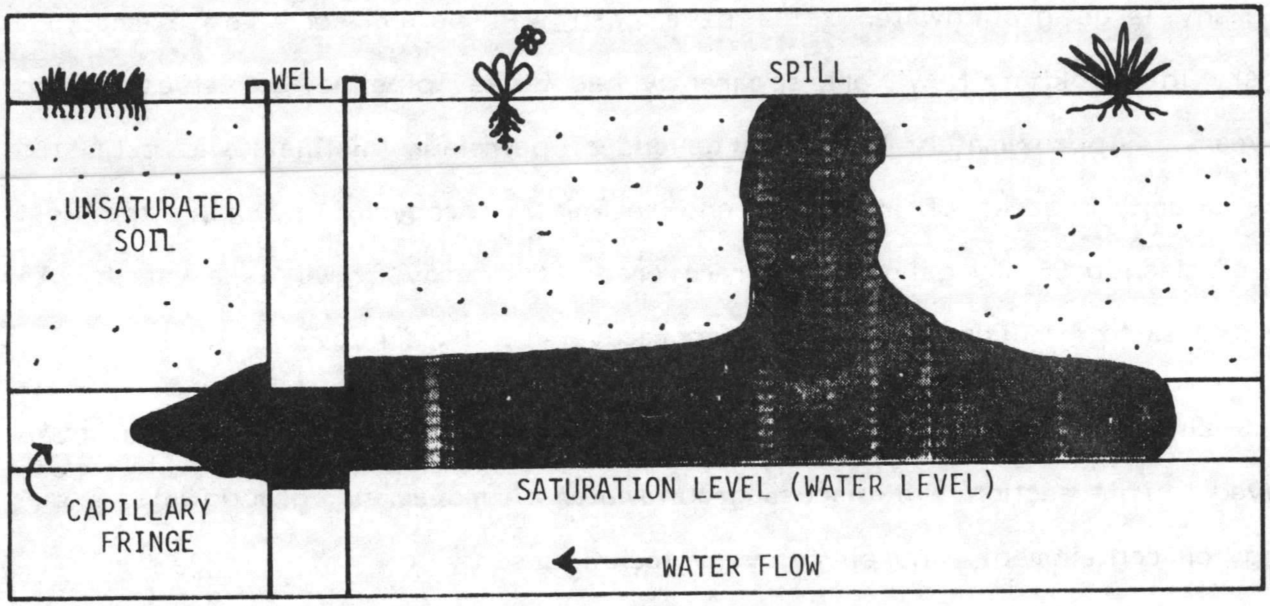

Figure 1. Oil Entering Groundwater (Horizontal View)

At first, oil thickness increases under the influence of continued descending oil. The force or pressure exerted by the accumulation of oil will displace water in the capillary fringe and possibly in the groundwater. As gravity influences the oil to spread and the pressure is released, the groundwater returns to its former level. In a uniform particle soil (all gravel, sand, or silt) oil will spread and move with water flow, and form an egg-shaped oil plume (Fig. 2).

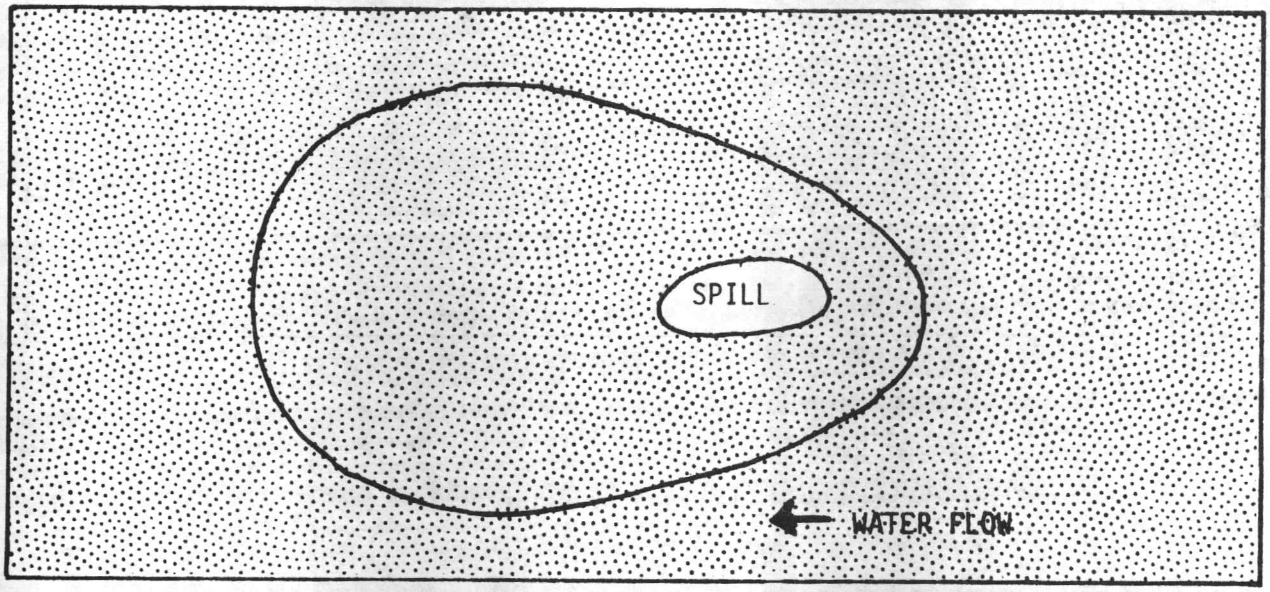

Figure 2. Oil On Groundwater (Tangential View)

If the oil comes into contact with a different size soil particle layer or rock fissure, it will change the oil spreading pattern. An impenetrable layer would not only change the shape of the slick, but also change the direction of oil flow.

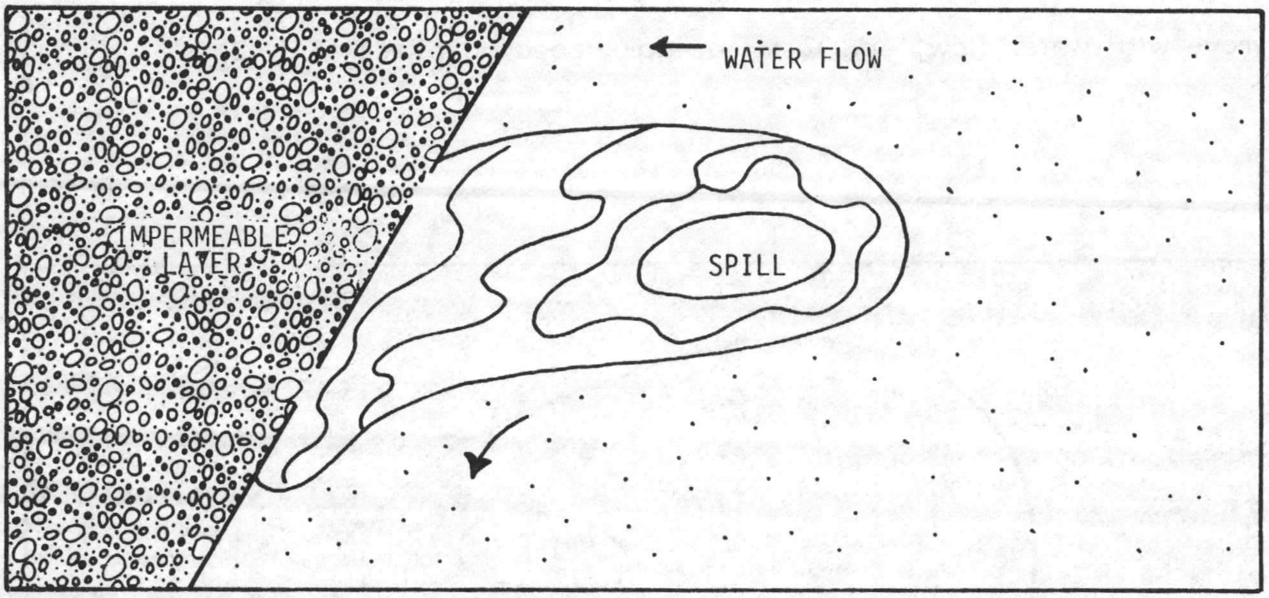

Figure 3. Oil On Groundwater With Impermeable Layer

As oil flows, some oil (up to 10 percent) will adhere to soil particles and rock surfaces and become immobile,[4] while soluble oil components can mix into the groundwater. If enough oxygen is available, bacterial and/or chemical decomposition can occur. In some cases decomposition increases water soluble components up to 10 times.[5] Although the factors which affect oil movement on groundwater are many and often interact with each other, spreading can be estimated using the following formula:[6]

$$S = \frac{1000\ V - A * R * D * K}{F}$$

Where S = maximum spread of oil on the water table in m^2

V = volume of infiltrating oil in m^3

A = area of infiltrating at surface in m^2

R = retention capacity of soil above water table in liters/m^3

D = depth of groundwater

F = oil contained above capillary fringe in liters/m^2

K = the approximate correction factor for various oil viscocities

K for gasoline = 0.5

K for kerosene = 1.0

K for light fuel oil = 2.0

"R" and "F" values are in Table 1.

TABLE 1. "R" AND "F" VALUES FOR VARIOUS SOIL TYPES

Soil	R	F
Stones, coarse gravel	5	5
Gravel, coarse sand	8	8
Course sand, medium sand	15	12
Medium sand, fine sand	25	20
Fine sand, silt	40	40

In using this formula, inherent errors in data can result from water table fluctuations (rises or falls with the season) by underestimating or overstimating "D" (the depth of groundwater). Also, oil thickness on the water table is not the same as oil thickness measured in wells. In some fine sand or silt soils, oil in a well may be lower than oil on the groundwater. This is due to a break in the capillary fringe caused by the well. Oil from the capillary fringe can flow into the well, since the water level in the well will be below the water level in the soil. A glass of water with different sizes of straws can demonstrate how this works. A small diameter straw will have a higher water level than a broader diameter straw. The small spaces between soil particles will conduct water higher than the opposite sides of the well casing. Therefore, oil will flow down the well due to gravity, increasing the amount of oil in a well.

The movement of oil due to groundwater flow can be estimated by the following equation:[7]

$$Q = \tfrac{1}{2} P \frac{(h_2^2 - h_1^2)}{L}$$

Where Q = flow rate of groundwater in m^3/day/m

P = permeability of m/day

h_1 = height of groundwater

h_2 = height of groundwater

L = length or distance between h_1 and h_2

Both of the estimates are usable for shallow groundwater problems or initial planning for deep groundwater problems. However, in deep groundwater problems, before time and money are spent on containment and recovery techniques a monitoring system should be initiated to deliniate plume characteristics and to aid in effective containment and recovery.[8]

Oil In Groundwater Monitoring

The first step in successful groundwater monitoring is the preliminary investigation. Information sources such as U.S. Geologic Survey maps and tables, Soil Conservation Service maps and tables, state geologic surveys, water resource personnel, university geology departments, city water department maps and personnel, past oil company personnel or companies that have drilled in that area, and consultants can be used. The information gathered can help you determine:

1. groundwater flow characteristics
2. aquifer to surface water boundaries
3. recharge areas
4. local abstraction points (i.e., city groundwater wells)
5. flow mechanisms through fissured or highly permeable zones

The second step is field investigation. Such an investigation may include soil samples, water samples, or other hydrogeologic tests. Soil samples may be examined for grain size in order to accurately define the nature and location of the soil horizons. From core samples one may also determine the porosity of each soil horizon. The boreholes may be used for water permeability measurements. In addition, hydrocarbon percolation tests may be made. The groundwater head distribution may be studied by inserting standpipes (for monitoring the water level) into the completed boreholes. Ground penetrating radar can be used for defining geologic sequences, investigating fractures, and locating buried objects. Electromagnetic frequency techniques can graphically show horizontal and vertical characteristics such as aquifer boundaries and geologic interfaces.[9] Both of these latter methods can improve mapping of oil plumes over plume estimates from just drilling wells. In fact, using these methods may prevent unnecessary drilling.

With some highly volatile products, the spread of the plume can be monitored by the vapors migrating through the soil surface. Although its presence in basements, oiled wells, trenches, and along disturbed soils (i.e., buried pipelines) can indicate where the oil is, its absence does not indicate that the oil is not present. Shallow boreholes and hydrocarbon monitors or explosiometers can help identify vapor penetration.[5] Field investigation may include choosing a water sampling program. A water sampling program may involve drilling wells, water and soil analysis, and/or mathematical modeling to estimate plume size and oil movement.

Generally, monitoring wells can be classified into three types, a piezometer, observation well, and a pumping well. A piezometer is a small diameter well that is tightly sealed so that detection of static pore water pressure can be used to determine the true direction of groundwater flow measured. More than one piezometer can be installed in a well boring by sealing piezometers at different depths from each other. Piezometers can be either pneumatic or electric.[10]

An observation well is larger in diameter than a piezometer well and is used to measure oil/water levels. Observation wells have been used to determine the direction of groundwater flow by injecting a tracer, such as fluorescein, Rhodamine WT, or salt water, among a number of observation wells.[11]

While a pumping well is the largest in diameter of all, it is used for the introduction of pumps or other equipment. Water samples can be obtained from observation and pumping wells. However, certain problems may arise in each well type.

Not only is the type of well important, but also where one drills a well. Permission must be obtained from those individuals or companies that have surface and mineral rights. The location of underground structures such as gas, petroleum, or water pipelines, powerlines, telephone lines, sewer lines, and storm sewer lines should in identified and visibly marked.

Monitoring wells should be placed in a down gradient direction to the flow of groundwater and spaced far enough apart to determine plume size. At least one well should be drilled up gradient to ensure that oil was not missed. Monitoring wells should be used to confirm the preliminary findings.

Some situations can complicate groundwater monitoring and oil recovery. One of the more difficult situations involves a land spill in a rocky area.[12] The oil moves into fissures and crevices and along joints of bedded rock and bedding planes. The upper layers of limestone, basalt, and sandstone usually show pronounced fissuring, especially if the area is in a zone of tectonic disturbance. Predicting the underground movement of oil in such areas is quite difficult. Spilled oil may follow fault lines in the direction of their dip. Sometimes recovery wells may be drilled along a fault line to intercept the spilled oil (Fig. 4). This technique in particular requires sound geological information before attempting any drilling operations.

In limestone, gypseaous, and saliferous rock, wide fissures, crevices, and solution channels may be present (Fig. 5). This represents a most difficult case, as solution cavities may hold hydrocarbons for years, releasing them only in time of drought. In central Pennsylvania in 1958, 50,000 gallons of crude oil were lost in a limestone terrain honeycombed with solution channels. Recovery wells were drilled, and much of the product was retained on the site. However, in the mid-1960's a drought caused the water table to drop and oil stored in the limestone was released, causing water well contamination. The problem persists today.[13]

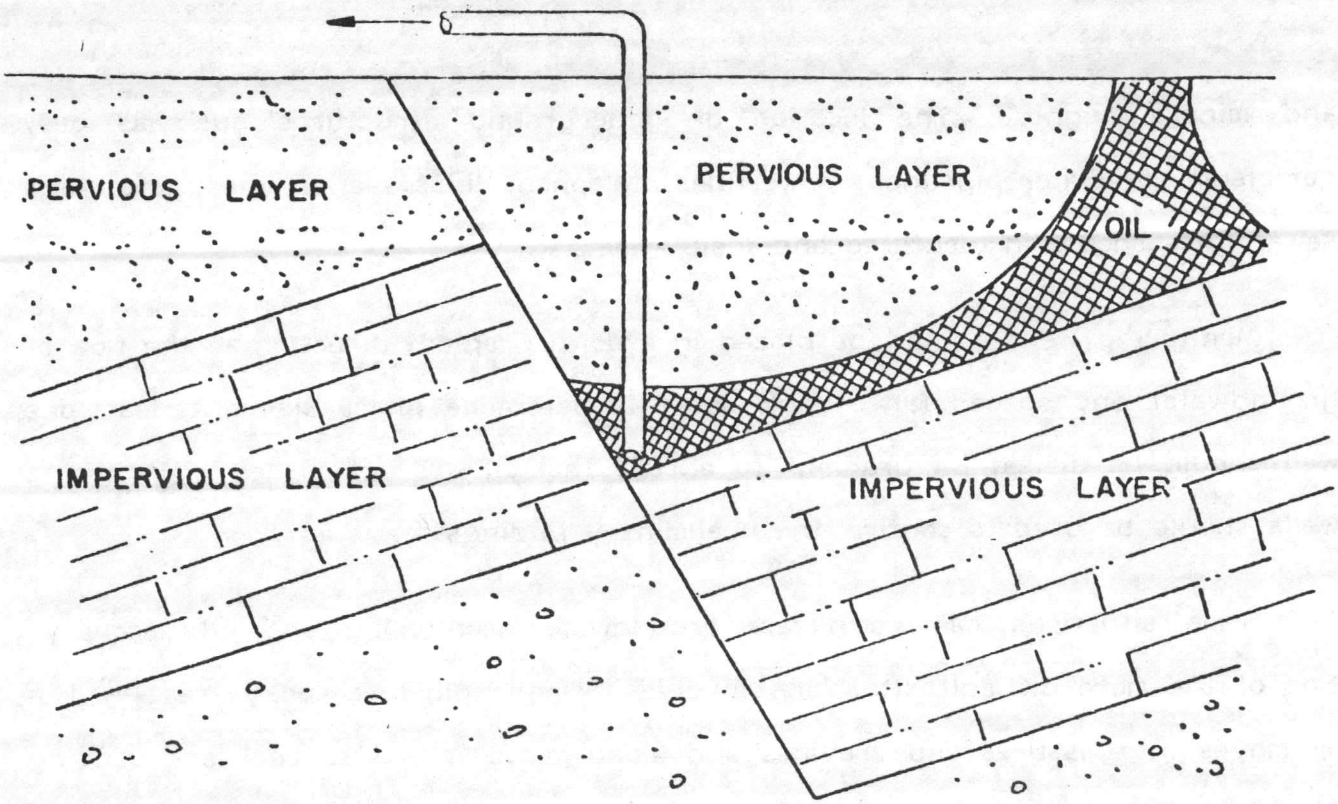

Figure 4. Recovery Well Along Fault Line

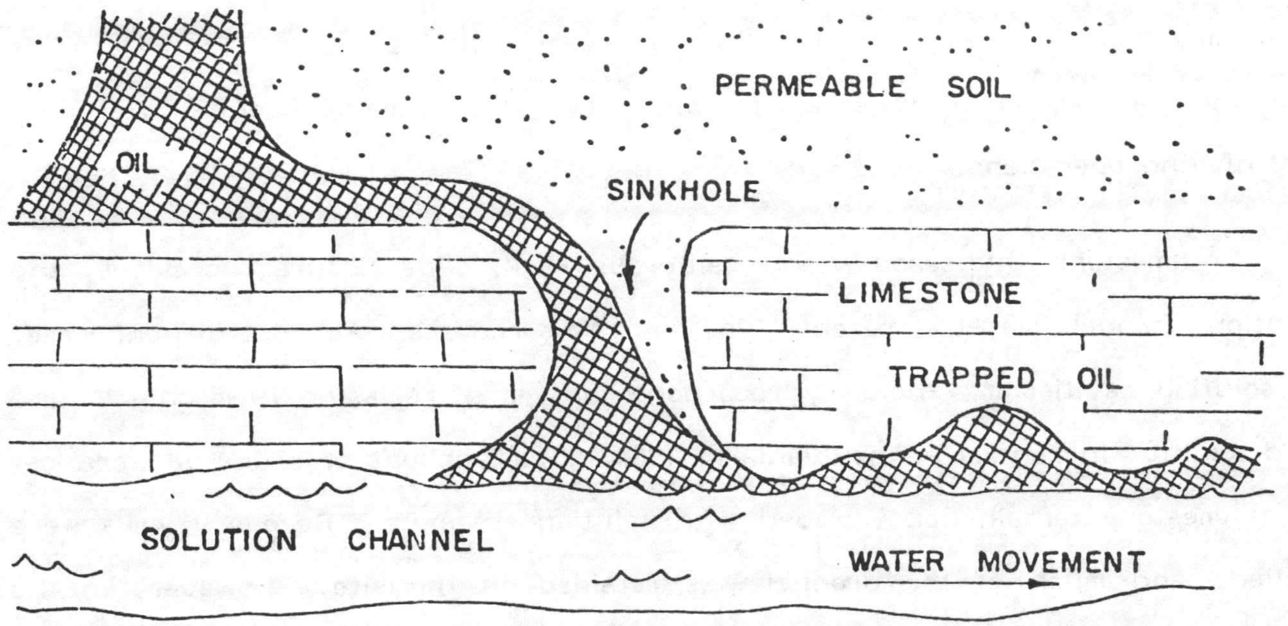

Figure 5. Solution Channels in Limestone

One method used in such areas to trace dispersion direction is fracture trace analysis. Air photo interpretation is used to find the major fractures which could be transporting the spilled product.[13] Observation wells may then be drilled in order to locate the oil.

These combined data offer a working knowledge of:[14]

1. the amount of hydrocarbon that must be spilled in order to reach the groundwater,
2. the direction and rate of migration of the product once the groundwater is contaminated,
3. the geological or hydrogeological boundaries that exist, and
4. the rate at which the product may be extracted from the ground.

This information can be translated into a cross-sectional map showing the probable direction of travel of the oil as it follows the groundwater system (Fig. 6).

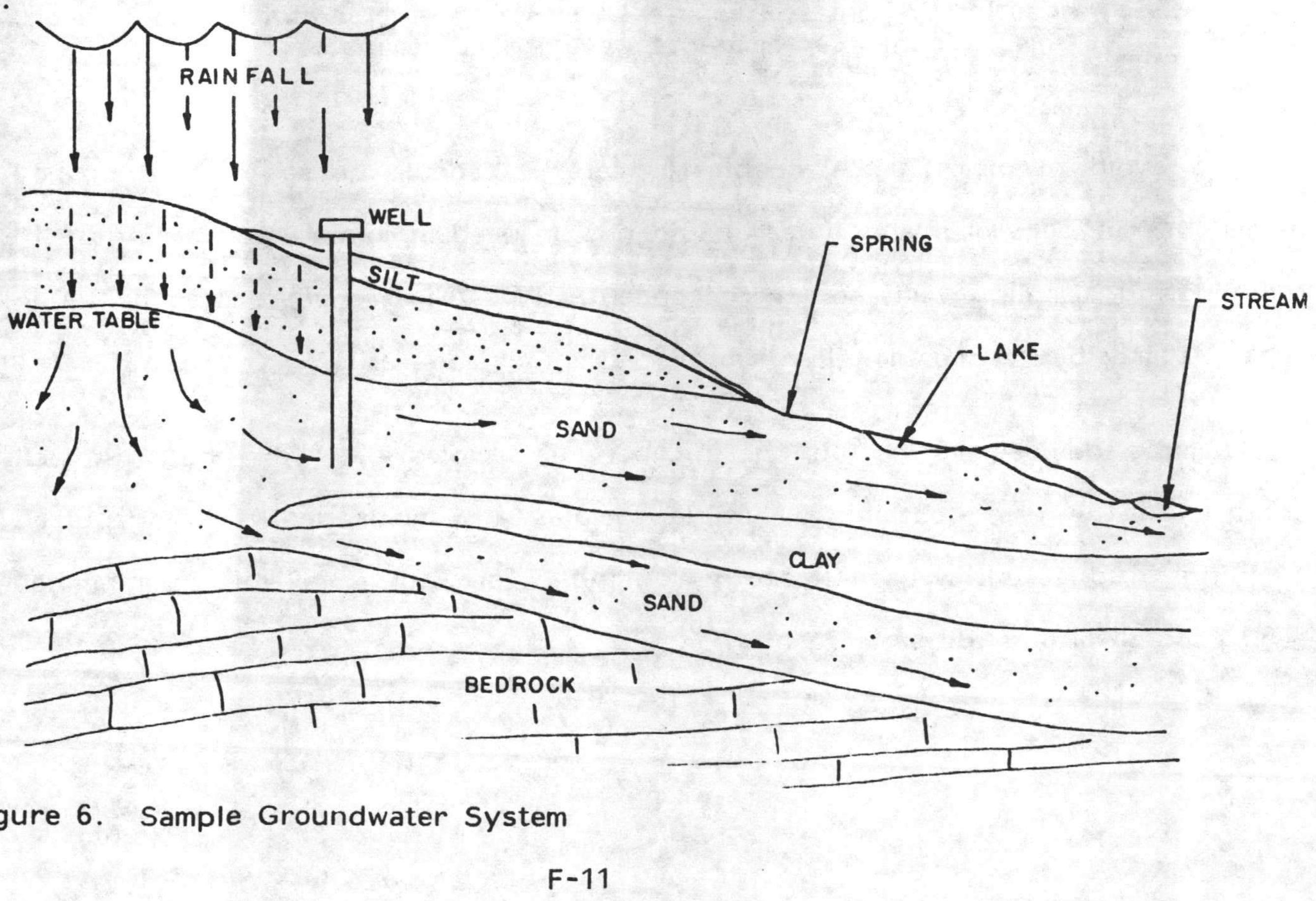

Figure 6. Sample Groundwater System

Sampling Devices for Monitoring Wells

Sampling devices may be as simple as an observation well with oil finding paste on a stick or as complex as intricate well casings which are designed to take samples and pressure readings at various depths. Although existing wells may be used, data analysis can become complicated. Drilling fluids can change the chemical or biological well environment, water from several aquifers can flow into a single well, surface contamination into a well can occur, and casing materials and pumping equipment can contaminate sampled water.[15] High concentrations of oil in groundwater may not require great accuracy in measurements so that polyethylene pipe casings can be used. However, when accurate samples are needed, a number of problems exist on choosing materials.

1. metal surfaces can catalyze certain chemicals (i.e., iron),
2. lubricants from pumps, oils on pipes, and glues from pipe joints can contaminate samples, and
3. plastics in pipes, transfer hoses, or sample bottles can absorb some organic contaminants or bleed contaminated elements, affecting samples.[16]

To avoid problems, metal or plastic materials should be soaked and washed before use in boreholes and glues should not be used in joining well casings. In constructing sampling wells for trace concentrations of some oils, glass or teflon materials may be needed in well casings or sampling apparatus.[15]

Sample devices vary with the number of samples per well and with well depth. In the past, obtaining multiple samples at various depths has required sampling in different wells. Recently, a single well with a multiple sampler has been used to obtain the same results.[10]

Shallow aquifer sampling (less than 30 feet from surface) will allow the use of vacuum pumps to transport samples out of wells. However, deep aquifers (greater than 30 feet from surface) will necessitate submerged pumps or air-lift systems. The air-lift system is a pressurized inert gas system with chambers and check valves to force samples to the surface. The advantage of an air-lift system is that samples are not oxidized since it does not contact any oxygen in the air. Several air-lift systems can be used within a single well if separated by seals. They become increasingly cost effective with increasing depths. The major problem with the air-lift system is that the check valves used in sample transfer can become clogged with soil particles if samples are not screened properly.[16]

For deep wells, changes in pressure can cause chemical changes such as precipitation in the sample.[16] With the additional data from samples, accumulation of oil and direction of flow can be confirmed and recovery devices can be placed for the most cost effective operation.

Product Recovery

Oil on groundwater can be removed three ways:

1. Open trenches
2. Back filled trenches with recovery crocks
3. Extraction wells

Water table depth and embankment slumping are the primary factors in selecting a recovery device.

When water table depth is less than 9 feet (3m) from the surface, trenching can be an economical method in oil removal. The depth of the trench should be about 3 feet (1m) below the groundwater level and the width no more than 6 feet (2m). Where possible the trench should span the entire down gradient edge of the oil plume (Fig. 7).

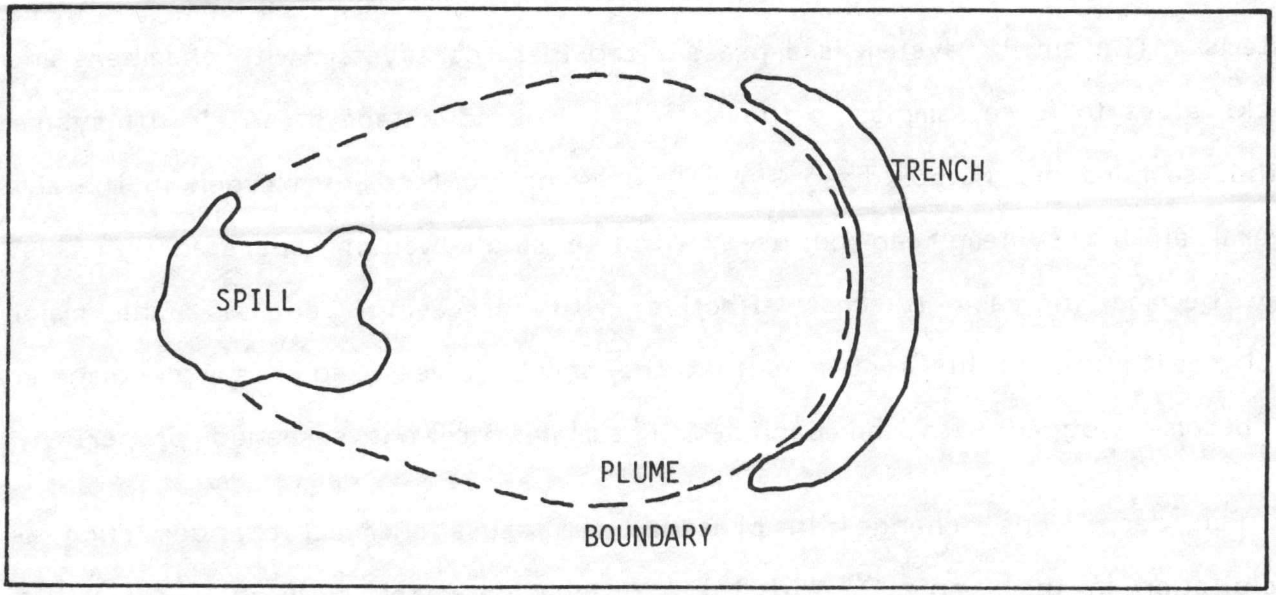

Figure 7. Aerial View of Trenches

Oil skimmers or vacuum lines can be lowered into the trench to recover oil and a groundwater depression pump used to increase the rate of oil and water flow to the trench. If the trench cannot be extended along the length of the oil plume, an impermeable barrier can be installed to divert liquid flow towards the trench. For example, bentonite clay slurry can be pumped into narrow slots in the ground or sheet pillings can be inserted or driven into the groundwater or aquifer base.[9]

When open trenches cannot be maintained because they rapidly fill with mud or if freezing weather would freeze water in/on open trench, a recovery crock can be used. A recovery crock consists of a pipe that reaches from the surface to about 6 feet (2m) below the water table. Some pipes can be up to 6 feet in diameter. The pipe is perforated with slots or holes (2.5 inches) to allow oil and water to enter. After a hole is dug larger than the diameter of the pipe, pea-gravel is placed in the bottom of the hole to decrease turbidity by limiting soil particle movement as water levels change. Next, the crock (pipe) is lowered into the trench so that the end stands on the gravel bed. Before the trench is filled in with a porous material (gravel, sand), a plastic lining or other impermeable barrier is used to line the down gradient side of the trench above and especially below the water table to guide oil to the crock and halt oil plume migration (Fig. 8). A variation of this system is to have radiating interconnecting perforated pipe at the water table to guide the product to the crock (Fig. 9).[6]

Product in crocks can be removed with skimmers or vacuum devices. Further, a groundwater depression pump can be used to create a cone of depression to encourage liquid flow toward the crock and increase oil recovery rates (Fig. 10).

For deeper water tables, augers, water jets, driven well points, and rotary rigs can be used to dig a recovery well (Table 2). Wells should be dug deep enough below the water table to allow for any groundwater depression techniques used. Auger types vary. Hand held power augers with six inches outside diameter can drill to 8 feet. Truck mounted augers with two inches outside diameter can drill to 120 feet. Hollow stem augers may be used to take undisturbed soil samples. Rotary rigs can be used for sampling soil when drilling, and for sampling water upon completion of the observation well. Depths of 1500 feet can be drilled.

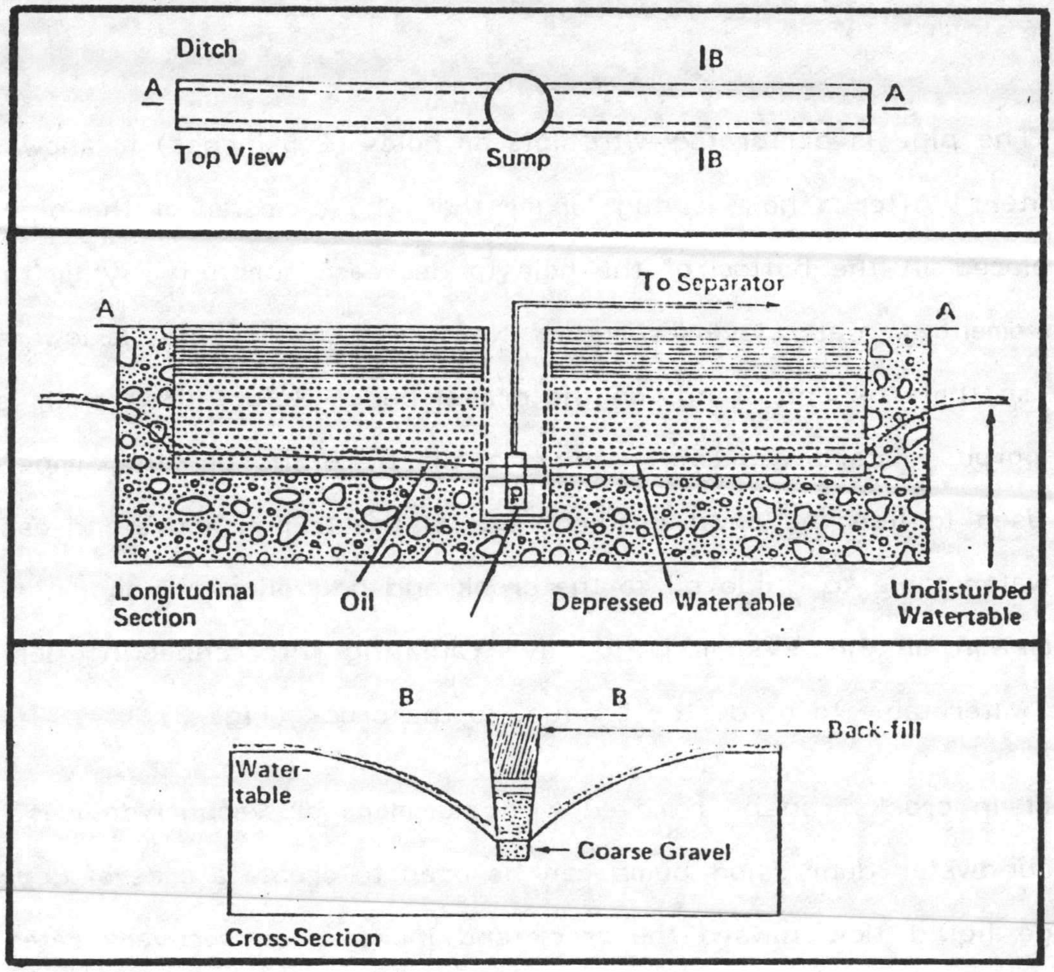

Figure 8. Recovery Ditch With Sump[6]

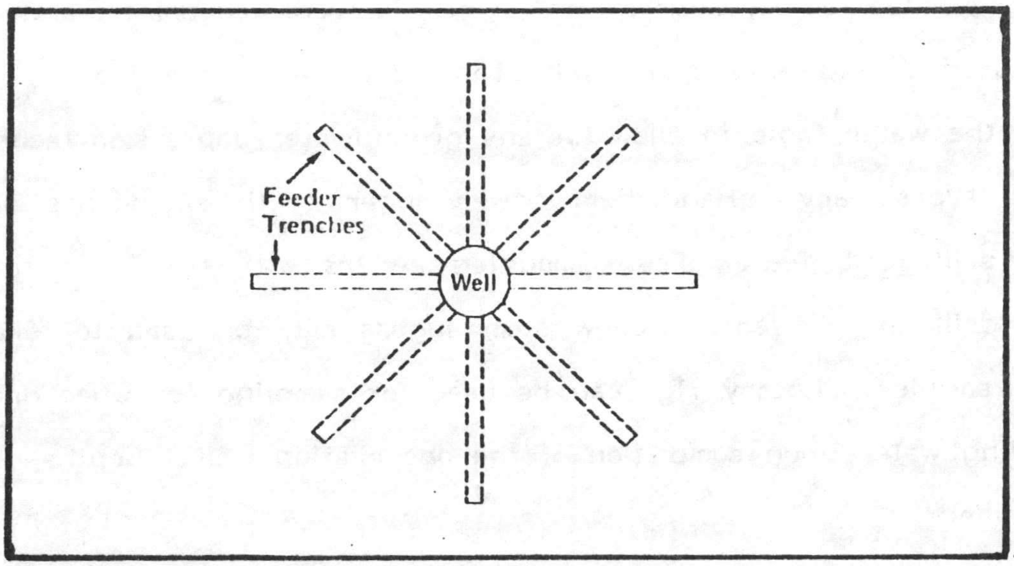

Figure 9. Collector Well With Feeder Trenches[6]

TABLE 2. BASIC WELL DRILLING METHODS[17]

	Drill Type	Normal Diam. Hole	Max Depth	Average Time Per Hole	Normal Expense	Advantages	Disadvantages
1.	Rotary	4"-20"	Unlimited	Fast	Expensive	1. Good for deep holes 2. Can be used in soils and relatively soft rock 3. Wide availability 4. Controls caving	1. Need to use drilling fluid 2. Potential bore hole damage with drilling fluid 3. Requires drilling water supply
2.	Stem Auger	4"-8"	30-50 ft.	Fast under suitable soil conditions	Inexpensive to moderate	1. Widely available 2. Very mobile 3. Can obtain dry soil samples while drilling	1. Difficult to set casing in unsuitable soils (caving) 2. Cannot penetrate large stones, boulders, or bed rock 3. Normally cannot be used to install recovery wells
.	Hollow Stem Auger	4"-8"	30-50 ft.	Fast under suitable soil conditions	Inexpensive to moderate	1. Good for sandy soil 2. Can set casing through hollow stem 3. Very mobile 4. Can obtain dry soil samples and split spoon samples 5. Controls caving	1. Casing diameter normally limited to 2"-3" o.d. 2. Cannot penetrate large rock, boulders or bed rock 3. Limited availability 4. Normally cannot be used for recovery wells
4.	Kelley Auger	8"-48"	90 ft.	Fast	Moderate to expensive	1. Can install large diam. recovery wells 2. Drills holes with minimum soil wall disturbance or contamination 3. Can obtain good soil samples	1. Large equipment 2. Seldom available in rural areas 3. May require casing while drilling
5.	Bucket Auger	12"-72"	90 ft.	Fast	Moderate to expensive	1. Can obtain good soil samples 2. Can install large diameter recovery wells	1. Hard to control caving 2. At times must use drilling fluid 3. Normally very large operating area required
6.	Cable Tools	4"-16"	Unlimited	Slow	Inexpensive to moderate	1. Widely available 2. Can be used in soil or rock	1. Slower than other methods 2. Hole often crocked 3. May require casing while drilling
7.	Air Hammer	4"-12"	Unlimited	Fast	Expensive	1. Fast penetration in consolidated rock	1. Inefficient in unconsolidated soil 2. Very noisy 3. Control of dust/air release 4. Excessive water inflow will limit use

TABLE 2. BASIC WELL DRILLING METHODS (Continued)

Drill Type	Normal Diam. Hole	Max Depth	Average Time Per Hole	Normal Expense	Advantages	Disadvantages
8. Casing Driving (well point)	2"-24"	60 ft.	Slow to moderate	Inexpensive	1. Very portable 2. Readily available	1. Limited to unconsolidated soil--cannot penetrate large rocks, boulders, bedrock 2. Difficult to obtain soil samples 3. Generally inefficient method to install recovery well
9. Dug Wells	Unlimited	10-20 ft.	Fast	Inexpensive	1. Readily available 2. Very large diam. hole easily obtained	1. Caving can be severe problem 2. Limited depth 3. Greater explosive hazard during excavating into hydrocarbons

Basically, wells can be classified into three types:

1. Single pump well
2. Double pump well
3. Double shaft well

Single pump wells use one device to remove oil and contaminated water such as a skimmer or vacuum device (Fig. 10). The major problems with single pump wells are: large volumes of oil and water require large capacity storage, separators are needed to treat oil/water mixtures, some pumps emulsify water with oil, and the pump must be able to handle air, liquid, and debris. The advantages for the single pump well are: they can be less expensive to install and operate than other recovery wells (especially when needed for a short time) and they are effective when low oil/water recovery rates are expected.

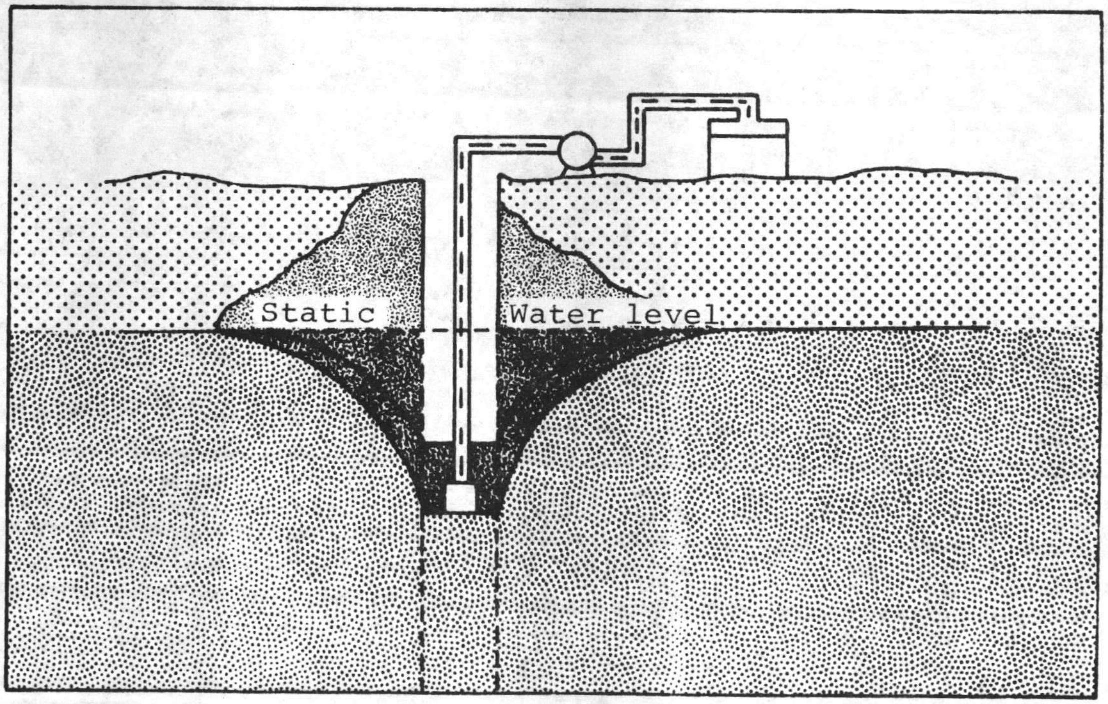

Figure 10. Single Pump Recovery System[6]

The double pump well combines a product recovery device and a groundwater depression device into a single well (Fig. 11). The double shaft well is similar to the double pump well except the oil recovery device and the groundwater depressing devices are in separate well casings (Fig. 12). The separation of devices allows better regulation of water level and flow within the well. The main advantages of double pump and double shaft wells are: they are cost effective for large spill volumes, they can recover relatively pure products, and they can be made fully automatic.[6]

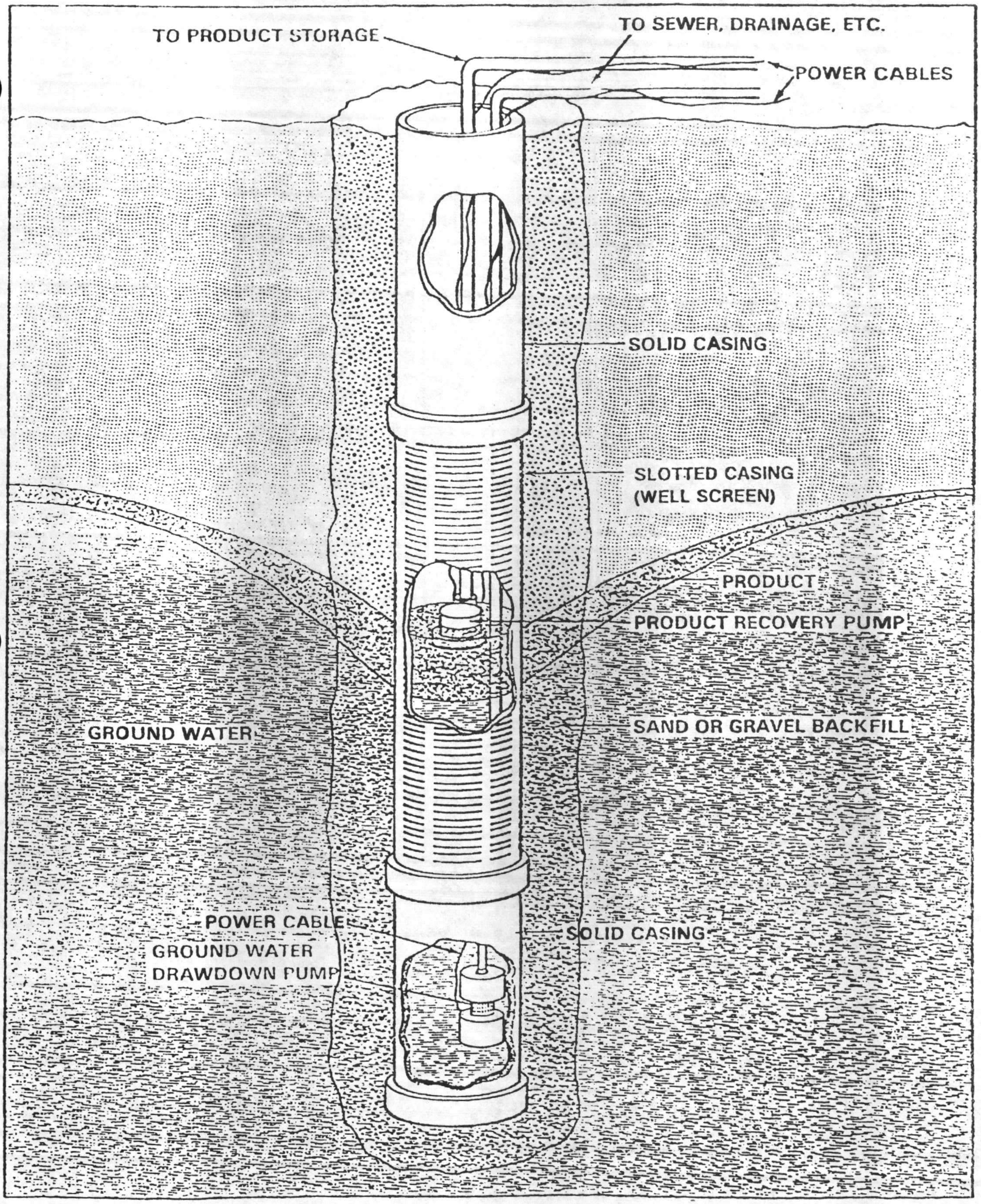

Figure 11. Double Pump Recovery Well

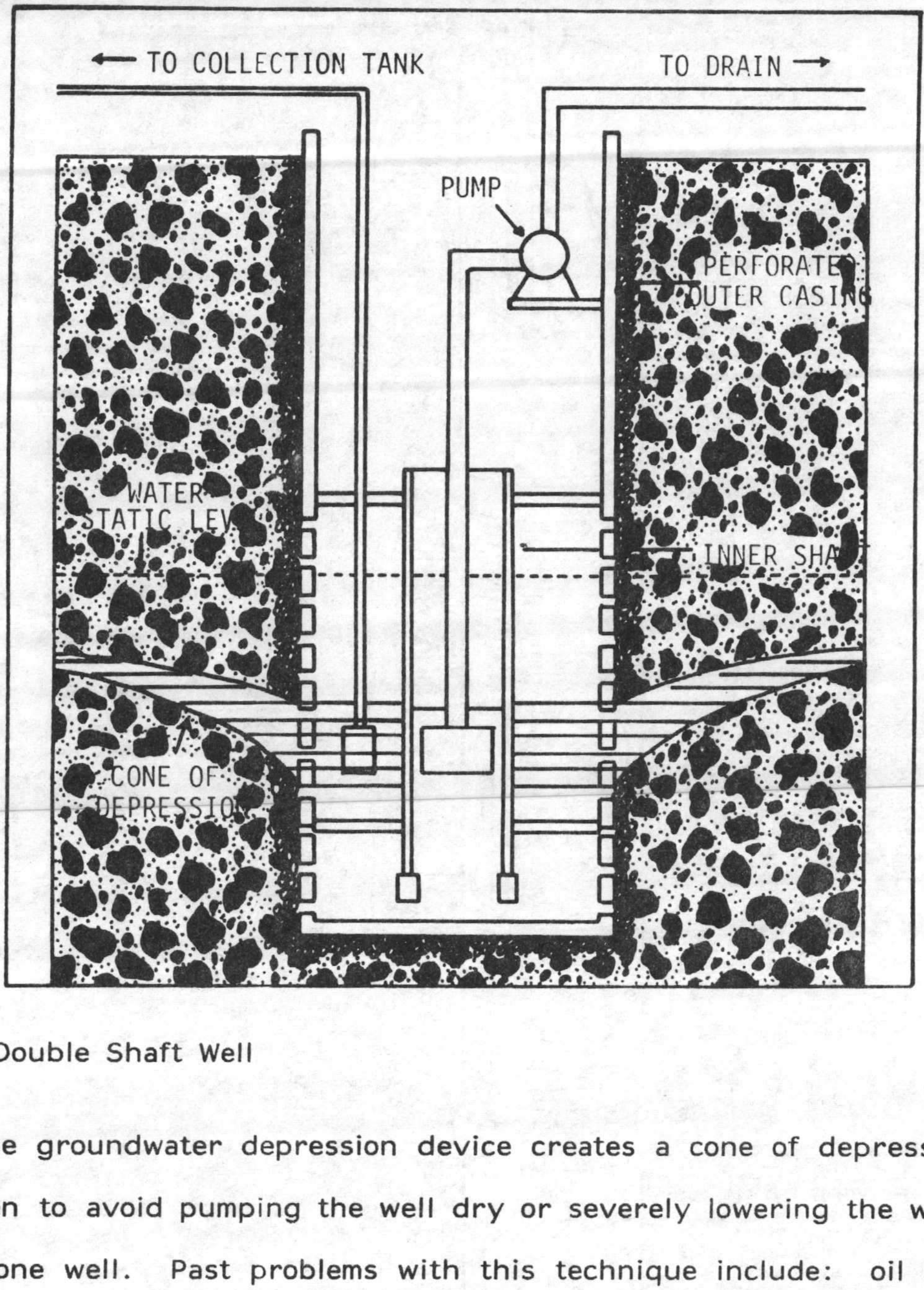

Figure 12. Double Shaft Well

When the groundwater depression device creates a cone of depression, care must be taken to avoid pumping the well dry or severely lowering the water level around any one well. Past problems with this technique include: oil displacing water in the soil and causing additional contamination and surface subsidence by collapse of geologic structures.[6]

In using groundwater depression pumps, provisions must be made to handle large volumes of water pumped from a well. Oil-water separation should be used before water is either transported to a waste handling facility or discharged onto the land. In some cases water can be reinjected into the ground to increase the recovery rate by flushing oil to the recovery point. In some cases, water has been added to the surface at the spill location to flush oil through the soil and to increase recovery rates. The non-residual oil droplets and soluble oils will be moved. It is most effective with light products such as gasoline, diesel, and kerosene. In applying large volumes of water to the spill site, the cone of depression must be maintained to keep flowing oil within the recovery area. If government regulations require purification before discharging water in or on the ground, several methods are available for treatment.[18]

Reverse osmosis uses high pressure to force a solvent (i.e., water) through a membrane but not the solute (i.e., oil). It is used primarily for removing dissolved organic chemicals. Ultrafiltration is similar to reverse osmosis but can remove larger organic molecules. Aeration with the use of air, ozone, or hydrogen peroxide oxidizes dissolved hydrocarbons. Biological treatment uses bacteria to breakdown organic molecules. Activated carbon filters collect dissolved organic and some inorganic molecules on specially prepared carbon particles. Some other techniques such as ion exchange and chemical treatment are usually not as effective as previously mentioned techniques. Where high quality water is required, a combination of techniques can be devised, such as an oil-water separation, followed by aeration, and activated carbon filtration.

Safety

When flammable materials are being recovered, fire prevention should be considered. Be sure submersible pumps are explosion proof and be sure pumps, engines, and other fire igniting sources are kept at least five feet from recovery wells. Electric underground cables should always be protected.

Summary

Oil on groundwater can be a serious problem. It can contaminate water used for drinking, irrigation, or industrial processes. Characteristics such as oil volume, oil viscosity, land area contaminate, depth to water table, and soil permeability will influence the amount of oil reaching the groundwater. The hydrogeologic factors within the aquifer will influence oil migration on the groundwater. Therefore, groundwater monitoring is necessary to have effective location and recovery of product.

Monitoring should include thorough preliminary investigation and field investigation. Field investigations require sampling that does not contaminate soil and groundwater samples. Sampling devices vary from sample probes to complicated well borings with intricate sample casings and sample pumps. Also, complications can arise in sampling due to highly fissured bedrock, solution channels in limestone, and irregularities in bedding planes.

Products can be recovered using open trenches, filled trenches with recovery crocks, or extraction wells. A properly constructed well can recover oil from a large area surrounding the well. Care must be taken in pumping large quantities of water from an aquifer. Water recovered may be required to be treated before discharge. Well types used are single pump, double pump, and double shaft wells. Well choice will depend on the situation.

Safety precautions must be taken when dealing with volatile products.

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CONTAINMENT OF OIL ON SURFACE WATER

CONTAINMENT OF OIL ON SURFACE WATER

Most containment devices are designed to hold oil "long enough" for the oil to be removed. However, no device should be expected to hold oil indefinitely. Depending on the water current, wind current, and wave heights, "long enough" might be a few minutes to several days. Due to the wide variety of water conditions, containment devices can be simple "home-made" devices or sophisticated commercial booms and air barriers.

Air Barriers

The use of air or pneumatic barriers has been demonstrated to be an effective means of controlling the movement of floating products in water with little or no current. Air barriers can be classed as air bubblers or coherent water jets.

The air bubbler is constructed by placing a perforated pipe or manifold in the water close to the bottom. Injecting air into the pipe causes bubbles to rise from the openings. The rising bubbles produce a vertical current in the water which causes a horizontal current or water flow on the surface. This horizontal movement counteracts the forward movement of the oil and prevents the oil from passing.

Advantages of this system include: rapid start up, unrestricted vessel movement, and continuous operation. There are a number of disadvantages as well. These include: ineffectiveness in high currents, silting or clogging of openings, high energy consumption, high initial cost, and system design problems.

Tests under controlled conditions have shown that the excess water at the surface tends to entrain oil droplets into the water column. This is because the water sets up a recirculating pattern near the bubble plant (Fig. 1). When a current is present, this entrainment causes massive oil loss. Losses occur at current speeds below 0.5 knots (Fig. 2).[1]

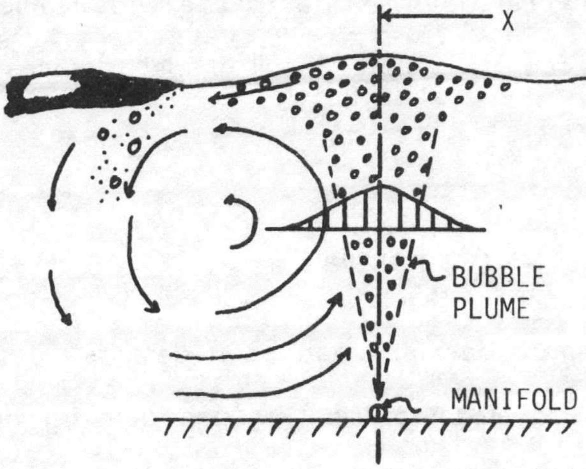

Figure 1. Air Barrier With No Current

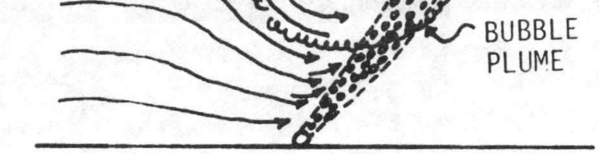

Figure 2. Air Barrier With Current

Under ideal conditions (no current or wave action), oil could be contained in areas such as barge slips with an air barrier. Oil layers could be contained up to five inches thick.

Silting in the manifold openings is a problem caused by placing the manifold system too close to the bottom. Raising the manifold off the bottom may prevent this from happening but may cause difficulty due to the decrease in surface clearance.[2]

The amount of air required to operate a system depends on the length of the perforated manifold, water depth, opening size, spacing of the opening, and the desired surface current. Systems in the 200 to 300 feet range typically require 400 to 1200 c.f.m., depending on the variables listed above.

System cost is one of the most prohibitive disadvantages of air barriers. A complete installation can run as much as $500/foot or even higher. Even if a compressor is already available, the cost for an installed manifold system can exceed $50/foot. Add to this the annual maintenance costs and energy costs and the operating expenses become high.

One area of new technology in air barriers is the use of coherent water jets. By directing a concentrated jet of water vertically into the water column, a large amount of air will also be introduced. The rising air bubbles will act as a typical air barrier. An extra oil holding ability is produced by the splashing of the water and a standard headwave that is produced. Tests have shown that the coherent water jet consumes less energy than standard air barriers of equal effectiveness.[4]

Booms

A boom is a device designed to contain oil floating on the surface of the water. Most booms will have the following characteristics:

1. a means of flotation or freeboard to contain the oil and to resist waves splashing oil over the top,

2. a skirt to prevent oil from being carried underneath the boom,

3. a longitudinal strength member to hold the boom together and provide a means of anchoring the boom, and

4. a weight.

The following discussion will primarily cover typical floating booms similar to the one shown in Figure 3. Fixed barrier booms, to be discussed later, supported from the bottom of a channel can also be useful in some cases.

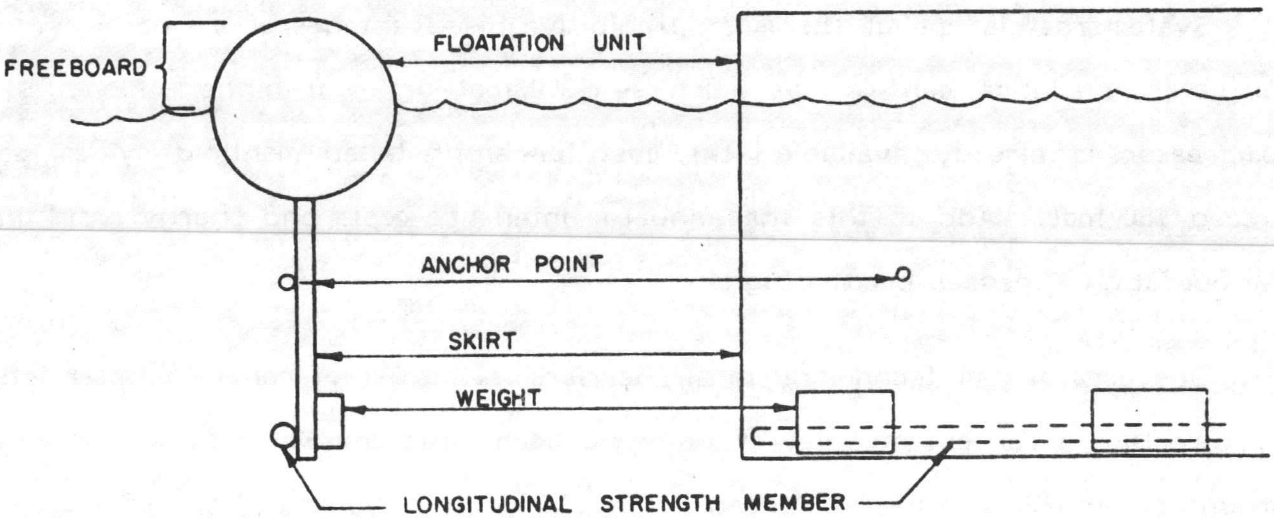

Figure 3. Cross-section of a Typical Boom Showing Major Parts

To be effective, booms should not only float on water, but must be stable in swift water currents, high winds, and waves. It should also be designed to minimize deterioration from the sun or during long periods of storage.

Oil Carryunder

Almost any boom will contain oil when placed in quiescent water. If there is a slight velocity in the water perpendicular to the boom, and no wind or waves, the boom will act in a way similar to that of a properly designed oil-water separator and will contain oil.

As the current moving perpendicular to the boom becomes greater, forces begin acting on the trapped oil and begin to carry the oil under the boom. Oil can move under the boom by at least two methods. The first phenomenon, called leakage, occurs when oil builds up to such a depth behind the boom that oil flows down the face of the boom and over to the other side. This happens when the oil is rather deep on the upstream side of the boom. The second phenomenon involves the carryunder of oil due to a "headwave" building upstream of the boom (Fig. 4). This usually occurs with heavy oil before leakage takes place.

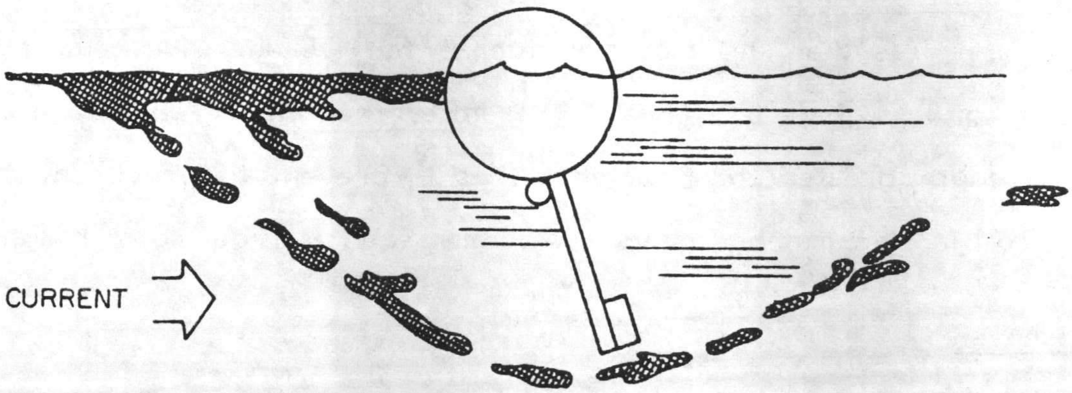

Figure 4. Boom Containment Failure Caused by Entrainment of Oil at Headwave

The containment effort fails when oil droplets break away from the headwave and become entrapped in the flowing water as it passes beneath the boom. Unless the headwave is at a considerable distance upstream of the boom, the oil droplets will not have time to break to the surface and be trapped. The amount of droplet carryunder is a function of the thickness of the headwave. The thickness of the headwave is related to water velocity and the specific gravity of the oil. Thus, the greater the velocity or the greater the specific gravity of the oil, the greater the carryunder.

For a given oil and skirt depth, carryunder will not occur until a critical velocity is reached. As the velocity increases above the critical velocity, the greater the carryunder will be. The critical velocity is slightly lower for a No. 6 oil than for a No. 2 oil because critical velocity decreases as specific gravity of the oil increases.

Increasing the length of the skirt increases the ability of the boom to retain oil, but the advantage is not substantial. Disadvantages of a longer skirt are the increases in weight, cost, and mooring requirements to hold the boom in position. A boom should be effective regardless of skirt depth when currents are below 0.75 feet per second for a No. 2 oil. For a No. 6 oil, no droplets are formed if the velocity is less than 0.4 feet per second, but leakage will occur if the boom has a skirt of less than 12 inches. Therefore, there is no advantage in making the skirt length greater than twelve inches to prevent the movement of oil beneath a boom in slow-moving waters. A longer skirt is required in rough waters.

Oil Splashover

Although a boom, properly deployed, can minimize carryunder, it may be subject to another form of failure - splashover. Splashover will depend on the basic boom design, freeboard, angle of the waves to the boom, wave heights, and distance between successive waves. No boom will be capable of holding oil under all sea conditions, but some boom designs are more effective than others. Under slow swell conditions in the open ocean, most booms will be flexible enough to conform to the waves. Under choppy conditions, it is difficult to keep oil from splashing over the boom. Such conditions require a boom with a relatively high freeboard and long skirt.

Commercial Boom Design

General Criteria

A bigger boom is not necessarily a better boom except for the advantage of preventing oil splashover in waves. Booms can be classified as round, fence, inflatable, and self-inflating (Figures 5, 6, 7, and 8). Each type has specific advantages and disadvantages which are compared in the figures.

Booms can be purchased in a variety of lengths. For spills in creeks and rivers, lengths of 100 and 200 feet are recommended. Each section of boom should be supplied with connectors to extend the length as required.

Anchor points should be constructed in the boom at several places along the length. A maximum distance would be about 100 feet between anchor points, with a 50-foot spacing preferable. Some booms can be supplied with handles to assist in deployment and recovery. Bright colors such as international yellow or orange make booms more visible, while dark colored booms are difficult to see, particularly at night. Not only is a dark colored boom an inconvenience to the cleanup personnel, but it may present a navigation hazard.

Several pieces of auxiliary equipment are important, such as tow bridles, boat attachments, anchor sets, shovels, pipes, and a sledge hammer for connections at beaches, floats, and sufficient rope. Much of this equipment will be used in the field exercises on boom deployment.

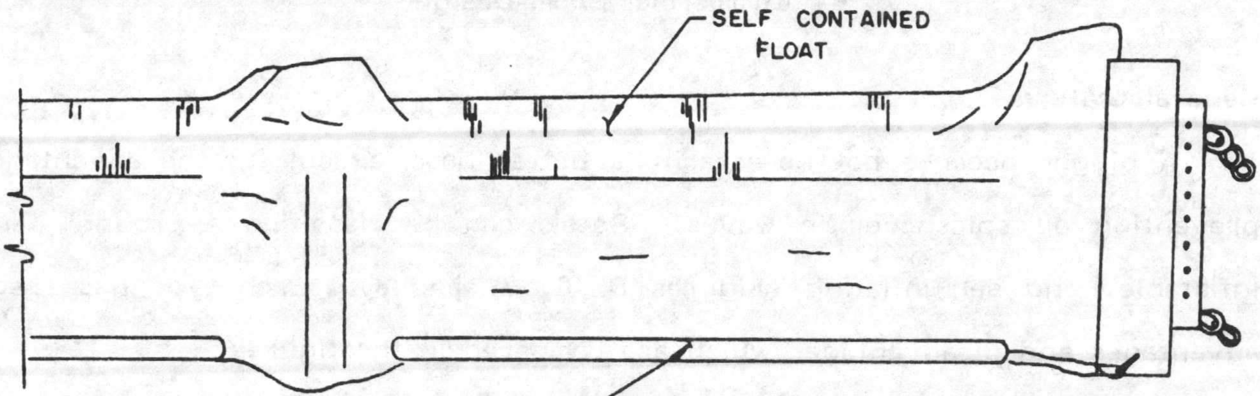

Figure 5. Generalized Round Boom

Possible Advantages

1. Good performance in chop and swell
2. Inherent reserve bouyancy
3. Tows well
4. Allows bottom tension design

Possible Disadvantages

1. Bulky to store
2. Not as easy to clean

Representative Types

1. Kepner
2. Slickbar
3. Acme
4. Bennett
5. American Marine

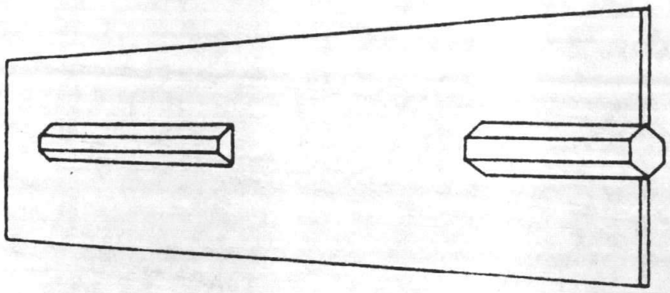

Figure 6. Generalized Fence Boom

Possible Advantages

1. Easy to store
2. Easy to clean
3. Abrasion resistant
4. Good freeboard performance

Possible Disadvantages

1. Twists and corkscrews in wind and current (some models)
2. Poor towing characteristics (some models)
3. Poor wave conformity
4. May require stiffeners that can chafe or break

Representative Types

1. Navy boom
2. Uniroyal
3. Bennett
4. Oilfence
5. Goodrich

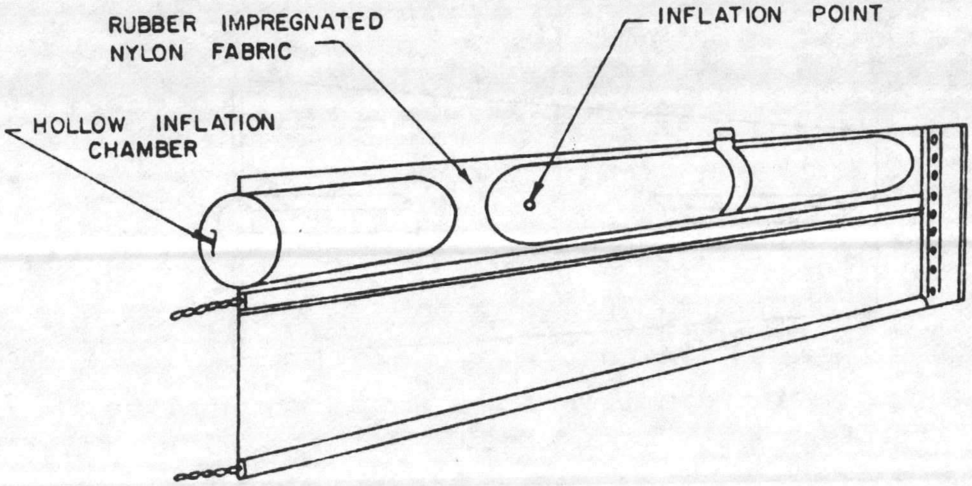

Figure 7. Generalized Inflatable Boom

Possible Advantages

1. Easy to store
2. Made in floating-sinking configuration
3. Good wave conformity
4. Easy to clean

Possible Disadvantages

1. Requires inflation prior to use
2. Requires deflation after use
3. Subject to puncture
4. Expensive

Representative Types

1. Vikoma
2. Goodyear
3. American Marine

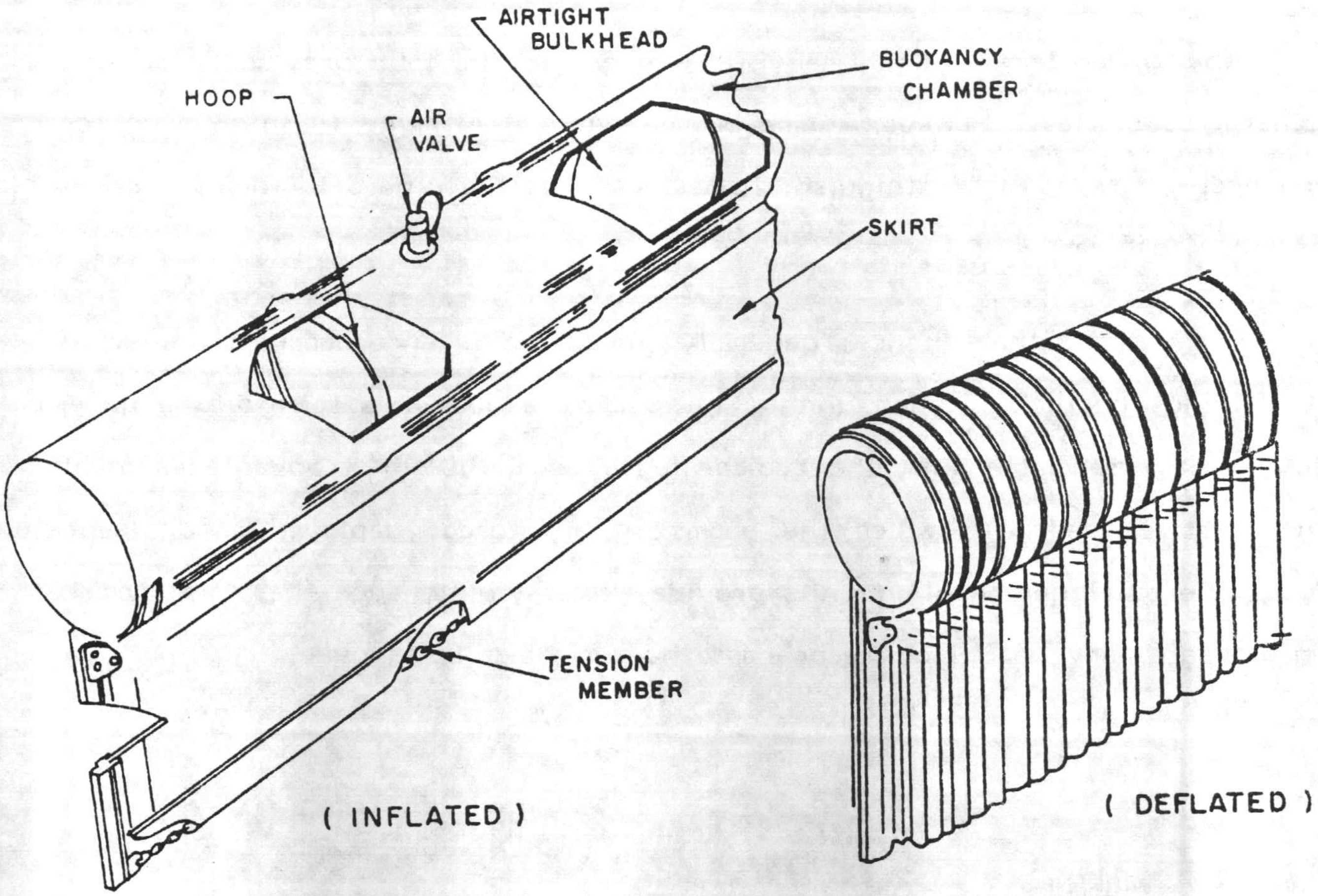

Figure 8. Generalized Self-inflating Boom

Possible Advantages

1. Easy to store
2. Compactible
3. Easy to tow
4. Self-inflating
5. Good wave conformity

Possible Disadvantages

1. Limited tensile strength
2. Subject to puncture
3. Subject to tearing and mechanical damage

Representative Types

1. Kepner
2. Bennett
3. Whittaker

Any given boom will normally fit into one of the four previously mentioned general categories. However, some booms, while they might fit into one of these four categories, often distinguish themselves from the others by distinct designs or other features.

For example the Oilfence, generally considered a fence boom, is unique with its folding "paddle" flotation units (Fig. 9). The boom has some of the generic advantages associated with the typical fence boom. Distinct advantages include the relative ease with which the boom can be stored, deployed, and cleaned. Also, the outrigger flotation units provide extra stability such that this boom has an extraordinary amount of freeboard to help minimize splashover.

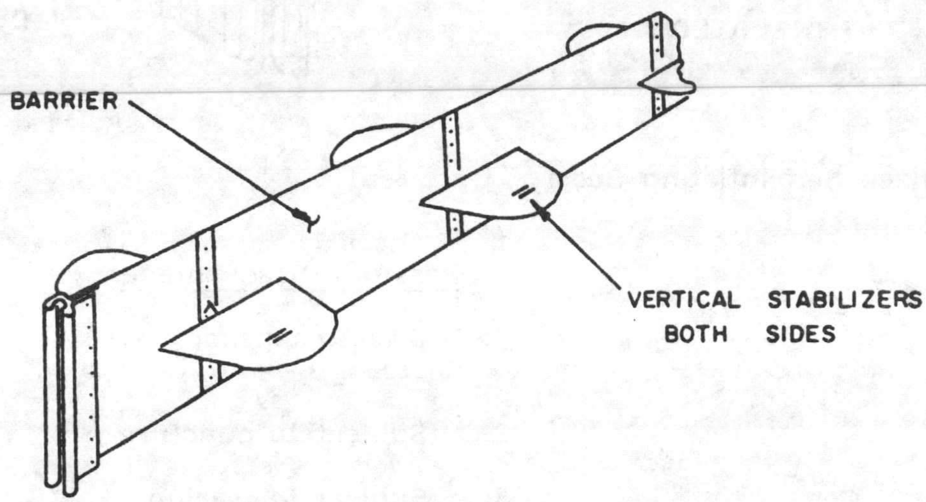

Figure 9. Oilfence Boom

Also, most boom manufacturers offer at least one type of high current option on their booms (Fig. 10). Frequently, these options consist of typical round boom flotation units with fairly short, solid containment skirts. Below this short containment skirt the boom typically has a large open-weave mesh or net connecting the boom sections. The netting allows water to pass through while the solid skirt material near the surface is designed to contain the floating product. This type of arrangement usually has most of the advantages and disadvantages associated with the typical boom. Distinct advantages include the boom's ability to remain stable and contain floating oil in swift currents and to substantially reduce the current load on the boom in high currents. Several major manufacturers offer this type of option on their various booms.

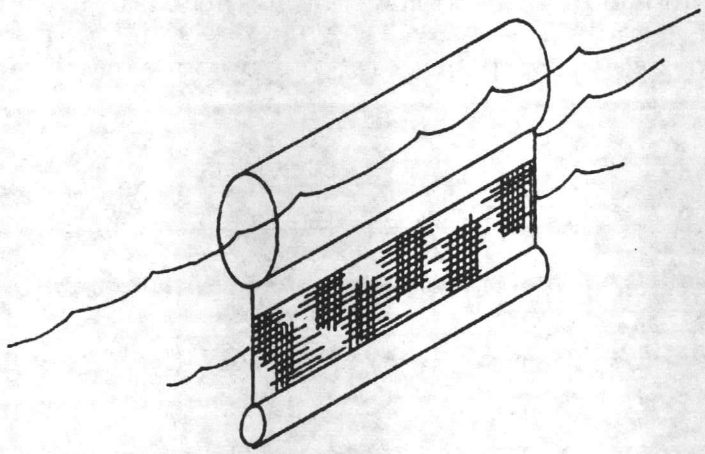

Figure 10. High Current Boom

Floats

Boom floats should be made of solid rather than granular material. The floats should be constructed in relatively short segments to better conform to waves, but they should be an integral part of the boom rather than detachable floats that can be ripped from the skirt. It is best to have the float constructed within the skirt material to eliminate metal connector straps that can be hazardous or plastic straps that can break. A round shape features a built-in reserve buoyancy and is preferable to a square or rectangular shape. The shape of the float can have a significant effect on the ease of deployment and operation.

Tension Member

Cable tension members are preferred over chain or nylon belting, since a light cable is usually stronger than a medium to heavy chain and will not pinch or chafe the boom as easily. Nylon belting is strong but can stretch more than other parts of the boom. Should this occur, the parts that stretch to a less extent could break. For ease of cleaning, an internal tension member is preferred. Many booms have been developed that use the actual fabric of the boom as a tension member. Booms with tension members constructed along the bottom of the skirt are recommended for oil containment in waves. For light service and short lengths, elaborate tension members may not be necessary. A simple, internal tension member would be less expensive and provide a much lighter boom.

Ballast

Ballast should be attached to a boom so that it does not shift or chafe the skirt. Multi-metallic fasteners promote electrolysis and subsequent corrosion. The ballast should be nonsparking and be heavy enough to keep the skirt vertical in a one knot current.

Skirt

The skirt should be made of durable material that does not tear easily and resists chafing. The skirt should be designed to be compatible in depth to the float. In any case, a skirt length over 18 inches is rarely justified. The owner's name should be stenciled on each section of boom or otherwise marked for easy identification. Skirts can be formulated or coated with an antifouling agent to retard marine growth.

Methods of Connection

Unfortunately, there is no universal or standard connector that can be used to connect booms made by different manufacturers. The Navy has developed a connector they are trying to standardize, but to date, this connector has not been widely accepted. An ideal connector is one that could be used by one man from a small boat, would not have any small parts that could be lost overboard, and would be leak-proof (close-coupled). One of the better connectors includes a pin to keep the parts from sliding. The parts are held to the connector by nylon rope. If several booms are used from different manufacturers, it is recommended that special short sections be purchased to act as connectors.

Boom Deployment

To direct an effective cleanup operation, a supervisor must know what factors govern boom operation and understand how to minimize the amount of oil that splashes over or comes under a boom. The three factors that affect oil containment by booms are:

1. boom design,
2. characteristics of the oil, and
3. positional method of boom deployment.

Obviously, the cleanup crew has no control over the type of oil spilled. And once a spill occurs, the cleanup crew must use the equipment available. The time to take advantage of the first two factors is before a spill occurs. A boom should be purchased that is compatible with the type of oil that may be spilled and with design features that work well in the stream, river, or open water at a particular facility. After a spill the cleanup crew has only the third variable to use to its advantage.

As discussed previously, oil carryunder will decrease as the velocity of the water perpendicular to the boom decreases. For any given stream condition, the velocity perpendicular to the boom will depend on how the cleanup crew angles the boom to the current. Figure 11 shows how to angle a boom against the current for various currents. The figure is based on a maximum water velocity perpendicular to the boom of 0.7 knots. As an example, if the velocity of the current in a stream is 2 knots (dotted line, Fig. 11), the boom should be set at a 24 degree angle with the bank.

The force on a boom caused by the current is significant. The force can be calculated using the following formula:[2]

$$F_c = 1.92 \times (V_c)^2 \times D_{ft}$$

F_c = Force due to current in pounds per linear foot of boom

V_c = Current velocity in feet per second

D_{ft} = Boom skirt depth in the water in feet

Assuming the worst possible where the boom is placed perpendicular to the current, the load on ropes and anchors can be calculated. For example, if 500 feet of a 24 inch boom, which has a 16 inch skirt, is stretched across a stream, which has a 2.11 feet/second current; the equation will estimate

$$F_c = 1.92 \times (2.11)^2 \times 1.33$$

$$F_c = 11.39 \text{ lbs/foot}$$

$$F_{total} = 11.39 \times 500' = 5{,}695 \text{ lbs.}$$

Although the figure estimates the worst case, it is useful in planning the types of anchors, ropes, boats, etc. that could be used during a spill. (Also see Table 1.)

The wind force can also add to boom loading; but compared to current, wind is usually negligible. However, the wind force can be calculated with the following formula:[2]

$$F_w = .00339 \times V_w \times H_{ft}$$

F_w = Force due to wind in pounds per linear foot of boom

V_w = Wind velocity in knots

H_{ft} = Height of boom above the water in feet

TABLE 1. CURRENT LOAD IN POUNDS PER LINEAR FOOT OF BOOM FOR VARIOUS SKIRT DEPTHS

Current Speed			Skirt Depth		
Knot	Feet Per Min.	Feet Per Sec.	6"	12"	24"
0.5	51	0.84	0.68	1.35	2.71
1.0	101	1.69	2.74	5.48	10.96
1.5	152	2.53	6.15	12.29	24.56
2.5	253	4.22	17.10	34.19	68.33

To secure a boom in place in a moving body of water, it is necessary to provide anchor ropes with sufficient working strength to carry the load. The load comes from the frictional force acting on the boom and attempting to carry the boom downstream with the water. Because of the many variables that can affect the loading, it is difficult to construct a table or figure that will incorporate all the parameters. A simplification which shows the relationship between required diameters of manila and nylon rope to boom length is presented in Figure 12. Since a boom will be angled to produce an effective current perpendicular to the boom of 0.7 knots, the figure was constructed for this velocity. Another simplification is that the figure assumes that the boom is placed perpendicular to the current which would not be done in actual practice. Although the effective length decreases when booms are angled, there is still the frictional drag over the actual length. To use the table with the actual boom length would result in an additional safety factor built into the system. Therefore, it is recommended to use the figure without a correction for angling the boom.

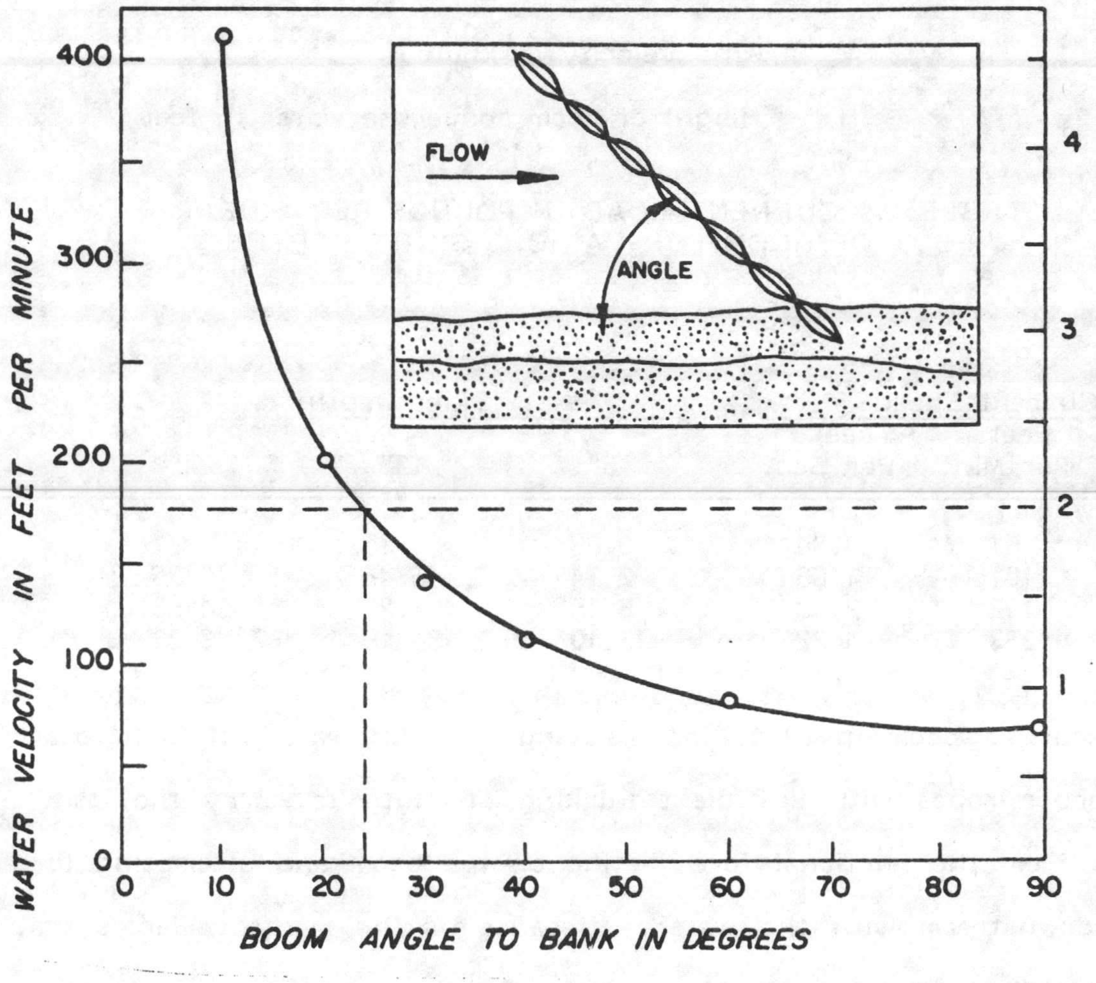

Figure 11. Boom Angles for Various Currents

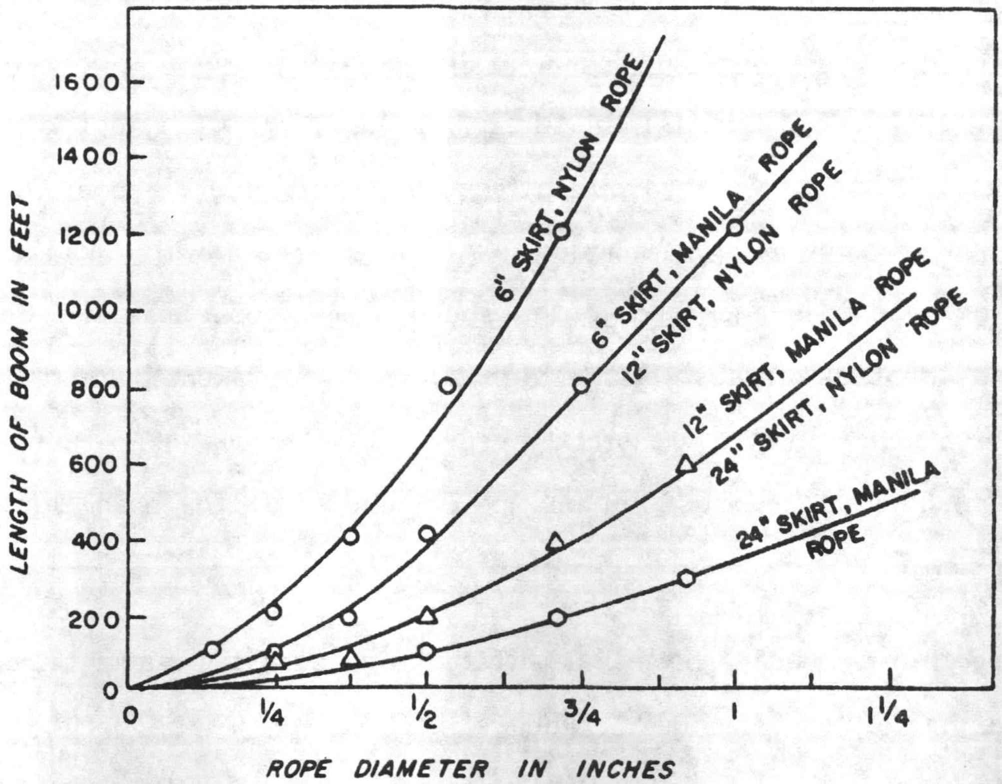

Figure 12. Relationship Between Required Diameter of Manila and Nylon Rope to Boom Length (boom is perpendicular to a 0.7 knot current)

To use Figure 12, one enters the left hand side of the boom scale with a length of boom such as 400 feet. If the boom has a 12-inch skirt, a 3/4-inch diameter manila rope should be the minimum size to consider.

High winds blowing against the freeboard of the boom are another force that will cause additional stress on the moving system. Under most conditions, wind forces will not cause a serious problem unless they exceed 25 knots and the freeboard is 12 inches high or greater.

Towing load can be significant when a boom is anchored on one end and pulled against the current. Boats must have sufficient horsepower and be properly rigged to tow. Ropes must be capable of withstanding the forces, and the boom must have a tension member capable of high loads. If the boom is extended behind the tow boat and pulled free in the current, there is only the frictional drag along the boom. Because this drag is a function of boat speed, a small boat with very little horsepower can pull a free boom. However, a boat with at least a 50 horsepower motor is recommended. Although free towing drag is low, when one end of a boom is anchored to the shore a small boat may not be capable of positioning the boom because of the high current drag exerted on the boom. The boom must also be able to withstand perpendicular forces. The tension member, if it is a chain or cable, must not become detached from the boom due to differential expansion.

Attempting to moor a boom in a straight line across a current from one point to another is not recommended. The result is a sag in the boom that will trap free floating oil at a point inaccessible to the shore. In swift currents the resulting forces on moorings can cause large ropes to break and result in possible safety hazards. The current can be so swift that the boom bobs in the water and becomes completely or partially submerged. When this occurs a readjustment of the boom's position becomes necessary. The total force on the moorings points will be a combination of the forces caused by currents, wind, and waves.

Because of such problems, boom positioning becomes an important subject. The first step is for the person in charge to decide where the boom should be located. Since almost all positions would be on an angle to the current, he should examine the area for likely sites to position the upstream end. Once this is secured he can deploy the boom at right angles to or on an angle upstream of the point, expecting the current to move his boat downstream. Boom should be secured to trees, vehicles, stakes, or anchors. The most difficult part of deploying the boom will be in securing the downstream end because the current pulls the end of the boom into the center of the stream. There will be a sag in the boom, but the objective will be to have the sag close to the downstream bank within easy collection distance. Intermediate anchor points may be needed to lessen the load on the end mooring points and to transfer the sag from the middle to the shore.

Figure 13 shows a typical anchoring set up with anchor, chain, rope, float, and boom. The chain acts as a shock absorber and keeps the angle between the bottom and the anchor line small. The float keeps the end of the boom from being submerged.

A good boom location must meet the following criteria:

1. the site must be accessible by truck or boat so that the cleanup crew can collect and remove the oil;
2. the site must be in the path of the oil so that the oil will be intercepted; and
3. the site must avoid high currents and poor anchoring locations.

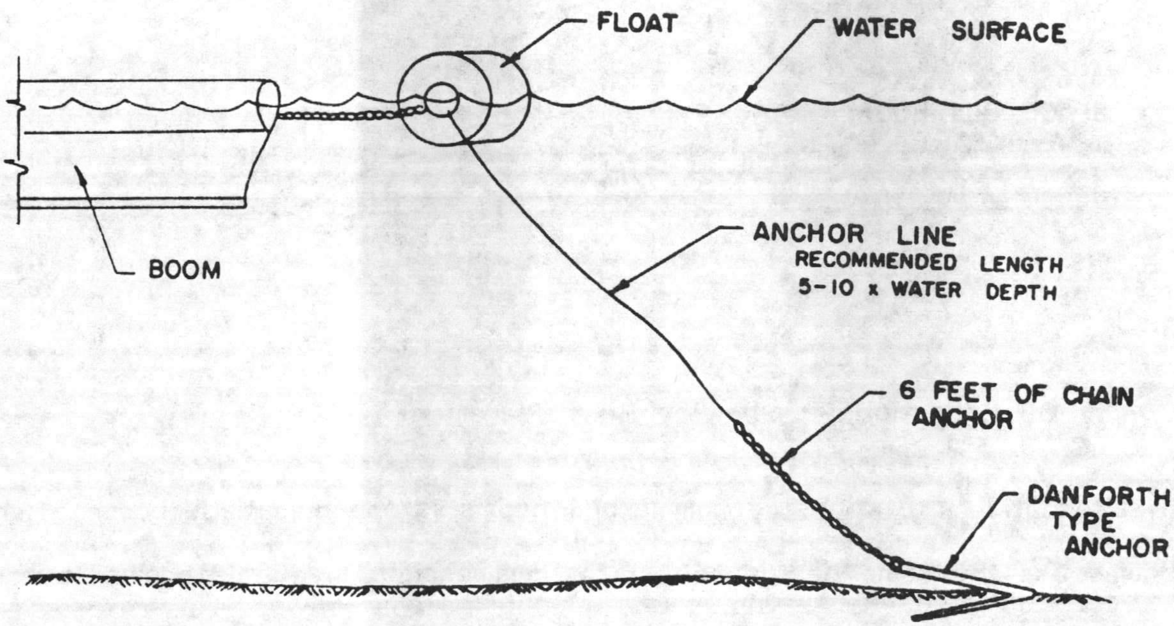

Figure 13. Typical Anchoring System for a Boom

Spills in Creeks

When a spill occurs in a shallow creek, stream, or pond, a commercially available boom may be too deep to be effective because it acts as a dam, causing the boom to lie flat or to back up the water to such an extent that it overflows the boom. If the water is too shallow, the stream might be deepened by a drag-line or backhoe. This equipment can also dig an oil collection pit to use with booms to direct the oil to the pit for recovery (Fig. 14).

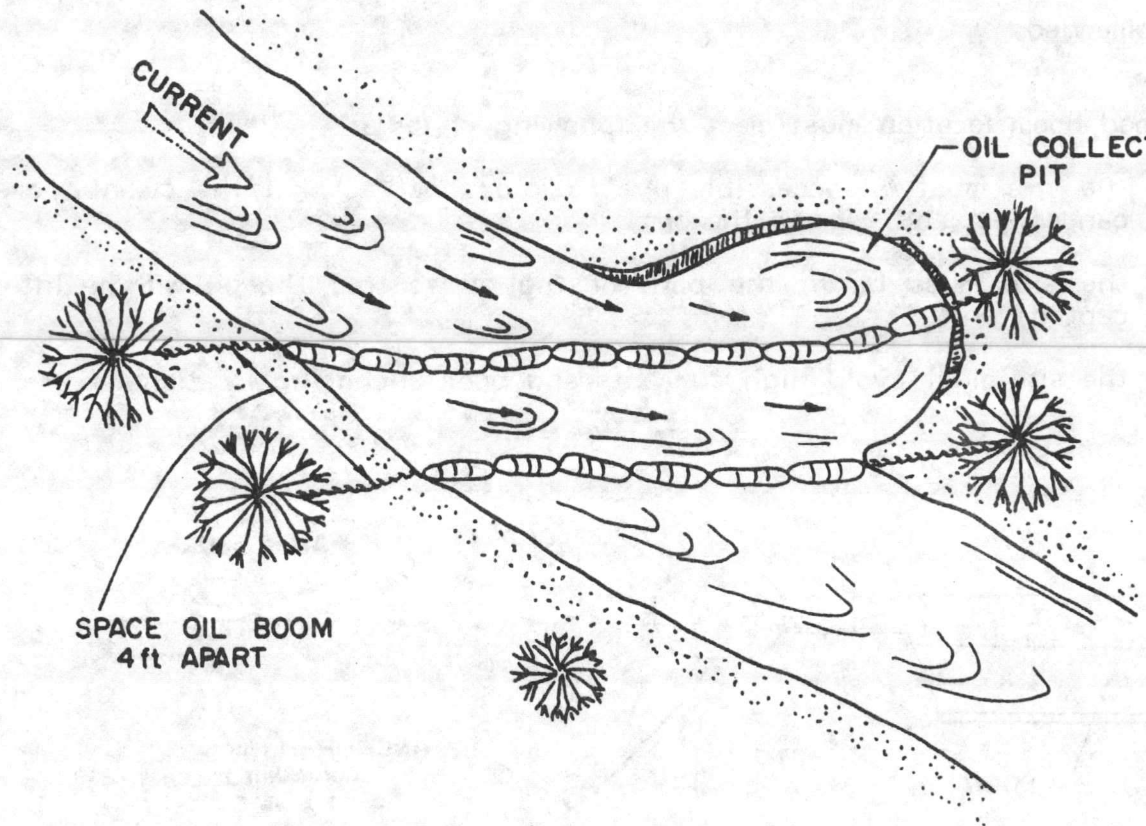

Figure 14. Oil Collection Pit Showing Boom Placement

An alternative to expensive commercial booms is the homemade boom. Home-made booms use the same design criteria as commercially available booms, but use materials such as boards, plywood, metal sheeting, or metal flashing. One simple design uses metal roll flashing with one foot long 2 x 4 floats spaced about 16 inches apart (Fig. 15). Floats are attached alternately.

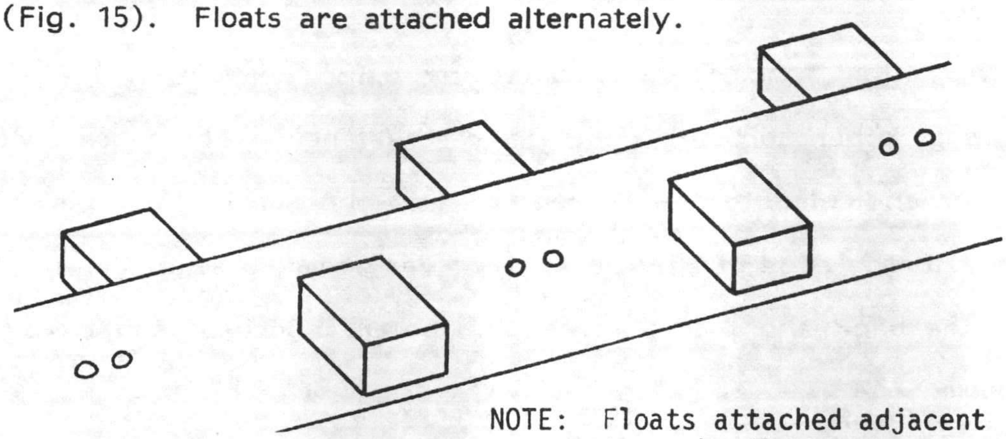

Figure 15. Metal Flashing Boom

Note: Floats attached adjacent to each other ¼ to ½ of the distance from the top of the flashing.

Another design uses wooden or metal stakes driven into the ground, spaced across a water body. Boards, planks, or metal sheets can be railed, bolted, or tied to the stakes at the surface to contain oil (Fig. 16).

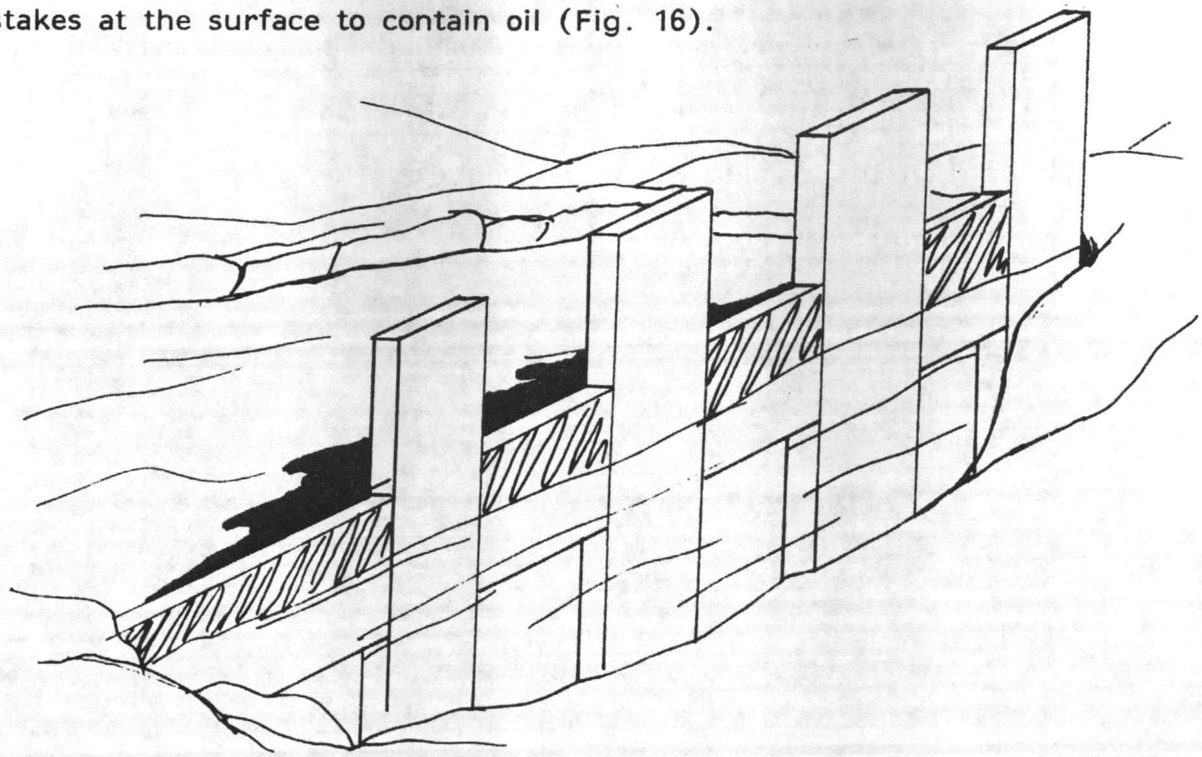

Figure 16. Wooden Fence Boom

If sorbent is placed behind the wooden fence boom, a sorbent filter fence has been created.

Another filter fence is constructed by using chicken wire and stakes with loose straw or other sorbents upstream of the fence. The fence should be constructed perpendicular to the current so that the sorbent will be contained and not carried to the edge of the creek. For very small creeks, a tree can often be cut along the bank and placed across the water. Sorbent can be placed behind the log boom.

In small creeks a sump might be constructed with an underflow dam (Fig. 17). An underflow dam consists of a length of pipe or culvert placed parallel to the direction of water flow with the upstream end lower than the downstream end as shown in the figure. The dam can be constructed with a dragline, backhoe, or bulldozer. The objective is to pass water through the pipe, but retain the floating oil. The culvert must be large enough to allow water to pass without backing up to a depth greater than the dam. Several pipes at various depths may be used in the dam to carry the required flow. An alternate method is to add a valve downstream to control the water.

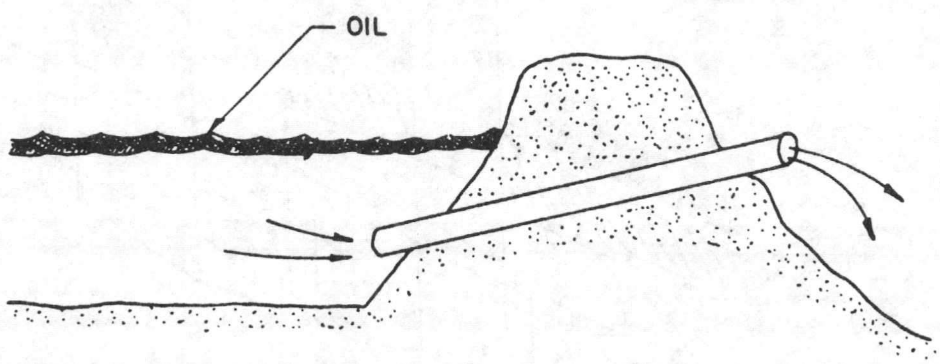

Figure 17. The Construction of a Culvert with an Underflow Dam in a Very Small Creek

Culverts in a creek will serve as a barrier for oil if the pipe is below the water surface. Existing culverts can be utilized at some locations along a creek by damming the creek downstream and thereby raising the water level above the top of the culvert.

Spills in small creeks and ponds can also be contained by bales of hay. Bales should be left intact and placed at strategic locations in the body of water to contain and sorb the oil. Bales must be removed and disposed of as necessary.

Spills in Rivers

Spills in a river are not usually contained by placing a single boom because strong currents or turbulence may cause some of the oil to sink temporarily and flow beneath the boom. Booms must not be placed perpendicular to a river because the pocket will be in the center of the river, currents will be high, and the loads can be excessive on the boom, rope, and anchors (Fig. 18). Booms deployed completely across a river will hamper river traffic. Remember, oil slicks moving down a river will eventually drift to one side of the channel.

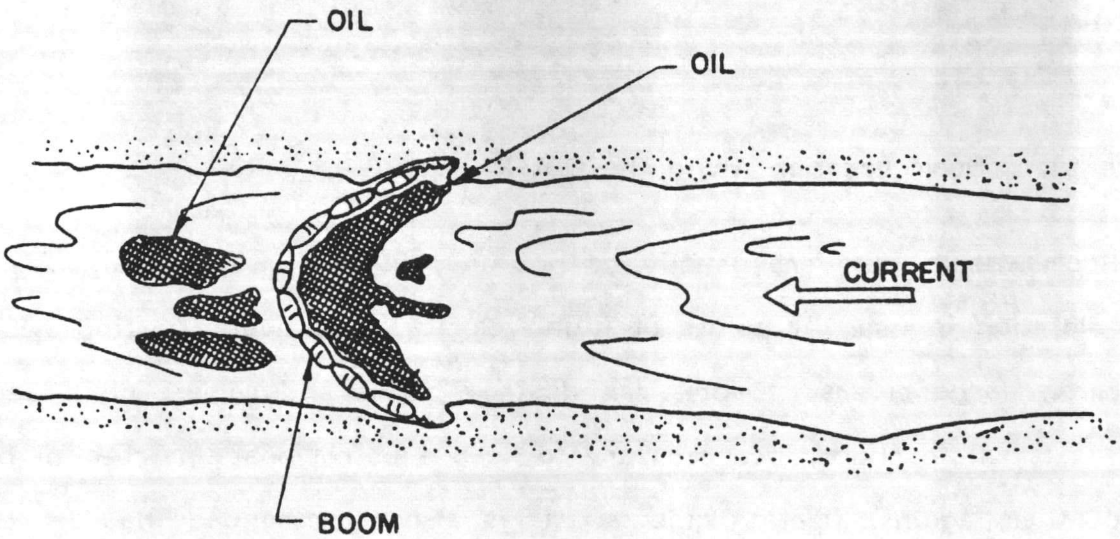

Figure 18. Boom Failure Due to Improper Deployment

By placing several booms at strategic points along the river one can take advantage of the oil's tendency to accumulate naturally in certain areas (Fig. 19).

Strategic locations can be the wide places in the river (pools) where the current speeds are low and booms are likely to be more effective. They might also be narrow places in the river (riffles) where the floating oil can be more easily intercepted, providing the currents are not too swift.

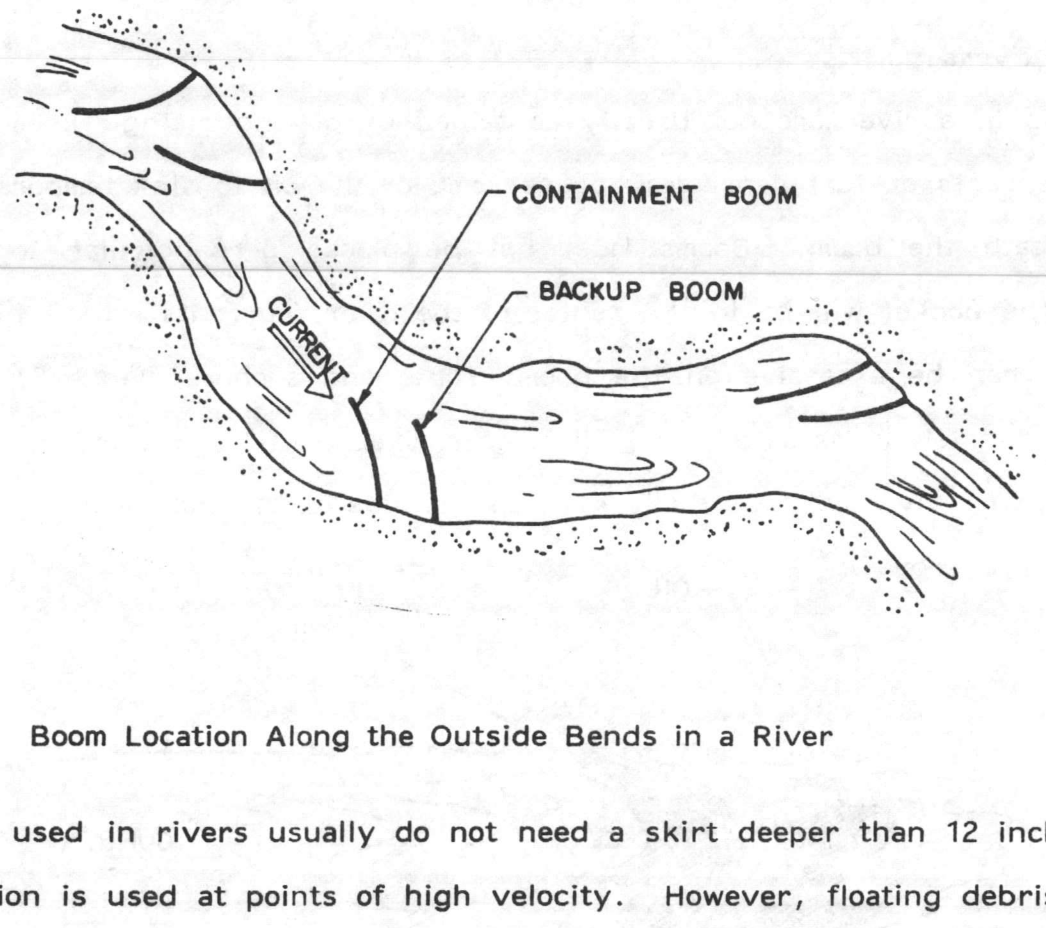

Figure 19. Boom Location Along the Outside Bends in a River

Booms used in rivers usually do not need a skirt deeper than 12 inches if extra flotation is used at points of high velocity. However, floating debris is a problem in large rivers. Debris can destroy booms and release oil already contained. It will probably be necessary to keep a patrol boat upstream of booms to protect them against floating objects. It is also recommended that debris booms be installed (Fig. 20).

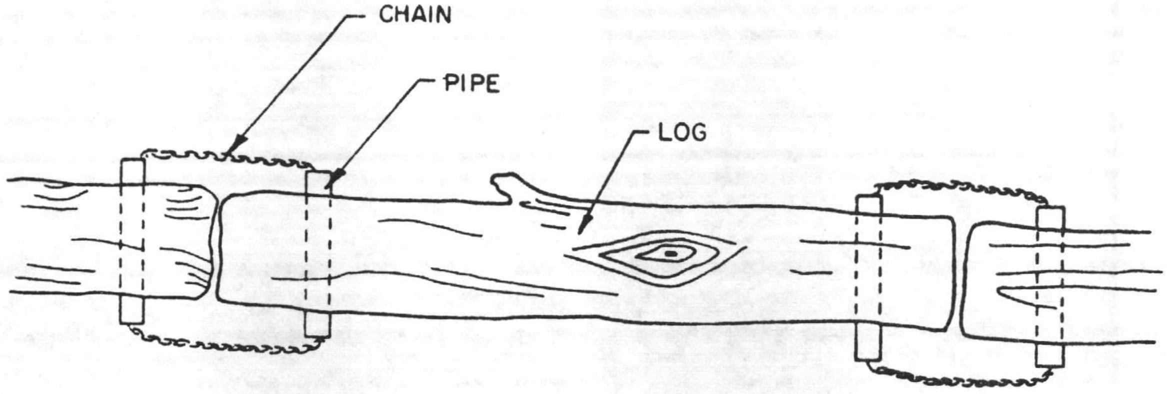

Figure 20. Constructing a Debris Boom by Tying Logs Together with Chain Strung Through Pipe

Spills in Lakes, Estuaries, and Bays

Containment of oil on lakes and bays is complicated by the special problems caused by river currents, boat traffic, and wind. Changes in wind velocity and direction can move oil across, against, or with the current.

Figure 21 illustrates the steps that can be taken to contain an oil spill in a lake or bay. After the cleanup crew deploys a boom at the proper angle downstream from the spill, as shown in the first drawing, a second boom is deployed as a backup in case any oil flows under the first. Because the spill in the lake or bay is subject to erratic flows from wind generated currents, a third boom is deployed upstream of the first to completely contain the spill, as shown in the third drawing. As the oil is skimmed from the pocket, the boom crew should begin taking in the boom to reduce the size of the pocket and contain the oil in a smaller area.

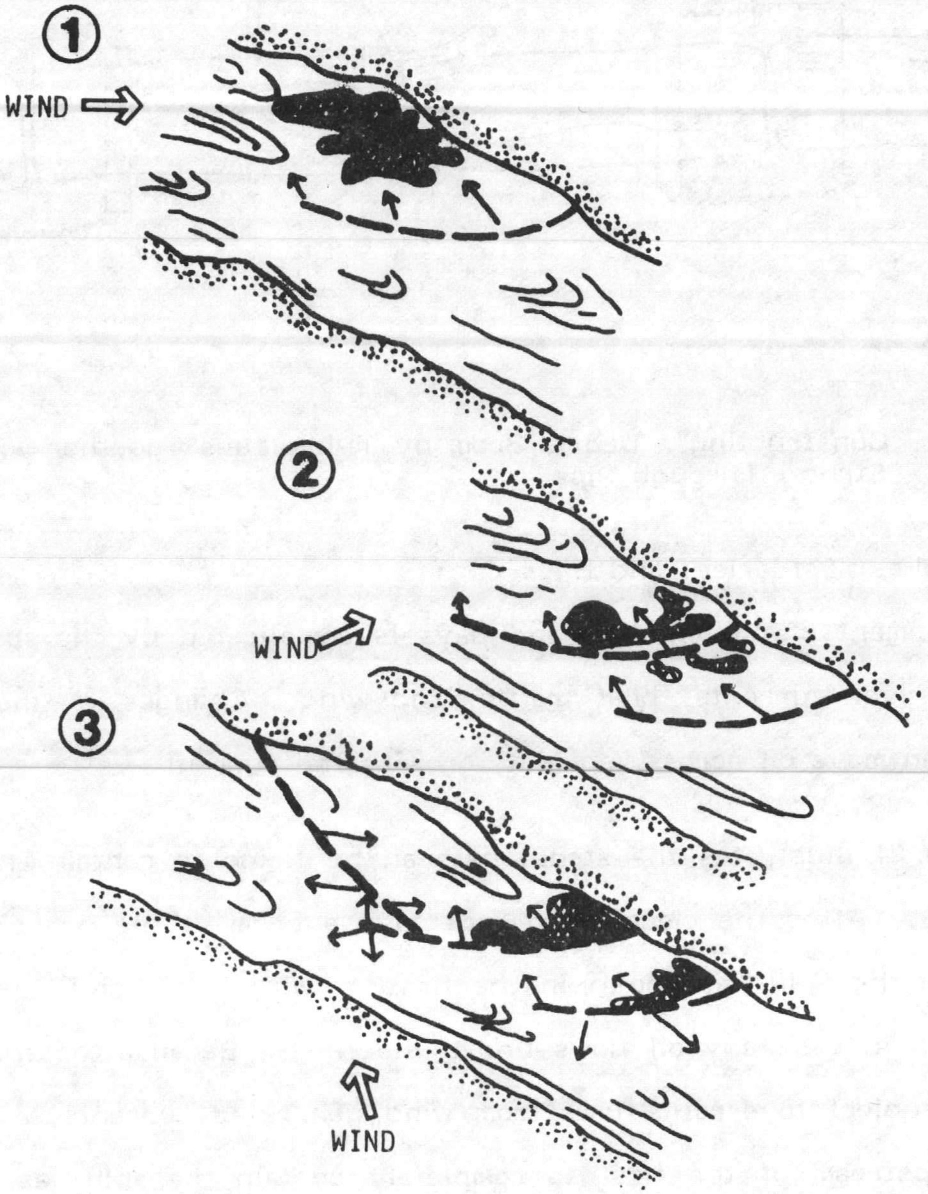

Figure 21. Steps to be Taken in Booming an Oil Spill

Cleaning and Storing Boom

Booms can be stored in several ways. One of the handiest is to store the boom on the deck of a flat-bottomed boat so that it can be deployed as needed.

When this is not available, the boom can be stored on a dock or barge and pulled into the water using a ramp or roller. Ramps and rollers also protect booms from wear. Booms may be stored in the water by attaching segments to floating anchors. Considerable lengths of booms can be stored in the water in a small area by folding sections back and forth similar to the way fire hoses are stored on trucks. One disadvantage is the problem of marine growths forming on the boom which add weight and drag to the boom.

Booms can be cleaned by breaking the boom into sections and laying each section flat on a clean sloping surface. Oil can be removed by washing the boom with water and steam spray. The boom washing area should direct the wash water to a sump where the oil can be collected.

Summary

Containment devices are designed to contain oil floating on the surface of water. A properly installed containment device will not only contain the oil, but will cause the oil to move to a selected location where it can be removed from the water surface. Air barriers use a current generated by air bubbles to contain oil. They work best in little or no current waters.

Booms constructed of sorbent materials such as hay can be effectively used in creeks. Culverts are also useful in stopping the movement of oil slicks. A series of booms are normally used in spills in rivers and other large bodies of water, because it is not usually possible to install one boom completely around the oil spill or across the body of water.

Booms are often stored on the deck of a boat or barge so that it can be easily and effectively deployed. Booms can also be effectively stored on docks and pulled into the water using a ramp or roller to assist in launching and recovery.

Boom Selection Checklist

1. Booms should be operational in waves with height to wavelength ratios of 8:1. Booms should work in winds equal to a Beaufort Force 5.

2. At an effective current velocity of 0.7 knots, the skirt should remain within 20° of the vertical.

3. The boom should be capable of being deployed from a reel or from a dock at a 5 knot rate.

4. The boom should be capable of being towed at 10 knots in a straight line without twisting. It should follow behind a maneuvering tow boat without twisting at up to 2 knots.

5. Sections should be capable of being connected and disconnected, without nuts and bolts or tools, from a small craft in not over two minutes.

6. Recovery and storage should be accomplished by not more than three trained men.

7. In calm water the boom should have a freeboard of at least 4 1/2 inches.

8. The boom should allow 180° folding at least every 10 feet of length.

9. The boom should have reserve buoyancy of at least 200 percent. The buoyancy should double within 18 percent of the normal water line.

10. The boom should have at least a 0.2 percent UV oxidizer/inhibitor coating or be capable of withstanding two years continuous exposure to direct sunlight.

11. The flotation should have a smooth surface for cleaning and must be puncture resistant.

12. Puncturing or cutting of a float section should not significantly reduce flotation or allow escape of flotation.

13. The flotation should be an integral part of the entire boom.

14. Flotation should be closed cell foamed plastic resistant to hydrocarbons. Granular type flotation material is not recommended.

15. The color should be international orange or yellow.

16. Skirt fabric should show good break strength, abrasion resistance, and be flame resistant.

17. The base fabric for the skirt should be polyester.

18. No laminated materials should be used in the skirt.

19. Stiffeners should not rust and should not wear through or puncture the fabric after one year of continuous use in the water with normal wave action.

20. The boom should be capable of a direct tensile load, end-to-end, of not less than 4,500 pounds.

21. The primary tension member should not elongate more than 10 percent at a 5,000 pound loading.

22. Tension members should be attached to the skirt and secured to the flotation at no less than six points every 10 feet.

23. Tension members should not be located where they would prevent the free-board from remaining vertically perpendicular to a 0.7 knot current.

24. Ballast must be non-sparking. If cable or chain is used, it should be covered to prevent chafing.

25. The ballast should not collect static electricity.

26. For a 0.7 knot current, the following minimum ballast are recommended per linear foot of boom:

Skirt Depth	Ballast lbs/ft of boom
6"	0.33
8"	0.44
10"	0.54
12"	0.75

27. The ballast should not be rigid for more than four inches in any one piece.

28. Anchor points should be placed every 100 feet on both sides and directly connected to the tension member.

29. End connectors should not permit oil leaking.

30. End connectors constructed of metal should only use stainless steel, lead, or anodized aluminum.

List of Common Booms

The following list of booms is for the use of the trainee as a guide and is not for the purpose of recommending a particular brand. Because of space limitation, not all booms are included in the list. If a boom is not included, this does not mean that the boom should not be used. The following classification system will be used to distinguish between booms appropriate to inland water, bays, and ocean service based on freeboard and draft.

Classification	Service	Freeboard	Draft
I	inland water	4-10"	6-12"
II	bay	10-18"	12-24"
III	ocean	18" & above	24" & above

MODEL	MANUFACTURER	FREE-BOARD (inches)	DRAFT (inches)	STANDARD LENGTH (feet)	WEIGHT (lbs/ft)	STORAGE Volume ($ft^3/100$)	FLOAT MATERIAL	TENSION MEMBER
O.K. Corral Boom	Acme Products Co. 2666 N Darlington P.O. Box 51388 Tulsa, OK 74151 (918) 836-7184	4	6	Up to 300 ft	1.54	14	Polypropylene foam sealed in "Jaton"840 denier nylon fabric	Ballast chain & an optional 0.31 in chain for top tension
		6	12	"	1.96	32		
		12	24	"	3.76	102		
Oil Fence (40 cm)	Albany International P.O. Box 1062 Buffalo, NY 14240 (716) 824-8484	7.87	7.87	100	2.88	45.9	Polyurethane	None
Oil Fence (61 cm)		12.0	12.0	100	3.74	70.62	Polyurethane	None
Oil Fence (91 cm)		17.9	17.9	100	5.24	144.7	Polyurethane	None
Mark I	American Boom and Barrier Co. 8051 Astronaut Blvd. P.O. Box 933 Cape Canaveral, Fl 32920 (305) 784-2110	6	12 or 18	100	1.8	33.3	Microfoam Floats	Chain
Mark II		7.5	12 or 18	100	2.2	33.0	Microfoam Floats	Chain

MODEL	MANUFACTURER	FREE-BOARD (inches)	DRAFT (inches)	STANDARD LENGTH (feet)	WEIGHT (lbs/ft)	STORAGE Volume ($ft^3/100$)	FLOAT MATERIAL	TENSION MEMBER
Minimax 17	American Marine Co. P.O. Box 940 Cocoa, Fl. 32922 (305) 636-5783	6.0	11.0	100	1.18	22.2	Slab Ethafoam	Galvan-ized chain or cable
Minimax 18		6.0	12.0	100	1.7	33.2	Rolled Micro-foam	"
Optimax 19		7.0	12.0	100	2.0	33.2	Rolled Micro-foam	"
Supermax 36		12.0	24.0	50	2.9	58.0	Rolled Micro-foam	"
Swedish Oil Trawl	B.C.P. Products, Inc. 13742 97th Ave. N.E. Kirkland, WA 98033 (206) 821-8880	29.5	53.1	65.6		94	Styrofoam	Chain
				131.2		188		
				196.8		282		
KL-8D	Bennex A/S Dept. of Oil Recovery Systems N. Tollbodkai P.O. Box 1992 N-5oll Bergen Nordnes Norway Telex: 42908 Sea N	33.46	39.37	45.7	8.7	330	PVC Floats	Kevlar Rope
				50.9				
				60.9				

MODEL	MANUFACTURER	FREE-BOARD (inches)	DRAFT (inches)	STANDARD LENGTH (feet)	WEIGHT (lbs/ft)	STORAGE Volume (ft^3/100)	FLOAT MATERIAL	TENSION MEMBER
XF-11	Bennex A/S (con't)	39.37	39.37	76.2 152.4	20.1	417	PVC Floats	Kevlar Rope
HL-50E		11.8	29.52	7.6 15.2 30.4	4.69	523	Solid foam covered with PV-C	Line at base of stabilizing net
Reel Boom	Biggs Wall Fabricators, Ltd. Hampden House Arlesey, Beds SG15 6RT U.K. SG15 6RT 0462-731133 Telex: 826113 Biwalog	12.9	20.0	Up to 91	2.6	0.8	Air-filled chambers	DNA
Spilldam Boom 180	Brockton Equipment Corp. P.O. Box 1022 Brockton, Ma 02403 (617) 583-7850	6	12	100	1.25	15	Polyethylene floats	0.25 Polypropylene rope

MODEL	MANUFACTURING	FREE-BOARD (inches)	DRAFT (inches)	STANDARD LENGTH (feet)	WEIGHT (lbs/ft)	STORAGE Volume (ft^3/100)	FLOAT MATERIAL	TENSION MEMBER
Harbor Boom	Clean Water, Inc. P.O. Box 1022 Court House Square Toms River, NJ 08753 (201) 341-3600	7.9	24	49.9	2.0	59.6	Polyethylene floats	Cable and galvan-ized chain
4X6 Boom	Containment Systems Corp. P.O. Box 1390 Cocoa, Fl 32922 (305) 632-5640 Telex: 566535 CSCCOCA	4.0	6.0	50	0.9	12.0	Solid Float	Galvanized chain
Performance Boom		6.0	12.0	100	1.6	31.0	"	"
Fence Boom		6.0	12.0	100	1.1	21.0	Plank	
Harbor Boom		12.0	24.0	50	2.7	116.0	Expanded polypropylene	Galvanized Wire rope at top; ballast at bottom
River Boom		6.0	12.0	100	1.9	31.0	Expanded Polypropylene	"
Conwed Disposable Containment Boom	Conwed Corp. 444 Cedar St. P.O. Box 43237 St. Paul, MN 55101 (612) 221-1144	10	10	7	2.9	24	polyethylene foam	Polypro-pylene line

MODEL	MANUFACTURER	FREE-BOARD (inches)	DRAFT (inches)	STANDARD LENGTH (feet)	WEIGHT (lbs/ft)	STORAGE Volume ($ft^3/100$)	FLOAT MATERIAL	TENSION MEMBER
Petro Barrier 24 in.	Crowley Environmental Services Corp. P.O. Box 2287 Seattle, WA 98111 (206) 583-8100 Telex: 321229	11	13	100	4.4	128	Closed-cell foam	Skirtmaterial
Petro Barrier 36 in.		13	23	100	6.5	200	"	"
High Seas	Dickson-Constant 249 Ruedu Fauborg de Roubaix B.P. 6 59010 Lille Cedex, France Telex: 820314 EDSA LILLE	31.5	35.4	82	10.1	DNA	Inflatable chambers	Metal frames and cable
Coastal		23.6	31.5	82	8.7	DNA	"	"
Sheltered		15.8	23.6	164	3.4	DNA	"	"
River		31.6	39.37	82	5.4	DNA	"	"
Sea-Sentry 9-18	Goodyear Aerospace Corp. Engineered Fabrics Rockmart, GA 30153 (404) 684-7855	9	18	68	5	32.7	Inflatable chambers	0.38 Galvanized chain
Sea Sentry 12-24		12	24/30	55	10	82	"	"
Sea Sentry 14-24		14	24	55	8.8	82	"	Two 0.5 Kevlar Ropes

MODEL	MANUFACTURER	FREE - BOARD (inches)	DRAFT (inches)	STANDARD LENGTH (feet)	WEIGHT (lbs/ft)	STORAGE Volume ($ft^3/100$)	FLOAT MATERIAL	TENSION MEMBER
Permint 36	Intertrade Industries 15301 Transistor Lane Huntington Beach, Ca. 92649 (714) 894-5566	12	24	50	3	128	Polyethylene foam	Polyester webbing
Compactible	Kepner Plastics Fabricators, Inc 3131 Lomita Blvd. Torrance, CA 90505 (213) 325-3162 Telex: 691646	7.1-20.9	13-75.2	167 to 200	1.3-12.7	6.4-84.57	Self-inflating compartments and polyethylene and/or polyurethane foam floats.	Glavanized chain boom fabric polyester webbing. optional: Galvanized wire
Super Compactible Sea Curtain		7.1-11.8	13-18.1	167	1.3-3.40	.36-1.0		
Reel Pak Sea Curtain Inland to Offshore models		7.1-16.5	13-18.1	100 or 200	1.34-4.0	.45-2.7		
Standard Sea Curtain: Bayou to High Seas models		4-26	9-42	50 or 100	1-19	7.1-49.3	Resistex Co-polymer, polyethylene, polypropylene, or polyurethane foam	Galvanized chain
Permanent Sea Tender		11.0	24	51 to 100	3.6	49.4	"	"

MODEL	MANUFACTURER	FREE-BOARD (inches)	DRAFT (inches)	STANDARD LENGTH (feet)	WEIGHT (lbs/ft)	STORAGE Volume (ft^3/100)	FLOAT MATERIAL	TENSION MEMBER
Baplac 41	Kleber-Colombes Services Commerciaux it Usine B.P. 224 rue lesage maille 76320 Caudebec- les Elbeuf, France 35-81-00-99 Telex: 770438	9.0	11.8	164	2.4	----	Solid flotation blocks and airspaces within fabric pockets.	Protected chain
Balaer 323		14.6	20.9	164	5.4	75.0		"
Balaer 333		21.3	29.6	164	7.7	98.2	"	"
Mini- Boom	Megator Corp. 136 Gamma Drive Pittsburgh, PA (412) 963-9200 Telex: 812573	2.0	7.0	16.4	0.6	15.9	Closed-cell foam covered with PVC-coated nylon cloth	None
Nordan Sea	Nordan Oil Pollution Control, Urupvej, 5550 Langeskov Denmark 09-323333 Telex: 50310 Nordon	13.8	20.1	32.8	6.0	DNA	Air-filled floats	Chain
Nordan Coast Guard		19.7	23.6	32.8	7.7	DNA	"	"
Nordan Ocean		23.6	35.4	26.3	10.5	DNA	"	"

MODEL	MANUFACTURER	FREE-BOARD (inches)	DRAFT (inches)	STANDARD LENGTH (feet)	WEIGHT (lbs/ft)	STORAGE VOLUME ($ft^3/100$)	FLOAT MATERIAL	TENSION MEMBER
30 HD	Norske Telektron Telektron garden, Drammenseien 126 Oslo 2, Norway 02-55-46-95 Telex: 16274	11.8	19.7	164	4.0	42.7	Nondeflatable air-filled floats	Fishing net
80 HD		31.4	39 to 78	328	13.4	64	"	"
100		39.3	39 to 117	328	16.1	81	"	"
Nat Oil Boom	Nouvelles Applications Technologiques 370, Avenue Napolean-Bonaparte, 92500 Rueil- Malmaison France Telex:202913	11.8	19.7	328 (or spec.)	1.48	10.8	Inflatable floats	chain
Offshore Oil Containment Barrier	Offshore Devices, Inc. Building 43 Summit Industrial Park Peabody, MA 01960 (617) 286-0767	21.0	27.0	612	16.0	1.3	Solid etha-foam panels within a steel panel and inflat-able floats	4" Double braid polyester line
H.G. 15	Oil Recovery International, Tuckton Bridge, Christchurch Dorset BH231JS U.K. 0202-486666 Telex: 41354 OILMOPG	5.9	9.8	50.8	1.6	20.3	Polystyrene floats	Galvanized chain
H.G. 30		11.8	18.1	101.6	3.5	89.0	"	"
H.G. 40		15.8	18.1	101.6	4.5	149	"	"

MODEL	MANUFACTURER	FREE - BOARD (inches)	DRAFT (inches)	STANDARD LENGTH (feet)	WEIGHT (lbs/ft.)	STORAGE VOLUME ($ft^3/100$)	FLOAT MATERIAL	TENSION MEMBER
Regular Duty Boom	Parker Systems, Inc. P.O. Box 1652 Norfolk, Va 23501 (804) 485-2952	6	12	100	1.7	30	Closed-cell foam	Galvan-ized chain
Basin Boom		4	8	25	1.0	15	"	"
Bantam Boom		3	4.5	25	0.9	8	"	Fabric
Harbor Boom No. 3000	Response Systems Inc. 820 Richie Highway 2A Seyerna Park, MD 21146 (301) 647-4424 TWX: 710-867-5829	11.8	18.5	82	2.0	12.0	Air-filled floats	None
Sea Boom No. 4300		18"	25.5	50	3.52	19	"	"
No. 2000		8	12	82	DNA	DNA	"	"
Rolip High Seas Boom	Rolba Marine Departement Marine 11, 15, Boulevard Paul-Langevin B.P., 3-F 38600 Fontaine France: 76-26-58-72 Telex: 320780 Rolba Fontaine	27.6	27.6	157.4	18.1	692	Closed-cell foam	None
RO-Boom	A/S Roulunds Fabriker DK-5260, Odenses, Denmark; Tel:11-55-15 Telex: 59873	26	51	663	12.1	16	Inflatable air-filled floats	Chain

MODEL	MANUFACTURER	FREE-BOARD (inches)	DRAFT (inches)	STANDARD LENGTH (feet)	WEIGHT (lbs/ft)	STORAGE VOLUME (ft^3/100)	FLOAT MATERIALS	TENSION MEMBER
Standard containment	Samsel Rope and Marine Supply Co. Pollution Recovery Systems Division 1285 Oil River Rd. Cleveland, OH 44113 (216) 241-0333	6	12	150	1.4	26.6	Unicellular Plastic foam	Ballast wire at bottom, and lateral tension tape at top
Inner Harbor Boom	Seaward International 6269 Leesburg Pike Falls Church, VA 22044 (703) 534-3500	7.5	10	50	2.6	128	Closed-cell foam with urethane elastomer	Parallel Kevlar fibers
Outer Harbor Boom	Telex: 899455	12	16	50	4	----	"	"
Lake Type	A.B. Sjuntorp S-46020 Sjuntorp, Sweden OS 20/40200	11.8	16.3	----	2.7	----	Cellular nylon	Coated rope & wire
Coastal Type	Telex: 42143	17.3	22.5	----	3.8	----	"	"
Open Sea Type		28.5	39.5	----	5.4	----	"	"
Zig Zag Boom	Skimmex Ltd. 270 Earls Court Rd. London, England SW59AD	20	24	40	4.5	----	Air inflated polyester fabric	Galvanized chain
Shoreline Barrier	01370 3315 67 Telex: 981986	9	12	40	0.8	----	"	"

MODEL	MANUFACTURER	FREE-BOARD (inches)	DRAFT (inches)	STANDARD LENGTH (feet)	WEIGHT (lbs/ft)	STORAGE VOLUME ($ft^3/100$)	FLOAT MATERIAL	TENSION MEMBER
Harbor MK7	Slickbar, Inc. 250 Pequot Ave. Southport, CT 06490 (203) 255-2601	8	16	Increments of 3¼'	3.6	50	Hard-skinned Polyethlene foam	None
Harbor MK10		5	9	Increments of 5'	1.85-2.83	30	"	"
Harbor MK11		5	9	Increments of 5'	1.85-2.83	30	"	"
4 in. Boom	Spill Control Co. 828 N. Grand Ave. Covina, CA 91724 (213) 339-1259	4	14	50	1.28	DNA	Ethafoam floats	Galvan-ized chain or cable
6 in. Boom		6	18	50	1.84	DNA	"	"
Combi- Boom		5	13	50 or 100	1.72	4	Closed-cell Urethane	Polypro rope
Bantam	Trelleborg A/B, Box 501, S-231 01 Trelleborg 1, Sweeden 0410-510-00 Telex: 32948	11	18.5	314.9	3.5	38.7	Polystyrene foam	Rope System
Universal		15.8	25.6	236.1	3.7	1.9	"	"
Giant		19.7	39.4	186.9	5.2	3.2	"	"

MODEL	MANUFACTURER	FREE-BOARD (inches)	DRAFT (Inches)	STANDARD LENGTH (feet)	WEIGHT (lbs/ft.)	STORAGE VOLUME ($ft^3/100$)	FLOAT MATERIAL	TENSION MEMBER
18 in. Mini	Uniroyal, Inc. Engineered Systems Mishauaka, In 46544 (219) 256-8142	6	12	40	1.5	48	Fabric-covered ensolite	None
36 in. Standard		12	24	40	3	69	"	"
36 in. 2-ply		12	24	40	5.8	138	"	"
7/11 General Purpose	Versatech Products, Inc. 60 Riverside Drive N Vancouver, B.C. V7H 1T4 (604) 929-5451 Telex: o435 2686 Bennpoll VCR	6	11.4	50	1.6	50	Polyethylene floats	Galvanized chain
Permanent Harbor		12	18	50	8.9	228	Polyethylene floats filled with urethane	"
Inshore		12	23	50	2.2	100	Polyethylene floats	"
Zooom Boom Series 7 Model 11		6	11.4	100	1.4	6.0	Inflatable Polyester floats coated with PVC or Polyurethane	Galvanized chain or synthetic fiber
Zooom Boom Series 12 Model 18		10	19.6	100	2.0	18.0	"	"
Zooom Boom Series 18 Model 18		15	20.3	----	3.9	35	"	"

MODEL	MANUFACTURER	FREE-BOARD (inches)	DRAFT (inches)	STANDARD LENGTH (feet)	WEIGHT (lbs/100)	STORAGE VOLUME (ft^3/100)	FLOAT MATERIAL	TENSION MEMBER
Oceanpack	Vikoma International, Inc. Crest House 39-41 Thames St. Weybridge, Surrey U.K. Weybridge 43315/6 Telex: 929329	27.2	17	1640	3.0	73	Self-inflating 840 denier-nylon tubing coated with neoprene	None
Seapack		27.2	17	1640	3.0	100		"
Coastalpack		17	17	820	2.9	24		"
General Purpose 4 in.	Welsh Oil-Tech, Inc. 15711 NE 92nd St. Redmond, Wa 98052 (206) 885-5759 Telex: 321182	4	8	50	1.5	192	Urethane foam	None
Containment Boom 12 in.		12	24	50	2.5	640	"	"
High Compression Oil Barrier (HCOB)		12	18	10	DNA	180	Air-filled floats	"

This list has been adapted from The 1981 International Directory of Oil Spill Control Products written by the center for Short-Lived Phenomena and published by Cahners Publishing Company, P.O. Box 716, Back Bay Annex, Boston, Massachusetts 02117.

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2. Smith, M. F. 1975. Planning - Equipment and training for oil pollution control. Slickbar Inc. 98 pp.

3. Texas A&I University at Corpus Christi. Spill training and educational program. United States Energy Research and Development Adminstration Contract No. E-(40-1)-4995.

4. Breslin, M. K. 1981. Using coherent water jets to control oil spills. EPA-600/52-81-141. Environmental Protection Agency, Washington, D.C.

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Recovery of oil on surface

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RECOVERY OF OIL ON SURFACE WATER

RECOVERY OF OIL ON SURFACE WATER

The Purpose of a Skimmer

After the spilled oil has been contained, it must be removed. A skimmer provides one of the least expensive means of removal with the advantage of recovering oil without changing the physical or chemical properties of it. Although many skimmer units are commercially available, there are five basic types:

1. suction units,
2. floating weirs,
3. oleophilic disks, drums, or belts,
4. hydrodynamic inclined planes, and
5. induced vortex or cyclone skimmers.

Suction units and floating weirs are the most common types of skimmers because they are usually simple to operate, versatile, and generally cost less than other types. Most small skimmers can be compatible with each other, providing proper hose connections and couplings are available. Small skimmers can be used on small and large spills and should be a part of a company's oil spill equipment inventory. Large self-propelled skimmers are usually purchased by only cooperatives because of the expense involved.

Available Skimmer Types

Floating Suction Units

Floating suction units are constructed so that the area of the mouth of the skimmer is large enough to permit a wide coverage. In a floating suction head, a self-priming pump is needed to draw the oil into the head, and the suction head is balanced to float at the oil-water interface. Hoses float on top of the surface supported by flotation collars (Fig. 1).

The advantages of suction-type skimmers are that they are simple to operate, can be used in most situations, can recover oils of varying viscosities and can be used in most water depths. The flexible Manta Ray (Fig. 1) was designed to work in small waves. Since this skimmer's head is flexible it tends to conform to wave action and will skim oil in spite of small waves. However, like most skimmers, this unit becomes less efficient as the waves increase in size.

The capacity of the suction unit is limited by the size of the hose, the capacity of the pump, and the depth of cut. The main disadvantage to suction heads is their tendency to become clogged with trash. Also, the suction head and hose may become filled with air. Therefore, the pumps used with skimming units should be self-priming. For efficient operation a person should be stationed at each skimmer to remove trash, to adjust the skimmer as required, and to move the skimmer if necessary. Tether ropes tied to the head of the skimmer help to secure the unit to the bank and allow one to maneuver it toward the oil. The skimmer operator may find it necessary to move the oil to the skimmer. This can be accomplished by wooden paddles, blowers, water sprays, or even prop wash.

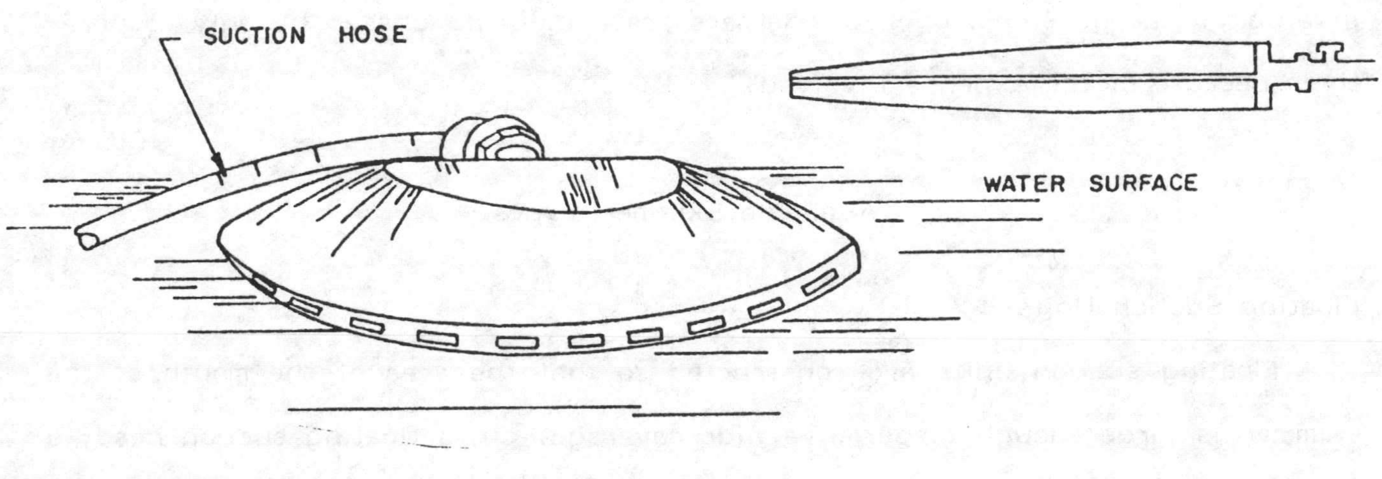


Figure 1. Floating Suction Skimming Unit.

Possible Advantages	Possible Disadvantages
1. Works well in shallow water	1. Debris clogging problems
2. Portable	2. Limited oil recovery efficiency
3. Relatively inexpensive	3. May perform poorly in swift currents or waves greater than about 6" high
4. No adjustments	

Floating Weir

Floating weir skimmers are designed to allow oil to flow over the top edge of a weir and into a collecting vessel where the oil is pumped away through a flexible hose. Theoretically, the edge of the weir can be adjusted so that it is set near the oil-water interface to maintain good oil recovery efficiency; in practice, this is difficult to do. The weir skimmer shown in Figure 2 obtains buoyancy from the floating cylinders that will keep the unit from sinking. However, the skimming depth or "cut" of the unit must be manually pre-set by adjusting wing nuts or thumbscrews. Each time the oil-water interface varies, the skimmer's cut must be readjusted manually.

Early units were often top-heavy and flipped over in rough water. Others were not balanced well and discharge hoses would cause the weir to cut deeper on one side than the other.

As waves become larger, the unit will tend to bob up and down and skim more water than oil. This type of skimmer is obviously better suited for quiet water.

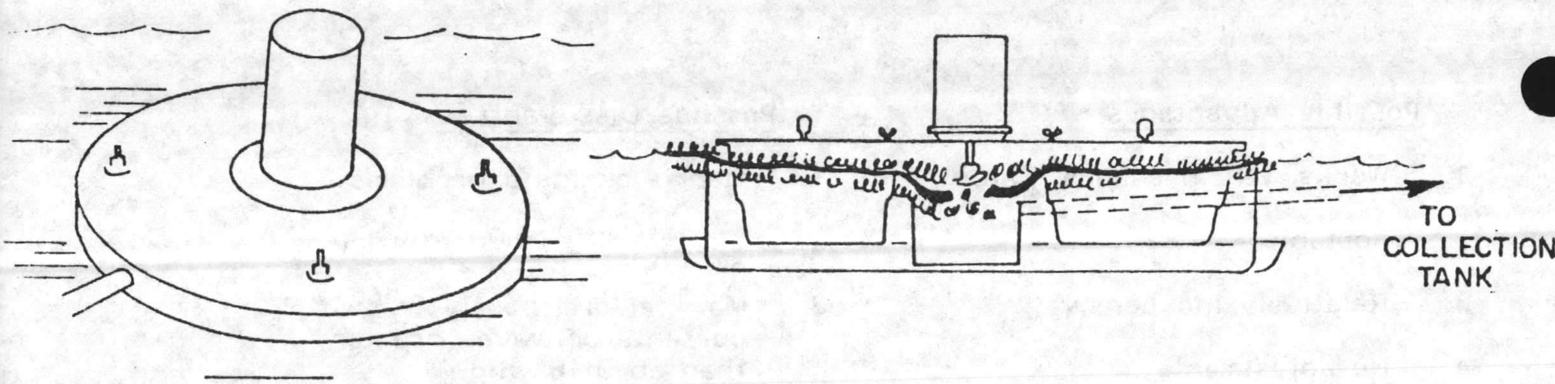


Figure 2. Floating Weir Skimming Unit.

Possible Advantages

1. Good oil recovery efficiency
2. Small units are portable
3. Small units are inexpensive
4. Can be used in relatively shallow water
5. Small units simple to operate

Possible Disadvantages

1. Large units cannot work in shallow water
2. Not good in waves and currents
3. Hydrodynamically unbalanced
4. Requires frequent movement

A hydraulically-balanced floating weir skimmer automatically adjusts according to a pre-set internal liquid or air level. A flexible suction hose is connected to the bottom of the unit to remove the oil as it collects inside the skimmer (Fig. 3). The main advantage of this type over the conventional weir is that the position of the hydraulically-balanced weir can be adjusted by changing the pumping rate. As the pumping rate is increased, the weir depth is increased. The unit has a screen on the front to keep trash from entering the unit itself, but the operator must remove trash from the screen as required. This unit, like the conventional weir, works better in calm water and with thick oil slicks.

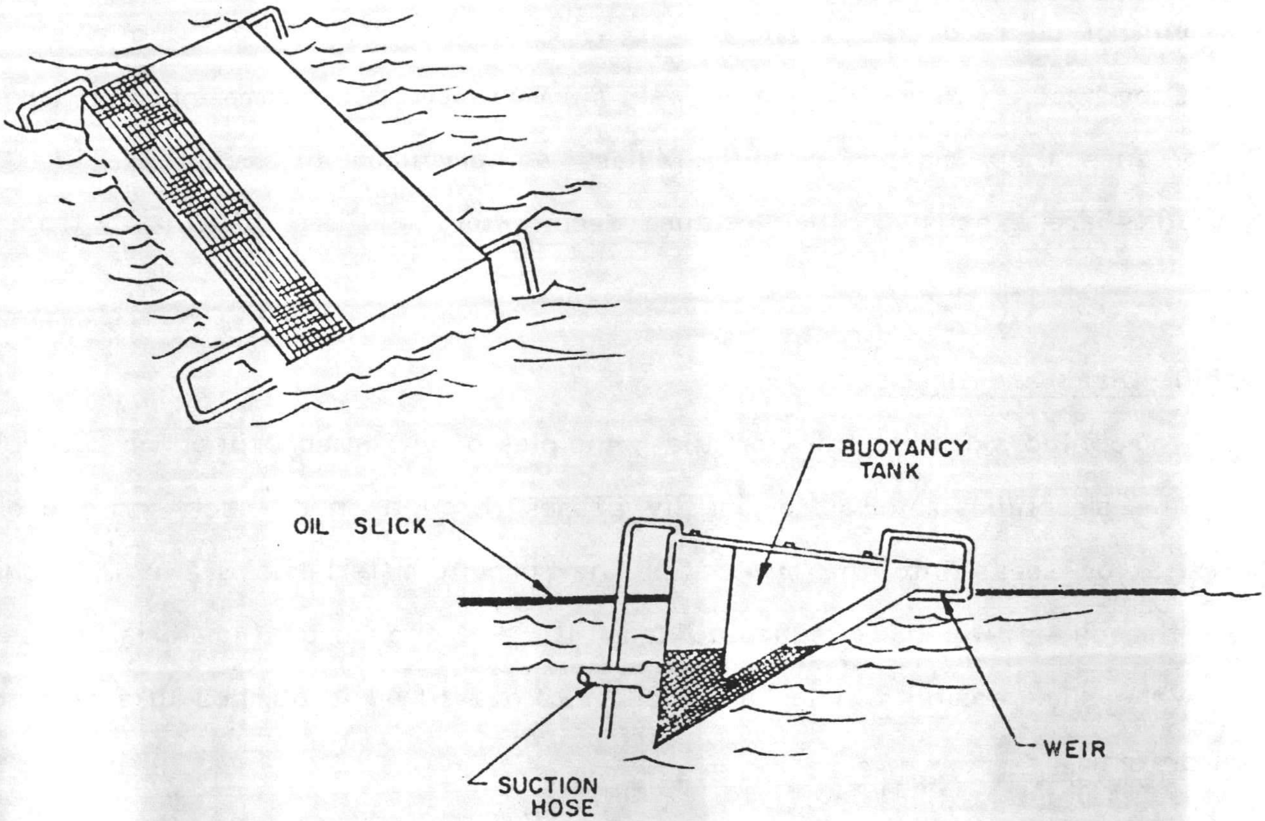


Figure 3. Hydraulically-balanced Floating Weir Skimmer

Possible Advantages	Possible Disadvantages
1. Good oil recovery efficiency	1. Cannot work in as shallow water as some units
2. Portable	2. Not good in waves and currents
3. Relatively inexpensive	
4. Hydraulic control efficiency	
5. Hydrodynamically balanced	

The primary disadvantage of weir skimmers is that their recovery capacities are limited by the relatively small surface areas of weirs. To reduce the amount of water taken in, the rate of recovery must be slowed down even more. Another drawback is that debris collecting around the edge of a weir drastically reduces the amount of oil recovered. The debris acts as a dam for the oil and must be removed for best efficiency. Floating weir skimmers are not recommended in large units because their manpower and auxiliary equipment requirements are great. Large units are expensive, they require deep water, and are difficult to transport.

Oleophilic Disks and Drums

All oleophilic skimmers work on the principles of either absorption or adsorption. The oleophilic material continually passes through an oil slick and the oil adheres to or soaks into the material. The sorbent material is drawn from the water, the oil is wiped or squeezed from it, and the sorbent material passes through the slick again to collect more oil. Recovered oil is pumped to a holding vessel or tank.

Some of the early oleophilic disk/drum skimmers (Fig. 4) were used sparingly because they were difficult to transport, worked poorly in very shallow water, and had some problems with debris clogging. However, new designs have eliminated most of these problems, and the newer skimmers work much better than their predecessors.

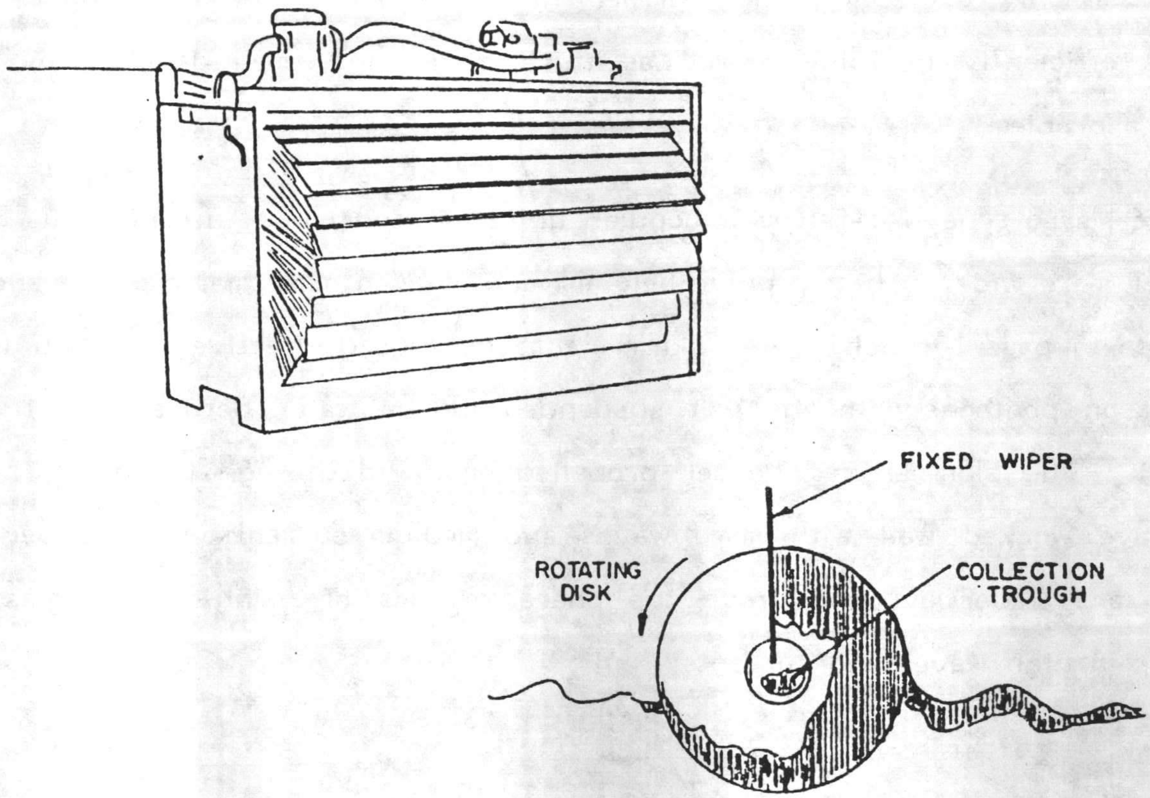


Figure 4. An Oleophilic Disc Skimmer

Possible Advantages

1. Good oil recovery efficiency
2. Can be operated relatively unattended
3. Available in a range of sizes

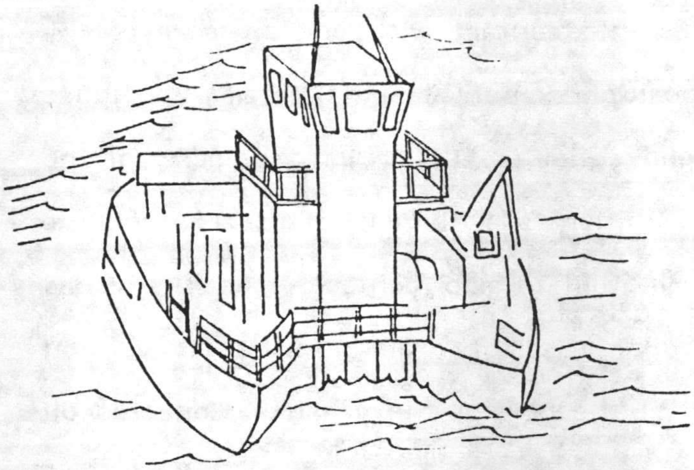
Possible Disadvantages

1. May perform poorly in high waves and currents
2. Large units may be awkward to move
3. Highly mechanical (complex machinery)
4. Often requires outside power source
5. Often relatively expensive

Oleophilic Belts and Rope

A commonly used oleophilic skimmer for oil spills is the fabric belt. It operates efficiently in thin as well as thick slicks and small debris does not present a problem.

The Marco-type skimmer is a popular unit that consists of a continuous belt a foot or more wide. The oleophilic belt is made of open mesh material and allows the water to pass through. This skimmer has been used effectively by mounting the unit on pontoons with the belt suspended in the water between the floats (Fig. 5). The skimmer can be self-propelled or towed through the oil. These units have worked well with some waves and medium currents. A number of projects are underway to improve the characteristics of using these types of skimmers in high waves and currents.



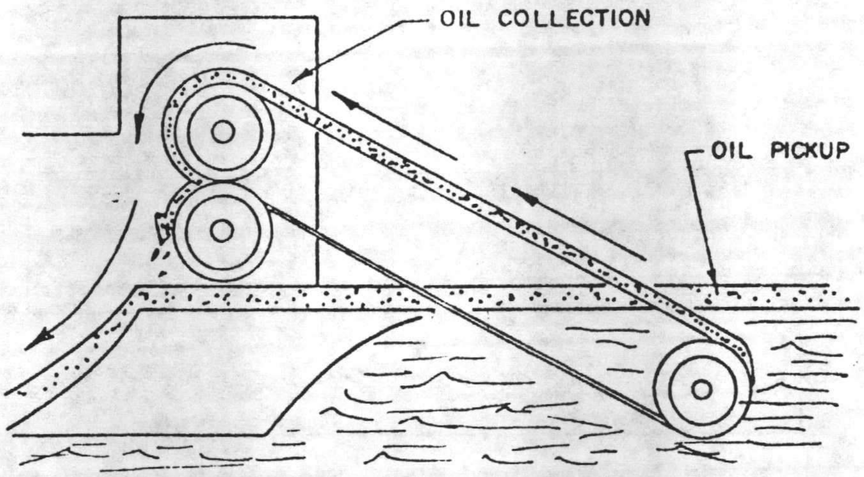


Figure 5. Oleophilic Belt Skimmer

Possible Advantages	Possible Disadvantages
1. High oil recovery efficiency	1. Not for close quarters work
2. Wave-dampening characteristics	2. Relatively expensive
3. Good trash handling	3. Must replace belt occasionally
4. Available in a range of sizes	4. Shallow water limitations
5. Maneuverable in self-propelled form	5. May require several trained personnel
6. Ordinarily in self-propelled form	6. Storage and maintenance costs may be high

The Oil Mop Dynamic Skimmer (Fig. 6) is a self-propelled catamaran approximately 38 feet long and 12 feet wide. As the oil slick passes into the space between the two catamaran hulls, it comes into contact with one or more of the six floating adsorbent ropes that are positioned between the catamaran hulls. These ropes are rotated forward at a speed equal to the forward velocity of the skimmer so that a zero relative velocity condition is achieved. This zero relative velocity condition reduces turbulance during oil-to-mop contact. As the ropes collect the oil they are drawn over a roller assembly, along a flat tray, and squeezed clean of oil by a wringer located at the bow of the vessel. Collected oil is offloaded by positive displacements pumps.

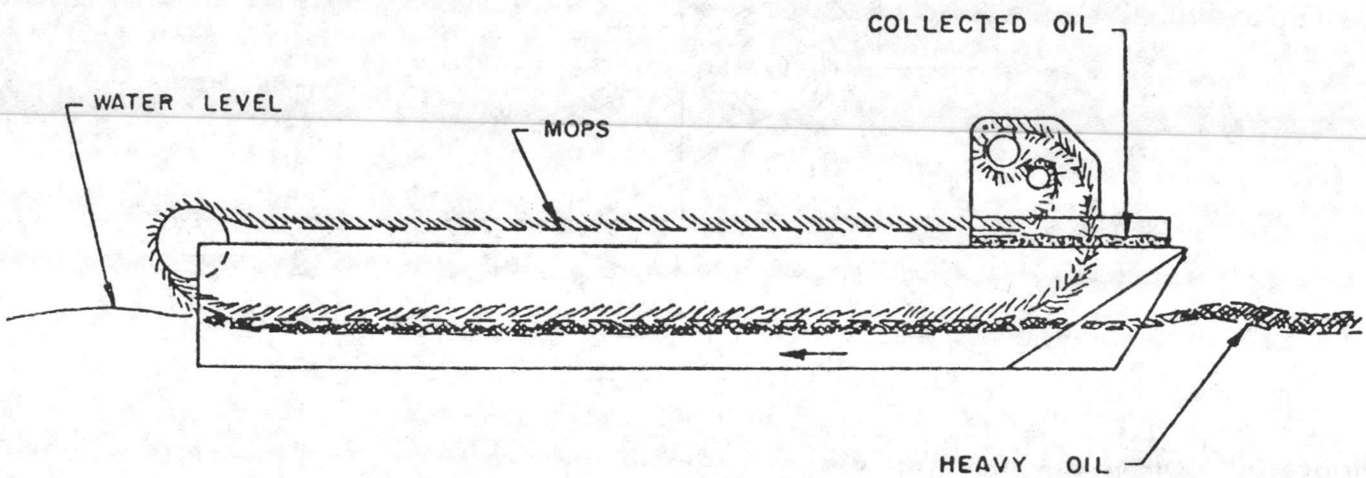


Figure 6. Oil Mop Dynamic Skimmer

Clean Bay owns a large self-propelled, two-belt Marco skimmer. This unit has lights for night operation, platforms for workers to fend off debris, plastic bags to catch small debris that is taken up by the belts, and tanks for recovered oil. The skimmer is powered by two diesel engines. There are radios and radar aboard. Oleophilic rope mop systems (Fig. 7) are available in a wide range of sizes with the smallest 55 gallon drum-mounted unit having a recovery rate of between 6-8 barrels per hour.

Larger units are capable of recovering up to 800 barrels per hour and can handle 3000 to 5000 feet of rope mop. The machines that propel and squeeze the rope mop can be driven by gasoline, electric, pneumatic, or diesel engines and can be fitted with various recovered oil storage tank capabilities. The floating tail pulley or shive can be anchored, tied to a tree or, when offshore, carried by a second vessel. Characteristically, these systems have a relatively high oil-water recovery efficiency. The ability to change the length of rope mop (which requires ten minutes) and to change the configuration of the rope by maneuvering the tail pulleys are important advantages of this system.

The units can operate in debris, shallow water, marshes, beneath ice, on ice, or even in sewers. Their portability allows good response time over large areas since they can be operated by one person.

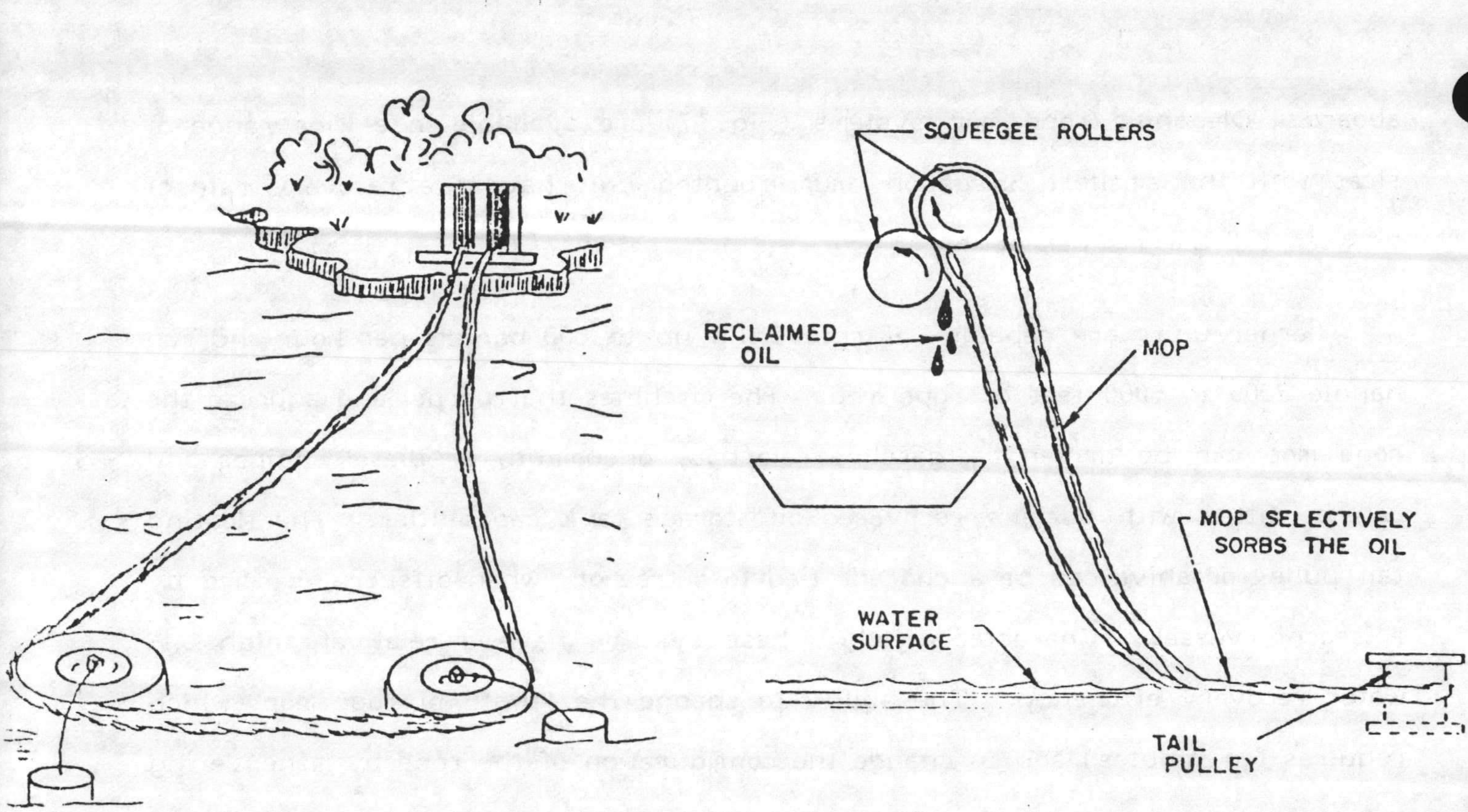


Figure 7. Oleophilic Rope Skimmer

Possible Advantages

1. High recovery rates with low labor factor
2. Effective in shallow water
3. May act as a boom
4. Works in currents when angled properly
5. Handles wide range of viscosities
6. Little water recovered
7. Non-debris fouling
8. Can be maneuvered easily by adjusting tail pulleys

Possible Disadvantages

1. Can recontaminate shore unless plastic material is placed under rope mop
2. Occasional replacement of rope mop is necessary
3. Possible safety hazard
4. Relatively fixed
5. Rope can twist in currents unless multiple tail pulleys are used

Hydrodynamic Inclined Plane

This skimmer consists of an inverted endless belt designed to carry the oil beneath the surface as the skimmer is maneuvered into the oil. The oil will leave the belt at the bottom and float upward into a collection well to be pumped away to recovery (Fig. 8).

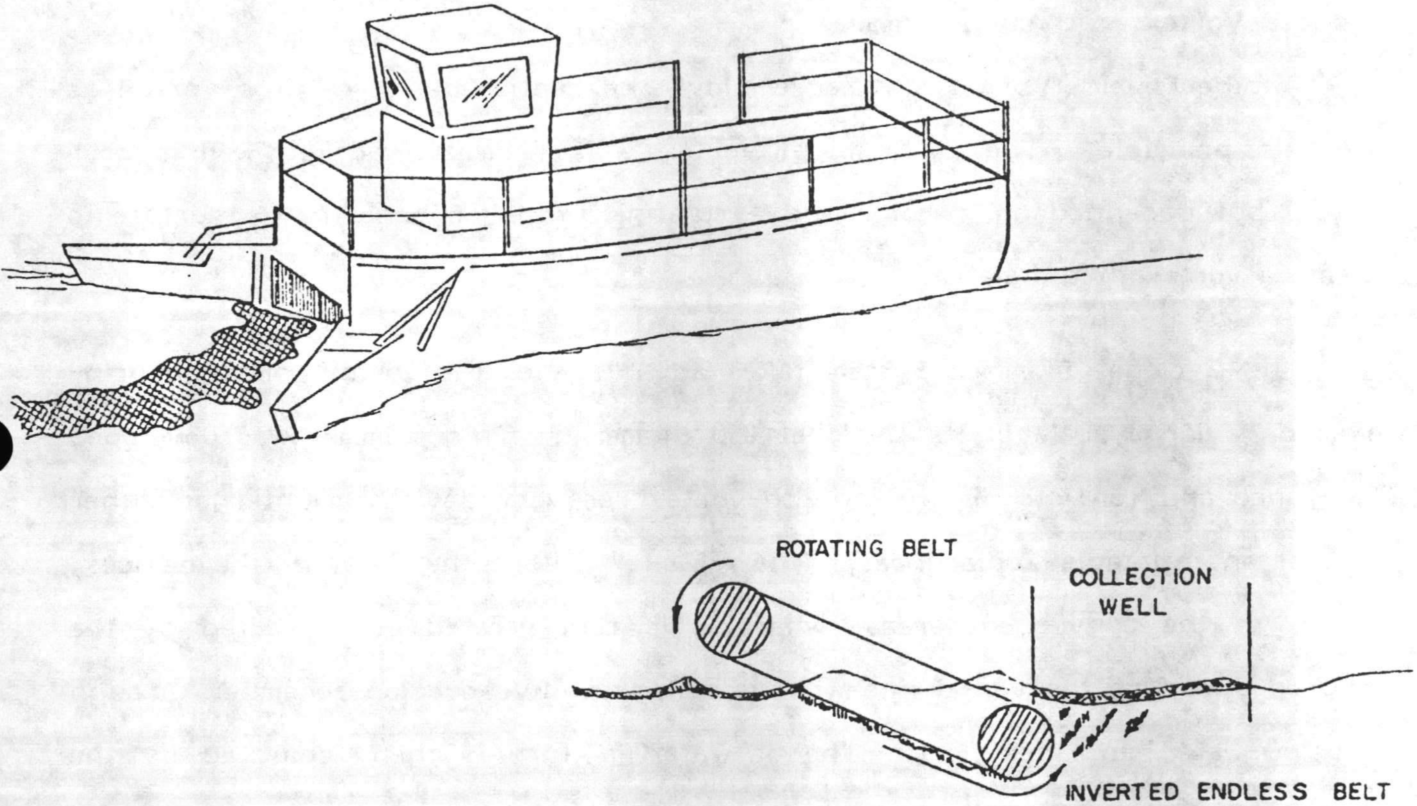


Figure 8. Hydrodynamic Inclined Plane Skimmer

Possible Advantages

1. High oil recovery efficiency
2. Range of sizes
3. Maneuverable in self-propelled form
4. Ordinarily in self-propelled form

Possible Disadvantages

1. Poor trash handling capabilities
2. Relatively expensive
3. Slow deployment speed

Possible Advantages (continued)

5. Low manpower requirements
6. Operates in high sea states
7. Can be transported by truck
8. Will remove sheens
9. Will pick up gasoline

Induced Vortex or Cyclone Skimmers

Another basic type of skimmer employs the centrifugal force of a vortex as its main principle. The early model vortex weir skimmers worked well in calm water, but depended on a motor and a rotating propeller beneath the surface to create a vortex in the water.

The Cyclonet Skimmer System takes advantage of the vortex collection principle on a large scale in its Cyclonet 050 Skimmer. This skimmer was developed in France and consists of two induced vortex recovery devices mounted on either side of an inflatable Zodiac boat. The oil slick enters the front of the devices, known as the convergent areas, where it is concentrated and directed by the forward speed of the vessel into what is called the hydrocyclone chamber through a below-water entrance port. The oil-water mixture is then separated by the centrifugal action of the vortex; oil accumulates near the top of the vortex and is pumped to storage tanks while water is expelled through an exit port situated on the hydrocyclone side wall.

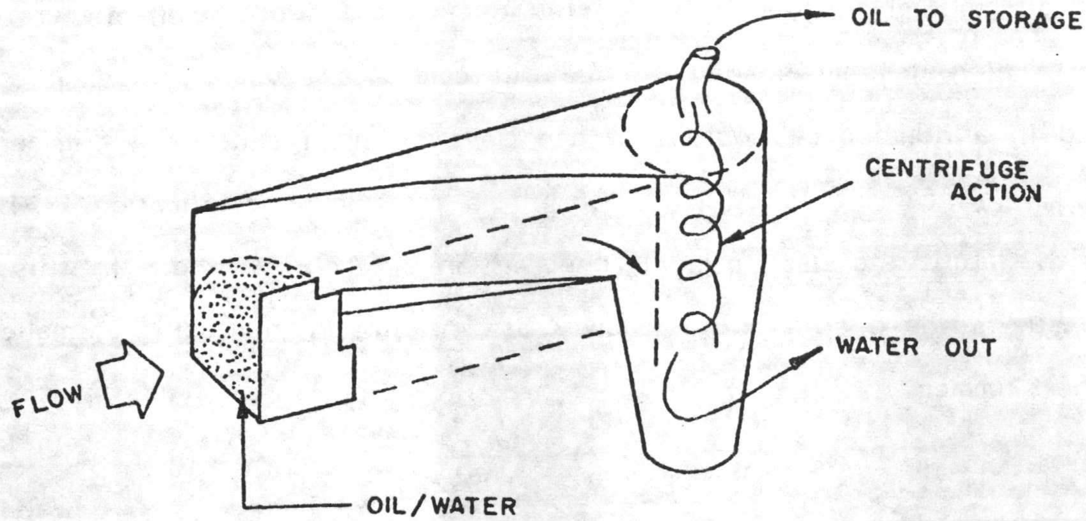


Figure 9. Induced Vortex Skimmer

Possible Advantages

1. Range of sizes
2. Usually self-propelled form
3. Low manpower requirements
4. Simple mechanism principle

Possible Disadvantages

1. Poor performance in high seas
2. Some loss of efficiency at high speeds
3. Expensive
4. Trash may create problems

Other Skimmer Types

Other skimmers have been developed for oil recovery services with varying degrees of success. While a number of these units rely on one or more of the basic principles already outlined, there are some innovative devices that are especially useful in special situations.

The Paddle-wheel skimmer (Fig. 10) is designed to pull oil up a perforated ramp by a rotating paddlewheel assembly. As oil and water are drawn up the ramp, the water settles out and drops through the ramp perforations. The remaining oil-rich mixture is then directed over the top of the incline and into a sump from which it is off-loaded. This unit comes in a variety of sizes and can be applied in a number of modes. It can be used as a stationary skimmer quite successfully and can be towed with boom in a catenary configuration. The unit also has the ability to use boom attached in an encircling mode. In this mode, the boom surrounds a spill and is slowly drawn into an increasingly smaller area toward the skimmer.

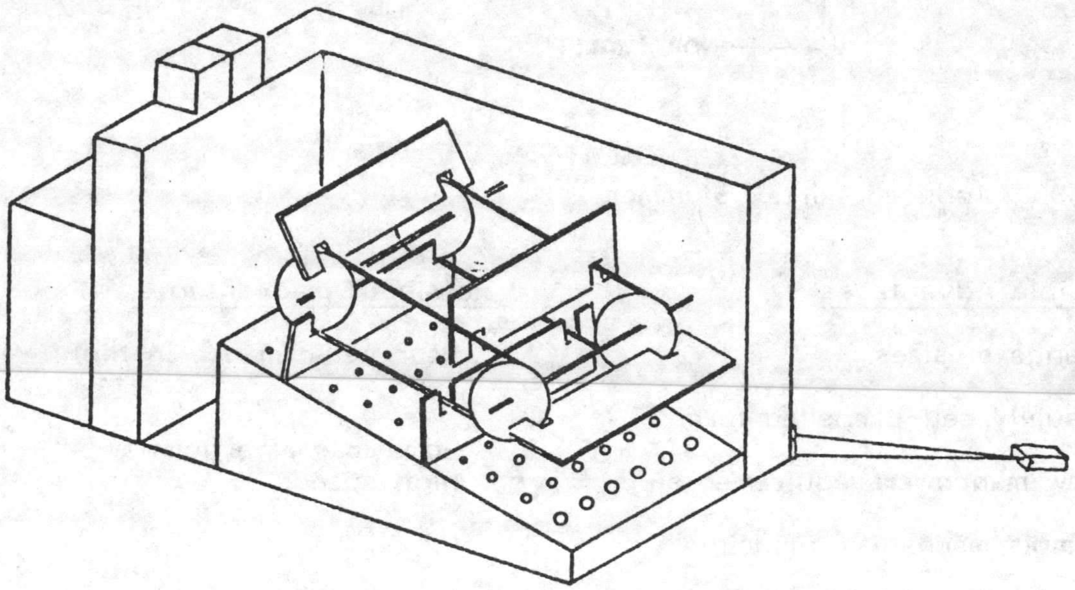


Figure 10. Paddle-wheel Skimming Unit

Possible Advantages

1. High oil recovery efficiency
2. Range of sizes
3. Can be used in a variety of modes
4. Handles debris well

Possible Disadvantages

1. Recovery limited by swift currents or high seas
2. Expensive
3. Exposure of a number of mechanical elements

How to Choose a Skimmer

For ease and efficiency of operation, oil skimmers should meet the following criteria:

1. capable of recovering oil with a wide range of viscosities,
2. able to pass small solids and debris without damage,
3. able to handle air without losing prime,
4. capable of operating in shallow water depths,
5. capable of operating continuously, and
6. simple to operate.

Several factors to consider in selecting a skimmer include:

1. capacity,
2. type of oil most likely to be recovered,
3. frequency of use,
4. ability to handle solids,
5. where the skimmer is to be used (waves, tides, etc.), and
6. ease of handling and maneuvering.

When considering skimmer capacity, one should estimate the probable spill size that could occur. A rule-of-thumb is to choose a skimmer capable of recovering approximately 10 percent of the volume of the average spill each minute. High capacity skimmers such as the Marco type can be bought by cooperatives rather than individual companies. The type of oil that you will most likely be required to recover should affect the choice of skimmer. Very heavy oils are probably more economically recovered with suction heads or floating weirs using conventional positive displacement pumps. It is a good policy to choose a durable skimmer that requires minimum manpower.

Skimmer Systems for Creeks, Rivers, and Estuaries

Although the proper skimmer is important, it is necessary to acquire an adequate skimmer system. The system consists of a skimmer, various hoses, pumps, a separator tank, and recovered oil tank (Fig. 11). With simple systems, a discharge hose provided with flotation collars is connected between the skimmer head and a pump. It is recommended that a positive displacement pump be used to reduce emulsion formation.

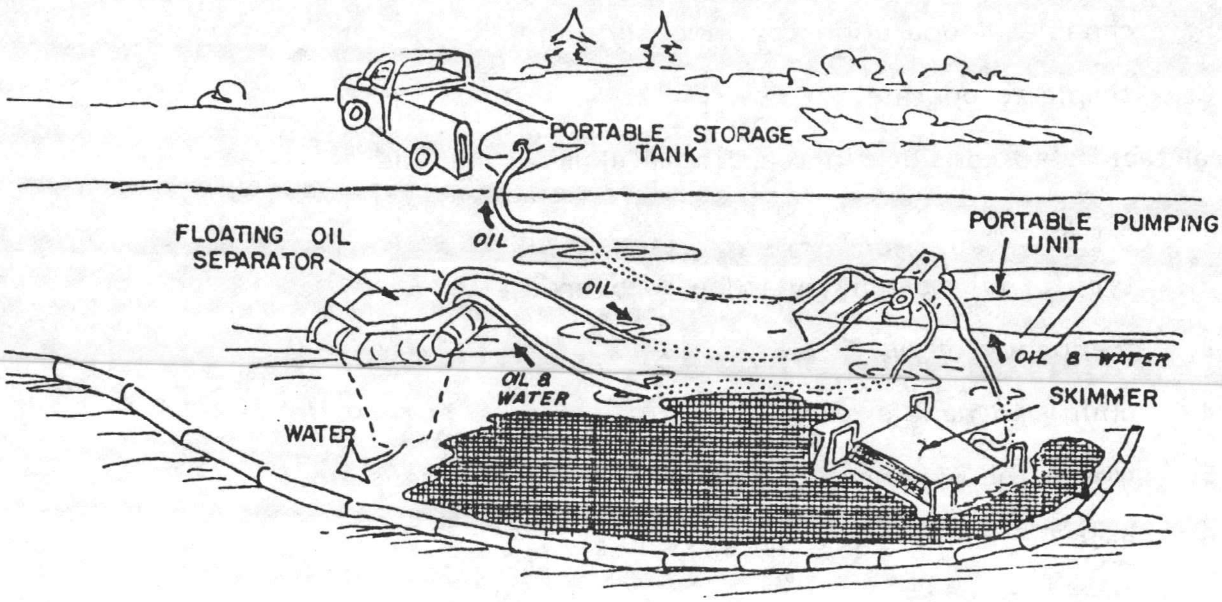


Figure 11. A Typical Skimming System Consisting of a Skimmer, Hose, Pump, Oil-Water, and Recovered Oil Tank

The skimmed mixture is usually pumped to an oil-water separator tank for decanting. A child's backyard swimming pool with an opening cut in the bottom can act as a simple and inexpensive separator unit. Commercially-constructed tanks can also be purchased that float in the water and have an opening in the bottom to permit the water to exit the separator while retaining the oil. As much water should be separated from the oil as possible at the spill site to reduce the amount of water handled by truck.

If a separator is used, a second pump or a manifold on a single pump will transfer the separated oil to a recovered oil tank. If a vacuum truck is used as a recovered oil tank, an extra pump will not be needed. Vacuum trucks can also double as oil-water separators. Be certain that the vacuum truck operators are not merely recovering water. Also, caution should be used when recovering light product spills using vacuum trucks. Any available vessel can act as a recovered oil tank. Some manufacturers sell inflatable tanks. These tanks can be obtained in a variety of sizes, are easy to store when deflated, and are built to withstand heavy duty use.

Skimmers, hoses, pumps, separators, and recovered oil tanks should be compatible. Three and four-inch diameter pumps and hoses are recommended over smaller sizes. If emulsion formation is a problem, vacuum systems or positive displacement pumps should be used. Otherwise, self-priming centrifugal pumps are acceptable. After a new system is purchased, it must be properly maintained and the response team properly trained with the equipment so that the operation of the units and the system will be understood and ready in case of a spill.

Moving Oil To Skimmers

In expediting oil removal from water, several techniques can be used to push the oil to the skimmer. Physical barriers such as mini booms or sorbent booms can be drawn toward the skimmer to pull the oil. These shallow depth devices are used so that oil is not pushed underneath the containment boom. Several passes with the device will be necessary.

Water current producing devices such as water spraying systems, firefighting systems, boat prop wash, and air fans or blowers can be used to push the oil to a skimmer. Water spraying devices can use attached booms to hold thick oil layers. Special care should be taken with firefighting systems and boat prop wash to ensure that oil is not emulsified by water droplets from spray or irregular wave patterns near the spray.

A third technique is chemical herding agents that work on thin slicks, especially oil sheens. Chemical herding agents will cause the oil slick to shrink and become thicker. These agents can interfere with oleophilic skimmers if the chemical herding agent contacts the olephilic belt, disc, or rope directly. The herding agent will keep oil from sticking to the oleophilic surface.

Summary

An assortment of skimmers is useful for oil spill cleanup. Each type has advantages and disadvantages, most skimmers lose oil recovery efficiency as waves and currents increase. Certain skimmer types work well from vessels while other skimmer types work best in confined shoreline areas.

Since most oil slicks contain a certain amount of debris, the pump on the skimming unit should not be susceptible to clogging and should be able to pass small solids without damage. If a skimmer will be used primarily in shallow water, choose a floating suction head or weir-type skimmer. Most types of skimmers will work in deeper waters under calm conditions. A skimming unit should be chosen for its ease of handling in a particular situation. If oil needs to be removed from restricted locations, vacuum skimmers are the best choice. Whatever the type, all skimmers require constant attention.

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DESCRIPTION:

Shoreline protection

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SHORELINE PROTECTION AND RESTORATION

Oil deposited on shorelines is one of the greatest problems of the cleanup crew because of the expense for cleanup and restoration. It has been estimated that up to 50 percent of the total cost for some spills was directly attributed to shoreline restoration. Cleanup cost will depend on the natural and manmade features of the shoreline, changes in water level, weather conditions, distance to disposal sites, and forms of restoration required.

Shoreline Parameters

The energy level is determined by the amount of current and wave action to the shoreline. These actions will influence oil persistence on the shoreline and contamination of other nearby shorelines. High energy shorelines are generally exposed to storm waves and swift currents that can bury or remove large quantities of oily sediments over a short time interval. Low energy shorelines are generally sheltered from wave cutting actions and swift currents. Indicators of high energy shorelines include:

1. Short transition from shallow to deep water
2. Rounded sediment particles
3. Highly sorted shoreline material (i.e., sand, pebbles, cobbles, boulders)

The shoreline access in transporting manpower and equipment to oiled shorelines is a prime consideration in deciding whether cleanup should be initiated. Based on these factors and biological productivity, a shoreline sensitivity index will indicate low to high sensitivity to an oil spill (Table 1).

TABLE 1. SHORELINE SENSITIVITY INDEX FOR OIL SPILLS

1. Exposed rocky shoreline
2. Wave cut platforms
3. Fine grained sand
4. Coarse grained sand
5. Mixed sand and gravel
6. Gravel shores
7. Sheltered rocky shoreline
8. Mud flats
9. Marshes and swamps

Other biological, physical, or cultural characteristics will also influence an area's sensitivity and uniqueness. Biological characteristics include (1) rare, threatened, or endangered species, (2) reserves and preserves, (3) waterfowl concentration areas, (4) mammal and bird rookeries, (5) commercially important species, (6) recreationally important species, and (7) ecologically productive areas (i.e., marshes). Physical characteristics include: (1) high erosion potential areas if disturbed, (2) geologically designated study sites, (3) fossiliferous formations, and (4) mineral-bearing formations. Cultural characteristics include: (1) archaeological study areas, (2) tribal fishing areas, and (3) historical monuments.

Recreation and industrial areas should be considered as to their use by the public. Public opinion can become adverse when favorite boating and swimming areas are fouled, private and public beach fronts are oiled, or private and public services are disrupted. For example, oil in cooling or process water intakes may reduce or totally close an industry. Contaminated domestic and agricultural freshwater supplies can temporarily reduce service in water consumption.

Problems with Shoreline Cleanup

Shoreline cleanup is certainly one of the most visible activities which will invite the press, private citizens, and volunteers to the cleanup site. When these people arrive at the site, company personnel should be assigned to direct the press to designated public relations personnel, and property owners with complaints to a claims person. Volunteers can be told that their help is not required or can be directed to the Coast Guard, EPA, or other government agency. Public relations and claims are covered in a later section. There is nothing wrong with sightseers watching cleanup operations as long as neither they nor their cars get in the way.

Often, operations must be conducted in confined areas where movement is severely restricted. In these cases one or more persons are necessary to direct the traffic of the trucks entering and leaving the shoreline. It is best to have a uniformed officer present to direct traffic where it enters the main road. This person can handle traffic as well as small incidents that may arise between citizens and the company. Off-duty policemen, sheriff's deputies, and constables are usually available for hire. They are trained to handle traffic, know how to handle confrontations, will place the cleanup operations in good stead with the police force, and will usually work for reasonable wages.

Methods to Limit Shoreline Damage

Under ideal conditions, there will be enough time between notification of an oil spill and its reaching the shoreline to take some measures to protect the beaches. Providing the wave action is not excessive, properly placed booms, angled away from the shoreline, will prevent oil from reaching areas that will be difficult and expensive to clean up (Fig. 1). Booms can be commercial or "home made," such as a log, boards, or metal sheeting. Booms angled toward the shoreline can divert oil to a specific area for recovery (Fig. 2). Small points, inlets, and sand bars can be effective recovery areas. Heavy equipment can be used to build temporary dams to block off marshes or swamps from rivers or lakes until the oil threat has passed (Fig. 3).

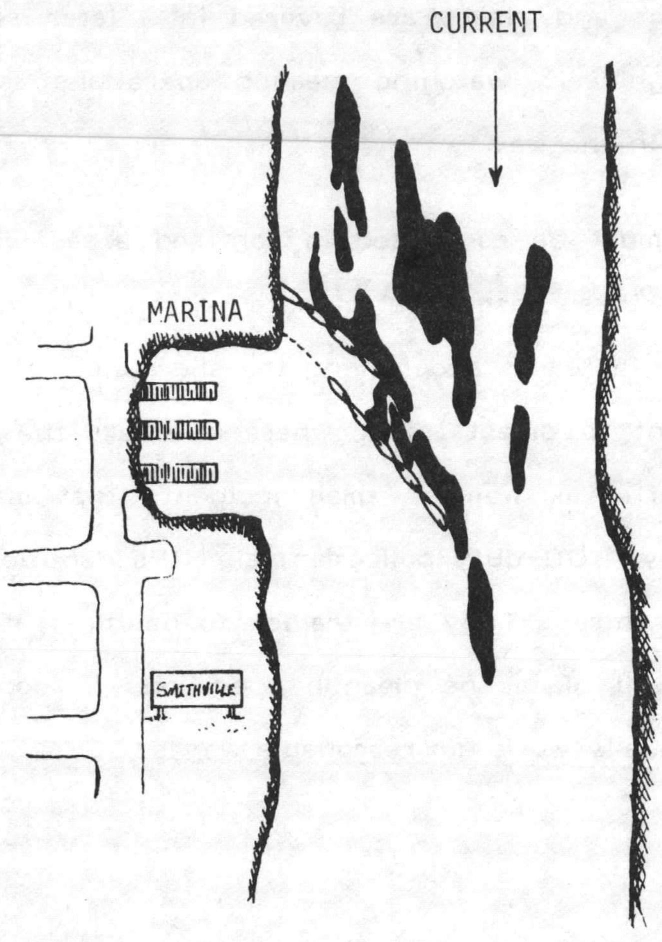


Figure 1. Oil Deflection Booming

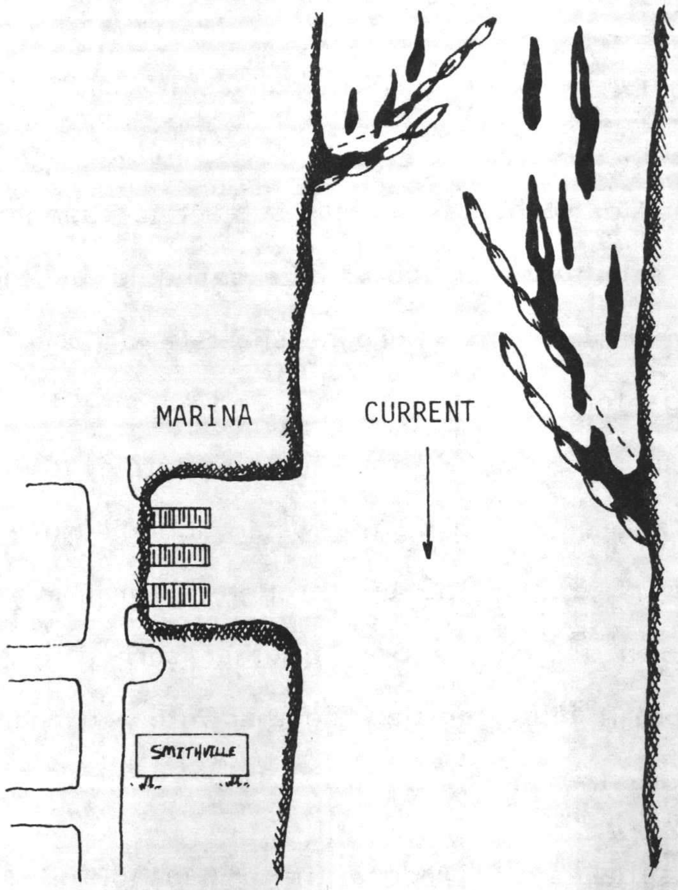


Figure 2. Oil Collection Booming

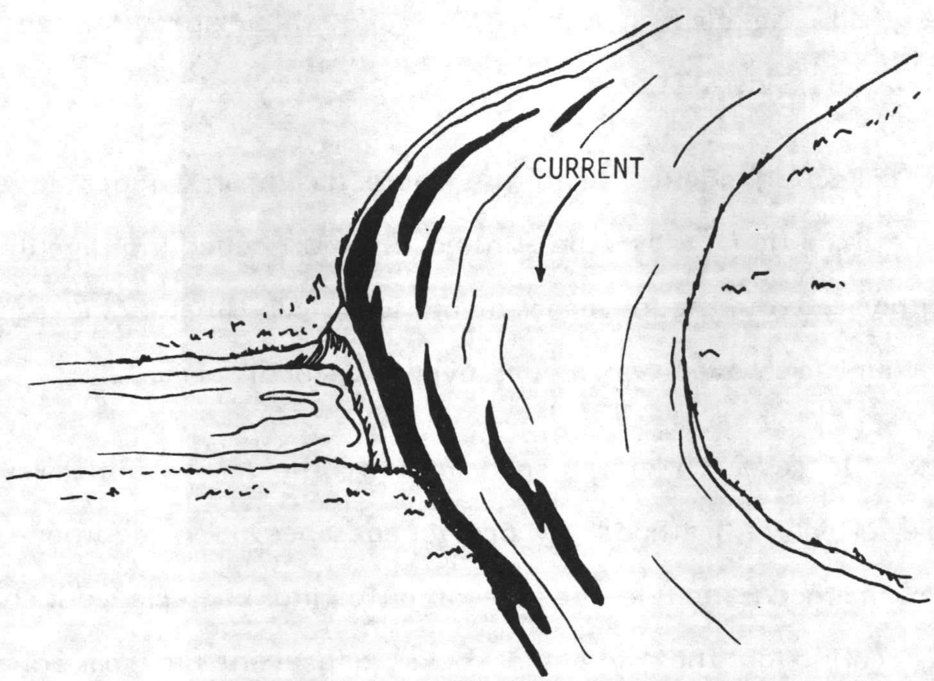


Figure 3. Oil Deflection Damming

Sorbents placed on the beach to sorb the oil as it comes in are useful for rivers or small lakes, but not for open bodies of water subject to breaking waves. For effective usage of sorbents in areas subject to changing water levels, reservoir engineers, soil scientists, or local citizens should be consulted to predict the optimum time for deployment. Sorbent sheets and booms are superior to loose sorbent, which tends to mix with the sand and silt and be carried out into the water, posing recovery problems. To be most effective, the sorbent should be laid along the low-water mark, and as the water and oil move up the beach, the sorbent should be worked into the oil through natural wave action or by mechanical means. Straw should not be used if other sorbents are available. It can be used on shore to limit oiling or tied together into a temporary boom when other materials cannot be secured quickly.

Spraying water on a beach will reduce the amount of oil that adheres to rocks or bulkheads. Water soaked sand beaches will reduce the low penetration of low viscosity oil into pore spaces. Continued water spraying can wash oil off sand, rock, or bulkheads.

Spraying collecting agents along the shore has been suggested as a method to prevent contamination.[1] In the United States, collecting agents cannot be used until authorized by the government on-scene coordinator and can be applied no more than four times every six hours over a 24-hour period.

A considerable research effort sponsored by the API is underway to develop new and more effective methods to protect beaches. In addition to chemical collecting, new methods include the use of oil-eating bacteria and chemical films that spread a coating on the sand and rocks to prevent oil from adhering to the shoreline. This work is still in the development stage.

Beach Restoration

It is desirable to clean up the beach only once, so cleanup operations should be delayed, if possible, until all the oil reaches a beach. However, authorities may expect cleanup to begin as soon as the first of the oil reaches shore.

When oil reaches a shoreline and contaminates the surface, various cleanup methods can be used that should be matched to the limitation of the shore substrate. These methods are:

1. Removal of oil with heavy equipment
2. Removal of oil with manual scraping
3. Evaporation of oil by tilling
4. Water flushing and oil collection
5. Removal of oil with sorbents

Many types of heavy equipment can be used on beaches[2] (Appendix 1 and 2). For long expanses of oiled, sandy beach, it is suggested that a motor grader be used in combination with a self-loading pan. The first step of the procedure is to windrow the oiled sand with the motor grader. Most graders are fitted with narrow tires which will bog the machine down on a sandy beach. This can be solved by fitting the grader with large flotation tires. The pans will have flotation tires and should have little trouble maneuvering on the beach. If this becomes a problem, the pans can reduce the volume of sand carried per trip.

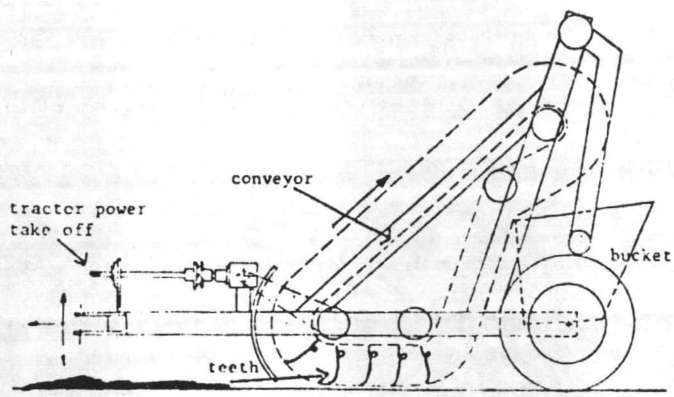
The motor grader-pan combination is considered to be the most efficient method to remove oiled sand. But, standard pans with pushers to help load the material and front-end loaders substituted for pans can also be used. Because the front-end loaders carry less material per trip than pans, a much lower production rate will be achieved. It is best to use rubber-tired front-end loaders because track-mounted loaders are slow and inefficient.

Another type of heavy equipment is the beach cleaner (Fig. 4). They are used on recreation beaches to remove debris that comes ashore. Oil, especially heavy oil, on top of a shoreline can be picked up. Many beach cleaners are towed by a tractor or front-end loader where a rotating blade or drum with blades scoops up surface material onto an inclined plane. Inclined planes can be solid, solid with small holes, or wire conveyor belts. The latter two inclined planes allow loose sand to fall back on the beach. At the end of the conveyor is a container for holding the debris.

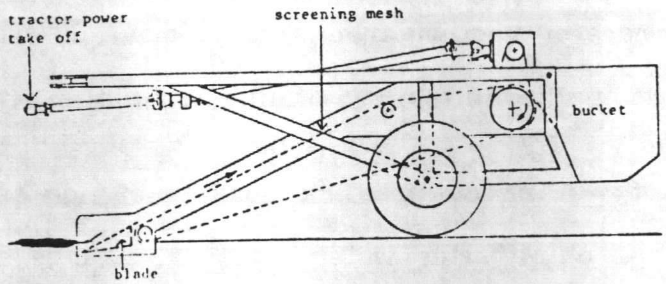
Heavy equipment can be used to remove most of the oily sand or rocks, but hand cleaning will be necessary around rocks, jetties, and marinas. For open beaches where heavy equipment cannot have access, it is suggested that oiled sand, silt, and debris be raked and shoveled by laborers into piles for pickup. Piles can be removed by front-end loaders or by manual labor. This technique removes less sand or gravel than using heavy equipment. Be sure not be remove more sand than is necessary and not to destroy vegetation bordering the beach. Accept slightly oiled spots around vegetation, boulders, and imbedded rocks.

Number 2 fuel oil poses a special problem to beaches because it penetrates deeply and quickly. This condition is best handled by exposing as much contaminated beach sand as possible to the sun and wind to speed evaporation. The oiled sand can be exposed with motor graders or by plowing. After oil removal, sites can be tilled to mix any unrecovered oil into the beach to increase biodegradation.

Moving Teeth



Inclined Blade



Rotating Drum

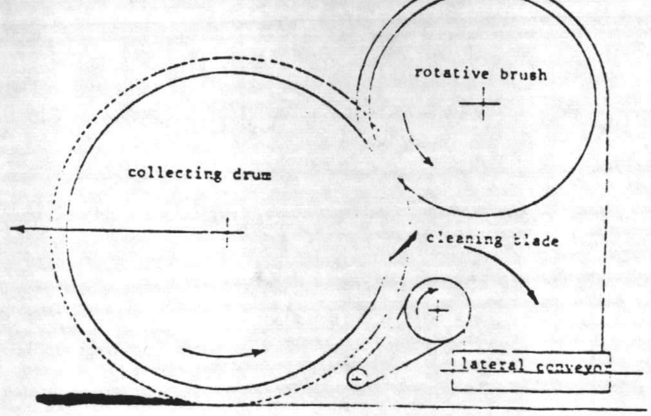


Figure 4. Beach Cleaner Working Principles[3]

Techniques used on gravel, cobbles, or shingle beaches are few. Due to the large pore spaces in the beaches, medium to light oils can penetrate below the surface which hinders cleanup operations. Most heavy equipment and draglines remove massive amounts of beach material.

Water flushing can float oil out of the beach or can drive oil deeper into the beach. Water flushing has been used on mud, sand, gravel, cobbles, and shingle beaches. It is used to remove non-sticky oils. Generally, large amounts of low-pressure water is sprayed on the highest elevation of contaminated beach to wash oil into containment devices. A series of low pressure hoses, perforated pipe, or irrigation sytems can be used to apply water. Berms can be built on the shore to channel the oil to a collection sump (Fig. 5) or booms can be placed just off shore. Skimmers or vacuum trucks can remove oil from the sumps. Test flushing should determine the suitability of this technique before large scale use.

Sorbents are useful at removing thick pockets of non-sticky oil. They can also remove thin sheens of oil after water flushing. Large scale use of sorbents will require sorbents, manpower, and disposal in massive quantities.

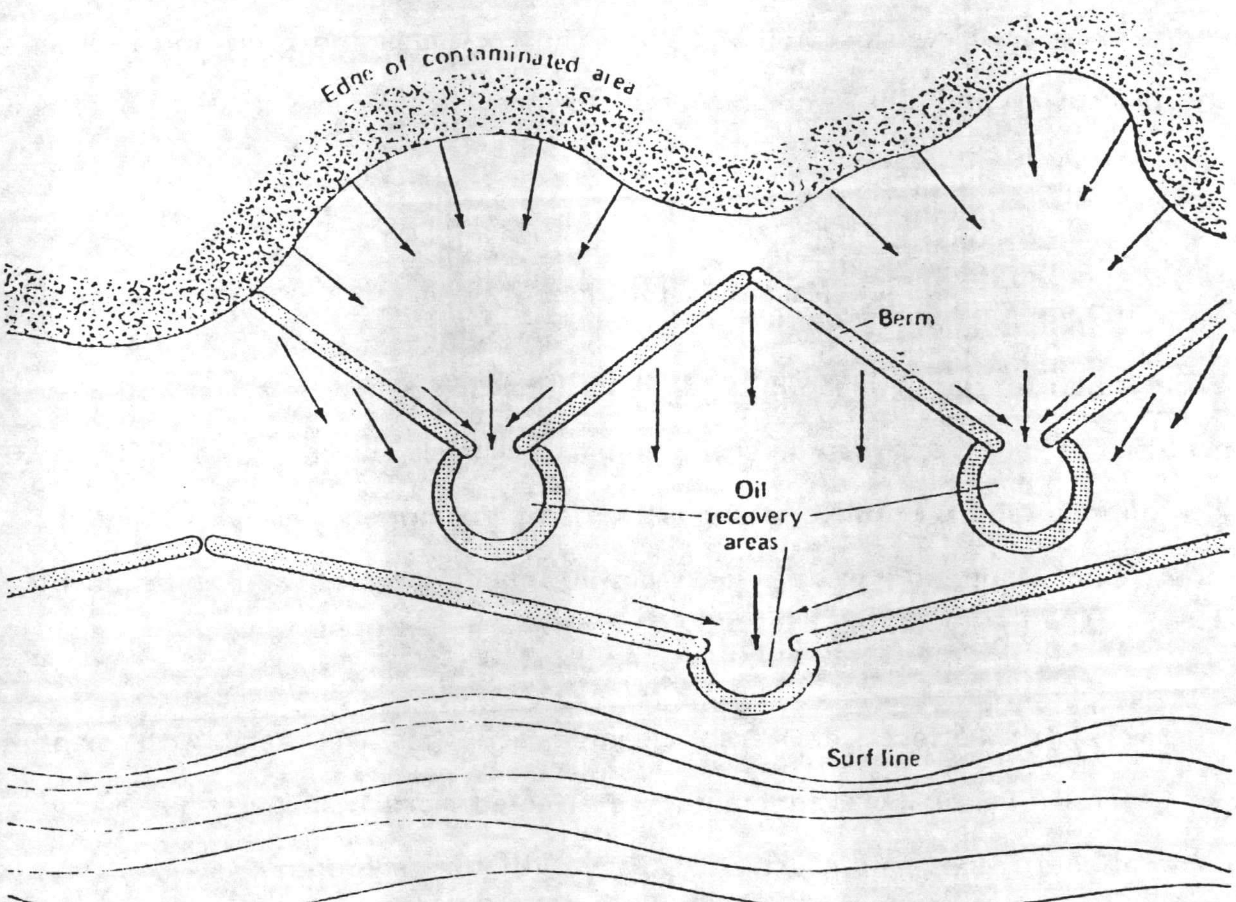


Figure 5. Low Pressure Flushing[5]

Oil Removal From Rocks and Bulkheads

Shoreline restoration often includes the removal of oil from rocks and bulkheads using high pressure water sprays or steam cleaning. High pressure sprays used for this purpose can produce working pressures as high as 10,000 psi and therefore require the operator to wear heavy work clothes, gloves, hard hat, and eye protectors. This is necessary because pieces of rock and oil can ricochet back to the operator. Protective clothing is also used in steam cleaning to protect the operator from the steam and hot water. The processes are slow and expensive; a skimmer crew must follow behind the rock cleaning crew and a boom should be placed around the working area to prevent recontamination of the cleaned area.

Marsh Restoration

The difficulty in marsh cleanup and restoration arises from its susceptibility to change from various factors. A change in water level, water drainage, burning, insect blights, and oil spill cleaning activities can trigger a marsh community change that can result in gradual or massive plant die-offs and subsequent changes.

Furthermore, the effects of marsh cleaning activities will vary with plant species.[4] Generally, annual marsh plants are affected more than perennial marsh plants. The effects from cleanup activities vary with the technique.[5, 6]

Some marsh cleaning techniques are manual or mechanical cutting of plants, use of sorbents, water flushing with skimming, burning, soil removal, and natural recovery. In some cases a combination of techniques are used. Cutting plants to remove oil has been successful after some spills. Although most marsh plants can withstand massive foliage loss from insects or cutting, marsh roots and rhizomes can be severely damaged by foot or vehicular traffic. Loss of plants can increase soil erosion and upset the entire marsh community. Some mechanical harvesters have been modified for marsh cutting and manual cutting from atop boats and plywood sheeting will minimize impact. Soil disturbance when foot traffic is used for sorbent recovery causes oil to penetrate into footprints (sometimes leg prints). In some cases this problem has been diminished by water flooding and skimming. Pumping water to an enclosed marsh and floating the oil to a recovery site does not require foot traffic. However, care should be taken to applying water so that channels are <u>not</u> dug at pump discharge sites. Natural or mineral sorbents may be added at the pumpsite. Sorbents may be collected in screens or from behind barriers. Care should be taken to return the site to its normal water level.

Another alternative is burning. Some marsh grasses are intolerant of burning. Additional problems can arise if the heat of combustion creates more harmful chemicals than the original oil. Another consideration is that even though marsh grasses may die, an increase in open water in a once dense marsh will provide more areas for ducks, herons, or blackbirds. Local authorities should be consulted about the effects of burning on the marsh and nearby human communities.

Cases of soil erosion upon soil removal in marshes are many. Making channels for "easy" oil removal have changed water flow patterns that have changed marsh plant dominance or eliminated marsh plants altogether. This technique is sometimes used for marsh drainage operations. Consult local authorities before removing soil from a marsh.

Small quantities of oil may produce fewer harmful effects than cleanup techniques. For large spills, removing most of the oil and naturally degrading the remaining oil may be a good choice.

Shoreline Revegetation

Revegetation of shorelines will most likely be marshes or mangroves. Many techniques are currently being developed.[7] Some studies are using artificially grown plants and transplanting them into a marsh by tieing the roots to 16-penny nails and sinking the nail into the marsh. Others are hand planting grasses or mangroves or seeds, juvenile plants, or adult plants. In transplanting intolerant marsh or mangrove species, some success has been demonstrated using seeds or plants from areas that have survived previous oil spills.

Termination of Cleanup

The decision to end cleanup activities and allow natural degradation of remaining oil must be made on a case-by-case basis. Generally, shoreline cleanup will terminate when fresh oil contamination is no longer occurring and the remaining oil is immobilized and not a threat to other areas. However, other factors that should be considered are:

1. When environmental damage from cleanup operations is greater than environmental damage from leaving oil in place.

2. When the local environmental expert or OSC agrees to a halt of cleanup activities.

3. When cleanup costs increase significantly while oil removal decreases significantly.

4. When occasional oil spots remain.

5. When public demand for cleanup ends.

6. When cleanup activities interfere with shoreline use more than remaining oil.

Summary

The problems with shoreline protection and restoration are many and vary with the location. The first consideration should be protecting sensitive areas with booms or other water or oil controlling devices. If the oil collects on a shoreline, various techniques can be used to remove the oil. However, the effects of a cleanup activity chosen should be compared as to benefits. Various techniques are suggested for removing oil from beaches, marshes, rocks, and bulkheads. In some cases, the best response may be to allow the site to recover naturally. Considerations for termination of cleanup activities are listed.

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APPENDIX 1. CLEANUP TECHNIQUES

Cleanup Technique	Description	Primary Use of Cleanup Technique	Technique Requirements
1. Motor grader/ elevating scraper	Motor grader forms windrows for pickup by elevating scraper.	Used primarily on sand and gravel beaches where oil penetration is 0 to 3 cm, and trafficability of beach is good. Can also be used on mudflats.	Good trafficability. Heavy equipment access.
2. Elevating scraper	Elevating scraper picks up contaminated material directly off beach.	Used on sand and gravel beaches where oil penetration is 0 to 3 cm. Can also be used on mudflats. Also used to remove tar balls or flat patties from the surface of a beach.	Fair to good trafficability. Heavy equipment access.
3. Motor grader/ front-end loader	Motor grader forms windrows for pickup by front-end loader.	Used on gravel and sand beaches where oil penetration is less than 2 to 3 cm. This method is slower than using a motor grader and elevating scraper but can be used when elevating scrapers are not available. Can also be used on mudflats.	Fair to good trafficability. Heavy equipment access.
4. Front-end loader - rubber-tired or tracked	Front-end loader picks up material directly off beach and hauls it to unloading area.	Used on mud, sand, or gravel beaches when oil penetration is moderate and oil contamination is light to moderate. Rubber-tired front-end loaders are preferred because they are faster and minimize the disturbance of the surface. Front-end loaders are the preferred choice for removing cobble sediments. If rubber-tired loader cannot operate, tracked loaders are the next choice. Can also be used to remove extensively oil-contaminated vegetation.	Fair to good trafficability for rubber-tired loader. Heavy equipment access.

CLEANUP TECHNIQUES

	Cleanup Technique	Description	Primary Use of Cleanup Technique	Technique Requirements
5.	Bulldozer/ rubber-tired front-end loader	Bulldozer pushes contaminated substrate into piles for pickup by front-end loader.	Used on coarse sand, gravel, or cobble beaches where oil penetration is deep, oil contamination extensive, and trafficability of the beach poor. Can also be used to remove heavily oil contaminated vegetation.	Heavy equipment access. Fair to good trafficability for front-end loader.
6.	Backhoe	Operates from top of a bank or beach to remove contaminated sediments and loads into trucks.	Used to remove oil contaminated sediment (primarily mud or silt) on steep banks.	Heavy equipment access. Stable substrate at top of bank.
7.	Dragline or clamshell	Operates from top of contaminated area to remove oiled sediments.	Used on sand, gravel, or cobble beaches where trafficability is very poor (i.e., tracked equipment cannot operate) and oil contamination is extensive.	Heavy equipment access to operating area. Equipment reach covers contaminated area.
8.	High pressure flushing (hydroblasting)	High pressure water streams remove oil from substrate where it is channeled to recovery area.	Used to remove oil coatings from boulders, rock, and man-made structures; preferred method of removing oil from these surfaces.	Light vehicular access. Recovery equipment.
9.	Steam cleaning	Steam removes oil from substrate where it is channeled to recovery area.	Used to remove oil coatings from boulders, rocks, and man-made structures.	Light vehicular access. Recovery equipment. Fresh water supply.

CLEANUP TECHNIQUES

	Cleanup Technique	Description	Primary Use of Cleanup Technique	Technique Requirements
10.	Sandblasting	Sand moving at high velocity removes oil from substrate.	Used to remove thin accumulations of oil residue from man-made structures.	Light vehicular access. Oil must be semi-solid. Supply of clean sand.
11.	Manual scraping	Oil is scraped from substrate manually using hand tools.	Used to remove oil from lightly contaminated boulders, rocks, and man-made structures or heavy oil accumulation when other techniques are not allowed.	Foot access. Scraping tools and disposal containers.
12.	Sump and pump/vacuum	Oil collects in sump as it moves down the beach and is removed by pump or vacuum truck.	Used on firm sand or mud beaches in the event of continuing oil contamination where sufficient longshore currents exist, and on streams and rivers in conjunction with diversion booming.	Heavy equipment access. A longshore current present.
13.	Manual removal of oiled materials	Oiled sediments and debris are removed by hand, shovels, rakes, wheelbarrows, etc.	Used on mud, sand, gravel, and cobble beaches when oil contamination is light or sporadic and oil penetration is slight, or on beaches where access for heavy equipment is not available.	Foot or light vehicular access.
14.	Low-pressure flushing	Low pressure water spray flushes oil from substrate where it is channeled to recovery points.	Used to flush light oils that are not sticky from lightly contaminated mud substrates, cobbles, boulders, rocks, man-made structures, and vegetation.	Light vehicular access. Recovery equipment.

CLEANUP TECHNIQUES

	Cleanup Technique	Description	Primary Use of Cleanup Technique	Technique Requirements
15.	Beach cleaner	Pulled by tractor or self-propelled across beach, picking up tar balls or patties.	Used on sand or gravel beaches, lightly contaminated with oil in the form of hard patties or tar balls.	Moderate to heavy vehicular access. Good trafficability.
16.	Manual sorbent application	Sorbents are applied manually to contaminated areas to soak up oil.	Used to remove pools of light, nonsticky oil from mud, boulders, rocks, and man-made structures.	Foot or boat access. Disposal containers for sorbents.
17.	Manual cutting	Oiled vegetation is cut by hand, collected, and stuffed into bags or containers for disposal.	Used on oil contaminated vegetation.	Foot or boat access. Cutting tools.
18.	Burning	Upwind end of contaminated area is ignited and allowed to burn to downwind end.	Used on any substrate or vegetation where sufficient oil has collected to sustain ignition; if oil is a type that will support ignition, and air pollution regulations so allow.	Light vehicular or boat access. Fire control equipment.
19.	Vacuum trucks	Truck is backed up to oil pool or recovery site where oil is picked up via the vacuum hose.	Used to pick up oil on shorelines where pools of oil have formed in natural depressions, or in the absence of skimming equipment to recover floating oil from the water surface.	Heavy equipment access. Large enough pools on land or thick enough oil on water for technique to be effective.

CLEANUP TECHNIQUES

	Cleanup Technique	Description	Primary Use of Cleanup Technique	Technique Requirements
20.	Push contaminated substrate into surf	Bulldozer pushes contaminated substrate into surf zone to accelerate natural cleaning.	Used on contaminated cobble and lightly contaminated gravel beaches where removal of sediments may cause erosion of the beach or backshore area.	Heavy equipment access. High energy shoreline.
21.	Breaking up pavement	Tractor fitted with a ripper is operated up and down beach.	Used on low amenity cobble, gravel, or sand beaches or beaches where substrate removal will cause erosion where thick layers of oil have created a pavement on the beach surface.	Heavy equipment access. High energy shoreline.
22.	Disc into substrate	Tractor pulls discing equipment along contaminated area.	Used on nonrecreational sand or gravel beaches that are lightly contaminated.	Heavy equipment access. Fair to good trafficability. High energy environment.
23.	Natural recovery	No action taken. Oil left to degrade naturally.	Used for oil contamination on high energy beaches (primarily cobble, boulder, and rock) where wave action will remove most oil contamination in a short period of time.	Exposed high energy environment.

APPENDIX 2. IMPACTS ASSOCIATED WITH CLEANUP TECHNIQUES

Cleanup Technique	Description	Physical Effect of Use	Biological Effect of Use
1. Motor grader/ elevating	Motor grader forms windrows for pickup by elevating scraper.	Removes only upper 3 cm of beach.	Removes shallow burrowing Polychaetes, bivalves, and amphipods. Recolonization likely to rapidly follow natural replenishment of the substrate.
2. Elevating scraper	Elevating scraper picks up contaminated material directly off beach.	Removes upper 3 to 10 cm of beach. Minor reduction of beach stability. Erosion and beach retreat.	Removes shallow and deeper burrowing polychaetes, bivalves, and amphipods. Restabilization of substrate probably slow; recolonization likely to follow natural replenishment of substrate; reestablishment of long-lived indigenous fauna may take several years.
3. Motor grader/ front-end loader	Motor grader forms windrows for pickup by front-end loader.	Removes only upper 3 cm of beach.	Removes shallow burrowing polychaetes, bivalves, and amphipods. Recolonization likely to rapidly follow natural replenishment of the substrate.
4. Front-end loader - rubber-tired or tracked	Front-end loader picks up material directly off beach and hauls it to unloading area.	Removes 10 to 25 cm of beach. Reduction of beach stability. Erosion and beach retreat.	Removes almost all shallow and deep burrowing organisms. Restabilization of the physical environment slow; new faunal community could develop.
5. Bulldozer/ rubber-tired front-end loader	Bulldozer pushes contaminated substrate into piles for pickup by front-end loader.	Removes 15 to 50 cm of beach. Loss of beach stability. Severe erosion and cliff or beach retreat. Inundation of backshores.	Removes all organisms. Restabilization of substrate and repopulation of indigenous fauna is extremely slow; new faunal community could develop in the interim.

IMPACTS ASSOCIATED WITH CLEANUP TECHNIQUES

Cleanup Technique	Description	Physical Effect of Use	Biological Effect of Use
6. Backhoe	Operates from top of a bank or beach to remove contaminated sediments and loads into trucks.	Removes 25 to 50 cm of beach or bank. Severe reduction of beach stability and beach retreat.	Removes all organisms. Restabilization of substrate and repopulation of organisms is extremely slow; new faunal community could develop in the interim.
7. Dragline or clamshell	Operates from top of contaminated area to remove oiled sediments.	Removes 25 to 50 cm of beach. Severe reduction of beach stability. Erosion and beach retreat.	Removes all organisms. Restabilization of substrate and repopulation of indigenous fauna is extremely slow; new faunal community could develop in the interim.
8. High-pressure flushing (hydroblasting)	High pressure water streams remove oil from substrate; oil is channeled to recovery area.	Can disturb surface of substrate.	Removes some organisms and shells from the substrate, damage to remaining organisms variable. Oil not recovered can be toxic to organisms downslope of cleanup activities.
9. Steam cleaning	Steam removes oil from substrate where it is channeled to recovery area.	Adds heat (> 100°C) to surface.	Removes some organisms from substrate but mortality due to the heat is more likely. Empty shells remaining may enhance repopulation. Oil not recovered can be toxic to organisms downslope of cleanup activities.
10. Sandblasting	Sand moving at high velocity removes oil from substrate.	Adds material to the environment. Potential recontamination, erosion, and deeper penetration into substrate.	Removes all organisms and shells from the substrate. Oil not recovered can be toxic to organisms downslope of cleanup activities.

IMPACTS ASSOCIATED WITH CLEANUP TECHNIQUES

Cleanup Technique	Description	Physical Effect of Use	Biological Effect of Use
11. Manual scraping	Oil is scraped from substrate manually using hand tools.	Selective removal of material. Labor-intensive activity can disturb sediments.	Removes some organisms from the substrate, crushes others. Oil not removed or recovered can be toxic to organisms repopulating the rocky substrate or inhabiting sediment downslope of cleanup activities.
12. Sump and pump/vacuum	Oil collects in sump as it moves down the beach and is removed by pump or vacuum truck	Requires excavation of a sump 60 to 120 cm deep on shoreline. Some oil will probably remain on beach.	Removes organisms at sump location. Potentially toxic effects from oil left on the shoreline. Recovery depends on persistence of oil at the sump.
13. Manual removal of oiled mate-ials	Oiled sediments and debris are removed by hand, shovels, rakes, wheelbarrows, etc.	Removes 3 cm or less of beach. Selective. Sediment disturbance and erosion potential.	Removes and disturbs shallow burrowing organisms. Rapid recovery.
14. Low-pressure flushing	Low-pressure water spray flushes oil from substrate and is channeled to recovery points.	Does not disturb surface to any great extent. Potential for recontamination.	Leaves most organisms alive and in place. Oil not recovered can be toxic to organisms downslope of cleanup.
15. Beach cleaner	Pulled by tractor or self-propelled across beach picking up tar balls or patties.	Disturbs upper 5 to 10 cm of beach.	Disturbs shallow burrowing organisms.
16. Manual sorbent application	Sorbents are applied manually to contaminated areas to soak up oil.	Selective removal of material. Labor intensive activity can disturb sediments.	Foot traffic may crush organisms. Possible ingestion of sorbents by birds and small mammals.

IMPACTS ASSOCIATED WITH CLEANUP TECHNIQUES

Cleanup Technique	Description	Physical Effect of Use	Biological Effect of Use
17. Manual cutting	Oiled vegetation is cut by hand, collected, and stuffed into bags or containers for disposal.	Disturbs sediments because of extensive use of labor; can cause erosion.	Removes and crushes some organisms. Rapid recovery. Heavy foot traffic can cause root damage and subsequent slow recovery.
18. Burning	Upwind end of contaminated area is ignited and allowed to burn to downwind.	Causes heavy air pollution; adds heat to substrate, can cause erosion if root system damaged.	Kills surface organisms caught in burn area. Residual matter may be somewhat toxic (heavy metals).
19. Vacuum trucks	Truck is backed up to oil pool or recovery site where oil is picked up via vacuum hose.	Some oil may be left on shoreline or in water.	Removes some organisms. Potential for longer-term toxic effects associated with oil left on the shoreline. Recovery depends on persistence of oil left in the pools.
20. Push contaminated substrate into surf	Bulldozer pushes contaminated substrate into surf zone to accelerate natural cleaning.	Disruption of top layer of substrate; leaves some oil in intertidal area. Potential recontamination.	Kills most of the organisms inhabiting the uncontaminated substrate. Recovery of organisms usually more rapid than with removing substrate.
21. Break up pavement	Tractor fitted with a ripper is operated up and down beach.	Disruption of sediments. Leaves oil on beach.	Disturbs shallow and deep burrowing organisms.
22. Disc into substrate	Tractor pulls discing equipment along contaminated area.	Leaves oil buried in sand. Disrupts surface layer of substrate.	Disturbs shallow burrowing organisms. Possible toxic effects from buried oil.

IMPACTS ASSOCIATED WITH CLEANUP TECHNIQUES

Cleanup Technique	Description	Physical Effect of Use	Biological Effect of Use
23. Natural recovery	No action taken. Oil left to degrade naturally.	Some oil may remain on beach and could contaminate clean areas.	Potential toxic effects and smothering by the oil. Potential incorporation of oil into the food web. Potential elimination of habitat if organisms will not settle on residual oil.

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Containment and

Recovery of Oil in Ice

and Snow

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CONTAINMENT AND RECOVERY OF OIL IN ICE AND SNOW

Spills In Water With Thin Ice

The primary concern with oil recovery where ice is involved is personnel exposure due to extreme weather conditions which can cause frostbite, loss of limb, or loss of life. This threat along with the possibility of sudden weather deteriorization makes oil containment and recovery particularly hazardous. Therefore, it is recommended that individuals working on or near icy waters have safety lines connected from themselves or their lifejackets to a buddy who can pull a fallen buddy from the water. Additional cold weather survival gear, such as a warming house to limit exposure and a helicopter for emergency response, should be available at the cleanup site.

Another concern with oil recovery is the oil's movement. Oil spreading rates in cold weather are less than oil spreading rates in warm weather. Those oils that are semi-solid or solid at 0°C will not spread significantly (i.e., Bunker C, heavy crude).

Oil in water with thin ice will move similar to oil in water. However, where currents are involved, oil movement will be slower where ice is encountered. Dark colored oil may be visible beneath thin ice to aid in locating the oil, but light colored oils, such as diesel or gasoline, may be difficult to observe under ice.

Containment techniques are the same as for oil in water. Although a thin ice sheet can be manipulated to aid in oil containment. The ice can be broken so that the ice ridge acts as an oil barrier in no current situations or can be broken at an angle to the current to act as a deflection device in a current. At the recovery site, a boom or other oil barrier should be used.

Oil can be recovered with either vacuum trucks or skimmers. The major problem with these is ice debris. The use of screens and the skimmer types chosen (see skimmer section) can reduce the severity of this problem. One particularly useful skimmer has been the rope mop skimmer. At subfreezing temperatures, diesel is recoverable with these skimmers. However, for higher viscosity oils, such as Bunker C, hot water baths can be used to remove oil from the mop.

Another potential problem can be the pumps used with skimmers. Once started, a pump should be run continuously to prevent freeze-up of product in hosing. Since draining of pumping systems may not be feasible in freezing temperatures, antifreeze solutions should be added into the pump intake when a pump is not running. When a product is moving through the hose, product warmers, which heat the product, or insulation placed below the hose (i.e., sorbent roll) can be used to keep the product moving. Since products under ice are near freezing temperature, subfreezing temperature above the ice surface can change the pumpability of products recovered. In some spills, bucket lines have been used to transport recovered oil from the skimmer to tank trucks when product in hosing has solidified.

Spills In Water Covered With Thick Ice

Oil can combine with thick ice in several ways to slow or stop its movement. Oil spilled on ice can stay on the surface or penetrate channels and cracks in the ice. Experiments with this phenomenon have recorded that as much as 25 percent of the crude oil spread on ice was absorbed in the ice. In sea water, brine channels form where salt is expelled from the ice. Generally, salt water is 31 parts per thousand (ppt) or less in salinity. However, first year ice is around 10 ppt in salinity, and as ice ages salinity decreases. These brine channels can allow surface oil to rise to the surface. Oil under ice can be trapped in sub-surface ice pockets or cavities. If the temperature decreases, oil will become encapsulated in the ice as the surrounding ice freezes. Oil under or encapsulated in ice can penetrate small channels that form as the ice freezes and melts to form surface melt pools. This process is accelerated when the dark oil under the ice surface absorbs radiant energy from sunlight. This can cause the ice to melt, forming more channels. Experiments have demonstrated that oil under ice can flow into channels to a height of 15 cm (5.9 in) above the water, containing about 5 percent of the spilled oil.

The use of sophisticated aerial photography for detecting oil under ice has been unsuccessful or impractical; and although the use of radar and acoustic techniques have shown promise, they need more research and refinement. The most widely used technique for finding oil under thick ice involves waiting for the oil to appear on the water surface or drilling test holes through the ice and waiting for the oil to surface.

In a current, oil movement can be predicted by assuming that the oil will move at the current velocity. However, the oil will usually move slower than the current velocity due to its contact with the ice. When oil does move in a current, hydrocarbon monitors, explosimeters, or "sniffers" can detect the presence of oil in test holes, ice leads, or other ice openings.

Other techniques that have been used in clear water are the use of underwater divers who can monitor the ice under surface for oil. The major difficulties with these two techniques are their inability to maneuver in fast currents and the expenses incurred.

A less expensive technique used when ice is clear or translucent is using lights lowered beneath the ice to reveal oil shadows cast through the ice when dark. Darkness will occur naturally at night or can be created using large black plastic sheeting over the ice during the day. The oil in the shadows should be confirmed by drilling an auger hole. Liquid can be removed from the hole to check for oil, or gas can be sampled with a hydrocarbon monitor for oil vapors.

When oil is found, the area should be marked, as additional snowfall can obscure a site and delay the cleanup response. Finding an unmarked site from memory will be difficult, as the site's physical characteristics may be changed by snowfall.

Before any oil spill control technique is initiated on ice, the ice thickness should be determined by drilling as many test holes through the ice as necessary. The weight bearing capacity of the ice should be checked, and other previously mentioned safety precautions should be observed.

Choosing a containment and recovery technique will not only depend on ice thickness, but also on the ice type. If ice sheets are rafted (overlapping broken ice sheets), oil may surface between sheets in the openings. However, working on sloping ice sheets that may sink or rise due to the surrounding pressure from other rafted ice can be dangerous.

If access is available to oil contained by rafted ice, burning can be initiated when the oil collects to a minimum depth of five centimeters. Ice can make an effective containment device by holding the burning oil in place and keeping the burning oil from spreading as it does in open water.

The main problems with burning oil are getting the oil to ignite and keeping the oil ignited. Since oil fires are always smokey, health risks are associated with dark colored particulate carbon and soot. They can cool and fall on snow or ice, where these particles readily absorb radiant energy and melt the surrounding ice, causing slippery conditions. If the oil is of high sulfur content, burning will release sulfur dioxide, which can cause respiratory problems for individuals near the smoke. All of these burning products are potential health hazards to surrounding residential areas, as smoke from oil fires has been carried 50 miles or more from the oil burning sites.

In areas where ice is relatively flat and stationary, oil can be contained with a number of subsurface barriers. One simple oil barrier can be made by cutting a thin slot in the ice and placing plywood or some similar barrier through the slot. Subsequent freezing will hold the material in place. These barriers should be placed at a 30° angle to the current to divert the oil to a recovery point near the shoreline (Fig. 1).

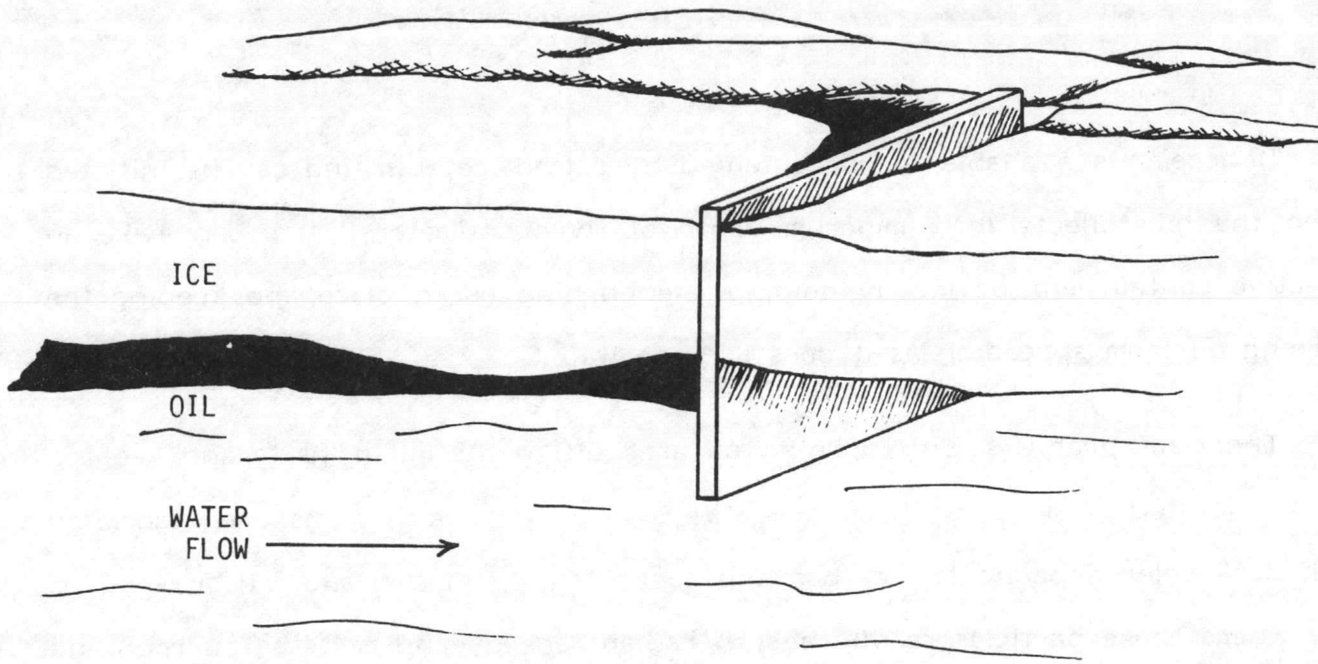

Figure 1. Subsurface Barriers

Barriers can also be constructed by simply using water on first year ice. This can be accomplished by adding water to the upper ice surface where it will quickly freeze. The added weight causes the ice to sink, forming a barrier (Fig. 2). Since the ice thickness varies due to temperature, the subsurface ice will melt slowly. Adding more water to the surface can quickly minimize the problems with subsurface ice melt.

Using the principle of ice thickness, response to temperature pockets or troughs in subsurface ice can be made by applying insulation to the ice surface (Fig. 3). However, do not expect the subsurface ice to melt rapidly.

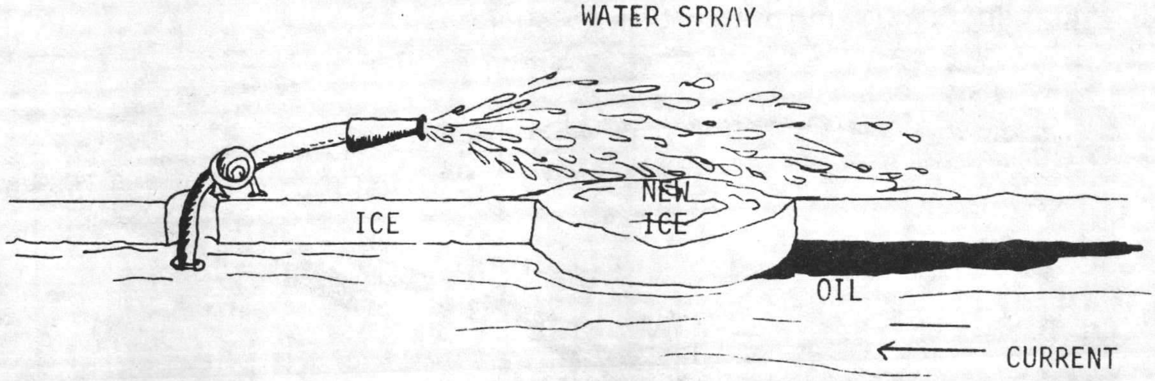

Figure 2. Ice Barrier

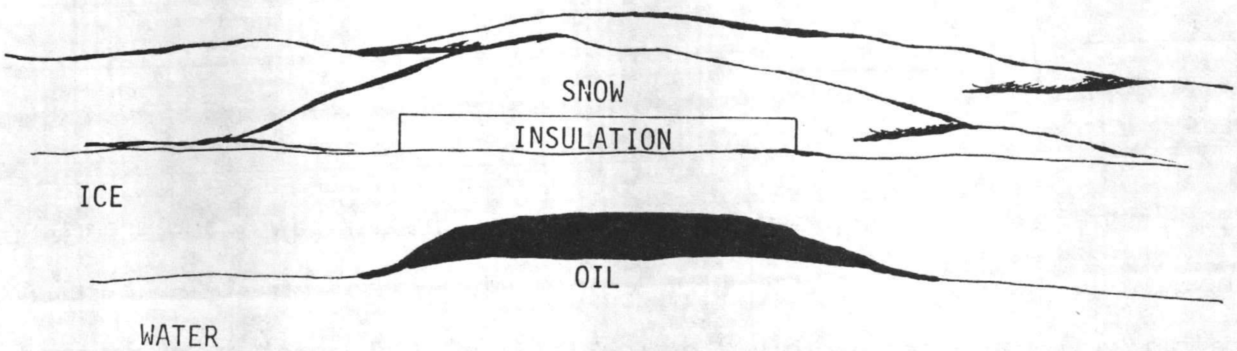

Figure 3. Ice Trough

Auger holes and slotting can also be used in conjunction with subsurface barriers or simply by themselves. These techniques allow oil to come to the surface waters. Since surface water will freeze, continued ice removal is required. Auger holes work best in stationary oil deposits. Care should be taken in coastal areas and in entrapped oil pockets where pressure from tidal action and ice crystal growth (respectively) can cause pressures under the ice, and force oil and water to spurt out of newly cut holes. In stationary or flowing waters, slots can be used. Slots cut in the ice above flowing water should be placed at angles up to 30° to the current to force contained oil to a recovery site (Fig. 4). Typically slots are one and a half times the ice thickness. This width allows oil caught in the flowing water time to surface.

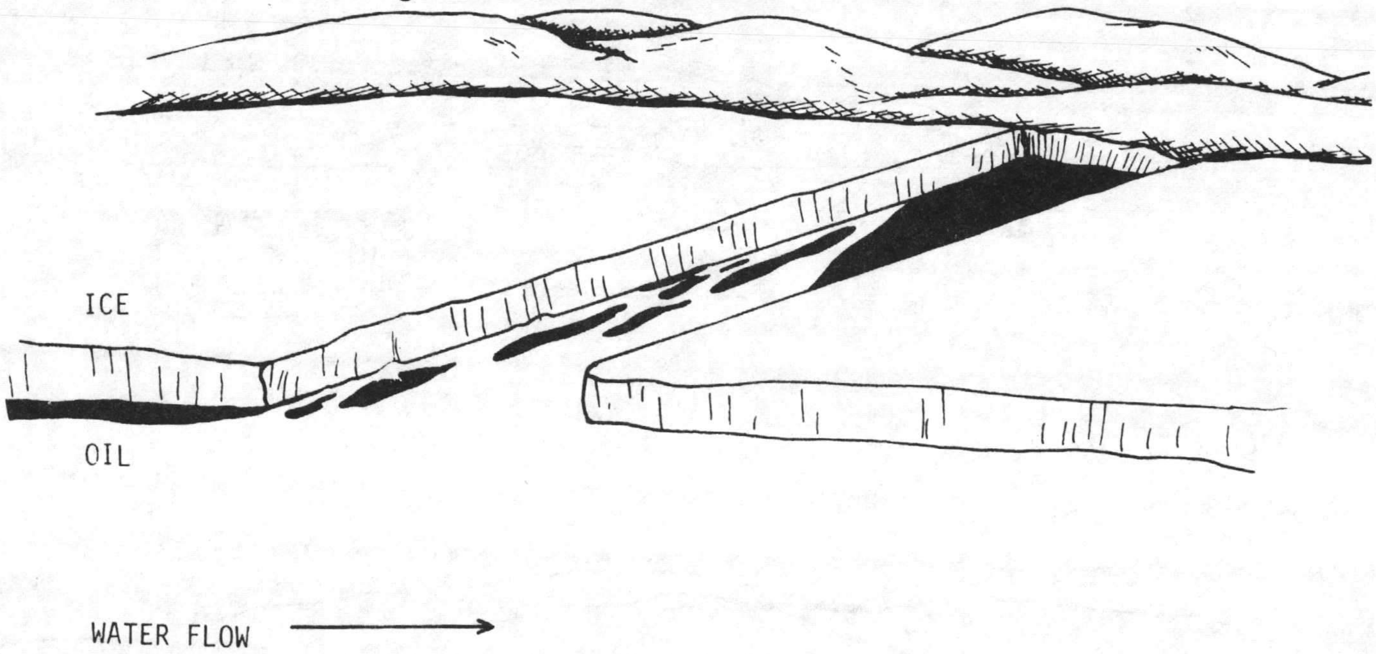

Figure 4. Ice Slot

Equipment used in making slots are chain saws, circular saws, and trenching machines; while manual or hydraulic lifts, cranes, and tractors are used in removing ice blocks. The water depth will determine if ice blocks need to be removed. Shallow water, sand bars, or underwater obstructions may necessitate ice removal. On the other hand, if the water is deep enough, some blocks can be pushed under the ice on the downstream side of the slot and can be utilized as an additional barrier in the spill response. Once completed, all slush and ice fragments should be removed from the slot to allow the oil to be carried down the slot by the current. Recovery equipment can be used to collect the oil on the down current side of the slot.

Another oil recovery technique that has been found to have limited success is contaminated ice removal. This method is usually considered unsuccessful since recovered oil is less than 1 percent of the total volume recovered. Even with the use of heavy mechanical equipment scraping oil off the ice, it is impractical at best.

Oil on ice or snow surfaces is relatively easy to recover. Oil can be mixed with snow which can contain 30 to 50 percent oil by volume. The use of heavy equipment or manual removal techniques on oiled snow will depend on the ice thickness. The use of snow as a sorbent material decreases when oil viscosity is high, when oil-snow temperature differences decrease, and when snow porosity decreases (wet snow).

If access is not readily available, waiting for future recovery may be necessary. Due to the slow weathering of oil in cold climates, the formation of tar-like residue may take many months to form.

Summary

A major concern with containment and cleanup of oil in icy waters is personnel safety. Oil can rise into pockets under ice sheets, freeze within ice, form surface pools, or surface between edges of ice sheets.

In a thin ice situation, conventional containment and recovery devices can be used once ice is broken. However, it may be possible to break ice in a way to aid in oil recovery.

Cleanup of oil with thick ice will involve finding oil and making cleanup sites. Containment of oil can include subsurface barriers, ice barriers, ice troughs, and ice slots. Oil can be removed by vacuum devices, skimmers, or burning. Oil on ice can be removed by manually or mechanically scooping oil into trucks, sucking oil with vacuum devices, or mixing oil with snow with removal by trucks. Since oil weathers slowly with ice, spill cleanup can be postponed until weather conditions improve if access is poor or if weather or ice conditions threaten personnel safety.

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PHYSICAL AND CHEMICAL TREATMENT OF OIL

Sorbents and How They Work

Sorbents are materials that collect liquids either by blotting or soaking (absorption) or surface adhesion (adsorption). An oil sorbent is a special material that preferentially collects oil. Loose sorbents, including sawdust, are often spread upon the floors of gas stations and automotive shops to soak up spilled oil. Sawdust is quite effective as a shop floor sorbent, but since it collects both oil and water indiscriminately it is inefficient in removing oil from water surfaces. Fortunately, improved oil-specific sorbents are available for recovering oil from water.

Although types of sorbents and methods of application have been refined, the basic idea remains the same. First, a sorbent is spread upon floating oil where it simultaneously collects oil and repels water. Then, after the sorbent becomes oil saturated it is removed from the water surface and either wrung out and reused or disposed of properly. Like other spill control techniques, sorbents are another tool to be used in conjunction with other methods.

Properties of Sorbents

Any acceptable sorbent material should have oil-attracting (oleophilic) properties. The more efficient sorbents demonstrate water-repelling (hydrophobic) properties and will not sink. Also, an effective sorbent should have a short saturation time, a relatively large capacity for collecting and retaining oil, and enough strength to withstand recovery and handling. Other desirable characteristics include resistance to mildew, rot, and insect and animal attack. Ideally, sorbents should be non-flammable, biodegradable, nontoxic, and unaffected by temperature and humidity extremes. They should be in a form easy to handle under the weather conditions at the spill and must be easy to recover for disposal or reuse.

Sorbents work by sorbing oil onto the surface of the material (adsorption), or into the material (absorption). Hence, both the surface area of the material and the viscosity of the oil determine the sorbent's capacity. This is why plastic foam and fiber type sorbents are often preferred over slick, flat sheets. Normally, the heavier the oil, the less susceptible it is to absorption. However, a viscous oil may be more easily adsorbed than a light oil. Generally speaking, absorbents work well on relatively thin oils while adsorbents work better on thick oils. Considering the cost per gallon of oil picked up, removal by sorbents may be more costly for oil spill cleanup than the cost of booming and skimming free oil. For this reason, sorbents are not usually recommended for recovering large spills. They are best for the small spill, for removing oil from confined places, and for final cleanup or polishing.

Types of Sorbents

Sorbents may be classified according to their origins into three groups: mineral products, natural organic products, and synthetic sorbents. Mineral products include vermiculite, perlite, expanded perlite, and volcanic ash. Each material can sorb from four to eight times its weight in oil. However, such sorbents may not be recommended because they are dusty, difficult to apply in wind, and can be hazardous to personnel if inhaled. Operators should wear masks or respirators to avoid breathing dust from these sorbents. Recovery of such loose material is also difficult and may require a sizeable amount of manual labor with skimming nets, vacuum equipment, or diaphragm pumps. Self-priming centrifugal or gear pumps, because of their susceptibility to abrasion, should not be used with loose mineral sorbents. Oil-soaked or not, loose mineral sorbents need to be recovered because they are persistent in the environment (do not degrade).

Representative natural organic sorbents are straw, ground corn cobs, peat moss, and sawdust. One disadvantage of natural organic sorbents is their tendency to sorb water as well as oil and eventually sink. Their oil recovery efficiency is slightly less than that of mineral products. The natural organics retain from three to six times their weights in oil.

Baled fibrous materials such as straw and peat moss can be distributed by a commercial mulcher. After use, materials are usually collected manually. Straw and peat are both relatively inexpensive and readily available but usually pose difficult recovery and expensive disposal problems.

Fine particulate sorbents, such as ground corn cobs and sawdust, are easier to spread than the fibrous materials. If they must be used, they should be distributed from the upwind side of a slick with a fan or blower. A boom should be placed downwind to collect both the oil and sorbent for easier recovery. Organic sorbents should be collected after application because, although they will biodegrade, decomposition of large quantities can create a biological oxygen demand that might be detrimental to aquatic ecosystems.

Synthetic sorbents include plastic foams (polyurethane) as well as plastic fibers (polyethylene and polypropylene). These types are by far the most efficient sorbents available. For example, polyurethane foam can sorb from 20 to 25 times its weight in oil.

The problems with using foams include distribution and collection. One method of reducing storage and transportation problems is to generate polyurethane foam in place. The liquid components of the foam are stored in drums and transported to the spill site where the foam is generated and allowed to cure or dry. Cured foam must be fed into a hay blower where it is chopped up to expose the pores that sealed over when the foam was generated. This method is somewhat impractical because of the recovery problem.

Companies that supply sorbents package their products differently. Pads, rolls, mats, and batts are used to remove oil from hard to reach areas. They are relatively easy to apply and to recover manually. Many can be reused by processing them through a hand or motorized wringer. However, such reuse of sorbents is often difficult to effect at a spill site and may not be economically feasible. Rolls are also used in open areas or beaches. Sweeps are long, flat portions of fiber sorbent with a rope attached along one side. They are particularly effective in removing rainbows from water and are easy to deploy and recover. Synthetic foam chips are used in the same manner as corn cobs and straw, which can be collected with nets or screens and incinerated. Pillows, filled with particulate sorbents, are used in catch basins to absorb traces of oil.

Long sorbent booms are stuffed with particulate sorbents or foam chips and should be used in conjunction with conventional booms. If they are placed downstream of containment booms they will act as safety devices to absorb oil that may be carried under. They should not replace conventional containment booms.

Sorbents can also be used on the shoreline before a spill soaks into the beach. Sheets and booms may be spread on the shoreline to soak up the oil as it moves in. Obviously, such usage would be ineffective in surf.

Sorbents: Storing Considerations

Choosing the sorbent that will work best may depend on how it can be stored. If a large warehouse is available almost any sorbent can be stored. However, this is seldom feasible. Many natural sorbents are biodegradable. If they cannot be stored in dry sites, their use will deteriorate. Some natural, mineral, and synthetic sorbents will absorb water. These sorbents will also need a dry storage site. Another consideration is sunlight, as some synthetic sorbents break down in sunlight if exposed for long periods of time. One of the biggest problems with all sorbents and other equipment made of plastics is mice and rats. Keeping large quantities of sorbents on hand may not be feasible if rodents are a problem. They can destroy sorbent usability by eating the sorbent packaging and the sorbents themselves.

Sorbents: Advantages and Disadvantages

When a spill occurs, one must first act to shut it off at its source. Subsequent actions include containment, recovery, and restoration. Sorbents can be used effectively in the last three phases. Unless recovery of oil-soaked sorbent is assured, sorbents should not be used; the crew must avoid complicating a simple oil spill. Most EPA regional contingency plans approve using straw, as well as other sorbents, and may recommend such products. Usually, loose sorbents should not be used if other options are available. Using straw blowers to spread straw on a water spill, for example, can hinder recovery. Straw and other loose sorbents might be used effectively on land spills or in small creeks where a sorbent boom could be made from baled materials. Loose straw is also useful in conjunction with a woven wire fence boom. Generally speaking, oil is best handled when it is free from debris, including loose sorbents. Yet, many sorbents are useful in containing and removing small spills on land and water and as safety backups placed downstream of a containment boom. Commercially available pads, rolls, and sheets have a number of useful applications. For example, they can be used to protect shorelines and recover spills in confined areas such as beneath piers and in swamps and marshes. Sorbent pads can also be used to wipe clean the sides of small boats and other equipment that may become oiled.

How to Use and Retrieve Sorbents

As stated earlier, it is wise to refrain from using loose sorbents since they are difficult to recover. Small square pads work well and can be retrieved by hand, pitchfork, poles, or other devices. Leak-proof containers must be ready to receive the oiled sorbents and care should be taken to prevent oil from slopping into a boat or onto banks and seawalls as the oil-saturated sorbent is transferred. Sorbent booms are easy to deploy initially because they are lightweight; however, like all booms they are bulky, and once they have sorbed oil they can become quite heavy. They must be anchored and angled like other booms and are generally useful only for short spans. Again, the boom must be retrieved and disposed of properly. Oil on adsorbent type of sorbents can be removed by placing sorbents in a warm place and allowing oil to flow off of sorbent.

Handling Contaminated Sorbents

Once a sorbent has been saturated with oil, it is usually either disposed of or cleaned for reuse. Some manufacturers indicate the number of times their products can be effectively reused. One manufacturer states that his sorbent, if properly squeezed, can be reused from 10 to 20 times. In many oil spills, it is difficult to facilitate reuse. The on-scene coordinator should determine whether or not the reclamation and reuse of contaminated sorbents will be efficient. Disposal techniques include incineration, open burning, landfill, and dissolving.

The unique method of dissolving is recommended by one company and involves heating the sorbent-oil mixture from 200° F to 280° F. At this temperature, the sorbent melts and mixes with the oil. The company states that a 1-2 percent sorbent/oil mixture (by weight) will produce no significant effect on the viscosity of the recovered oil. Burying saturated sorbent will be covered in the section on debris disposal. Oil on adsorbent type sorbents can be removed by placing sorbents in a warm place and allowing oil to flow off of sorbent.

Summary

In summary, one must remember that all sorbents should be recovered. Straw on open water offers a particularly difficult recovery problem because of its tendency to sink, and its use generally should be avoided. Similarly, other loose sorbents should be used sparingly because of the difficulties associated with harvesting the contaminated materials. Commercial sorbents can be purchased in many forms, pads and sorbent booms being two of the most useful. Sorbents are expensive, time-consuming and are most practical for final cleanup of sheens, land spills, swamps, and other restricted areas. Practically speaking, most sorbents are used only once, although many are capable of being wrung out and reused. Disposal will usually be handled in the same manner as other debris.

Chemical Agents

Need to Obtain Government Approval

According to the National Contingency Plan, chemicals, including biological and burning agents, can be used only with specific approval of the appropriate governmental representative. In some locations, several companies and co-ops have received prior approval to use collecting agents under specific circumstances. One should check with appropriate governmental agencies to determine whether or not prior approval for chemical agents has been authorized for a given area.

Burning Agents

Burning of oil slicks needs to be mentioned only because it presents such an inviting solution to oil spill cleanup. Since oil is a volatile compound, why not burn it? Theoretically, burning should be quick, nontoxic, and economical.

Unfortunately, the solution is not simple because spilled oil on water spreads quickly into a thin layer. As this occurs, the volatile fractions of the oil quickly evaporate. The remaining oil spreads over large areas into thin, broken patches and some emulsions form. All of these factors make oil difficult to ignite. Even if a wicking agent is added, only a portion of the oil will burn because heat is transferred rapidly from the flame to the water beneath the oil. Attempting to burn oil on water can be hazardous to personnel starting the fire, can result in clouds of unsightly black smoke, and will not completely burn the oil. While the problems associated with such a burn are chiefly cosmetic (black smoke, unburned residue), it may be better to spend the time and resources in recovering the oil by conventional means.

Burning may be useful for removing both spills on ice and oily debris along small creek banks in <u>some special</u> cases. However, burning necessitates having trained personnel start the fire and closely monitor it to ensure the safety of people and property. Since burning oil creates some problems, most states require prior approval, except in cases of emergency (immediate danger to life or property).

Biological Agents

Biological agents are "microbiological cultures, enzymes, or nutrient additives that are deliberately introduced into an oil or hazardous substance spill for the specific purpose of encouraging biodegradation to mitigate the effects of a spill." Most commercially available biological agents are special blends of naturally occurring bacteria that consume oil. Such bacterial agents may be freeze-dried and stored as fine dusts or powders. In theory, when a spill occurs, the agents can be used to seed the immediate spill vicinity. This seeding action might increase the rate at which the spilled oil is biodegraded. However, waterways in areas with petroleum facilities normally contain sufficient bacteria; nutrients to support biodegradation are usually the limiting factor. Biological agents, as well as other chemical agents, must be approved for use by the appropriate governmental representative.

Gelling Agents

Use of gelling agents in oil spills has been generally not practical due to high costs of gelling material and problems with gelling only oil. However, gelling the oil in leaking tanks or tankers might be a feasible alternative in preventing the oil from becoming a spill.

Gelling agents have in the past formed grease-like material, but some now form a solid (sometimes called oil solidifying additives). These latter agents use a liquid polymer and cross-linking system which react to form a molecule matrix which entraps large quantities of oil. Crudes at -5°C can be gelled in as little as 15 minutes. These agents work faster as temperatures increase.

Dispersants

Dispersants are surface-active agents that divide and suspend the oil into small droplets in water. Oil spill dispersants consist primarily of surfactants in a solvent base. Surfactants are long-chain molecules resembling oil molecules on one end and water molecules on the other. Because of this "bipolar" structure, the surfactant will migrate to the oil-water interface. At the interface, surface tension properties are reduced so that droplets of oil are formed and dispersed throughout the water. Again, prior governmental approval must be obtained before dispersants are used (except under emergency conditions involving fire or explosion hazards).

Fate and Effects of Dispersed Oil

The most important advantage gained by using dispersants is rapid oil dilution. Dispersed oil mixes downward in near-surface waters, removing the oil from most of the wind's influence. During a spill from a Gulf of Mexico platform dispersed oil was observable only about one mile from the spill site; untreated surface slicks extended six to nine miles on most days. These observations suggest that significant amounts of dispersed oil are much less likely to reach shore than untreated oil.

Dispersion greatly lessens the tendency of oil droplets to stick to each other and to solid surfaces. This could minimize the oiling of seabirds and fishing equipment. Also, since dispersed oil does not readily adhere to solid particles, less oil will be deposited in the sediment. Dispersion accelerates both biodegradation and physical weathering by increasing the surface area exposed per unit volume of oil.

Static laboratory bioassays have shown that oil treated with modern dispersants is only slightly more toxic than the same amount of untreated oil. However, such static bioassays are unlike field conditions. The test organism is exposed to dispersed oil for extended periods of time without provision for the dilution and the evaporation of hydrocarbons that naturally occur; also the avoidance capabilities of mobile marine organisms (nekton) and natural waste accumulation are not considered.

The marine environment can tolerate a limited quantity of oil such as might be caused by a prudently dispersed oil spill. This tolerance is not surprising since geologists estimate that there have been marine oil seeps for 300 million years. The total amount of natural seepage is estimated at 200 trillion barrels, hundreds of times more than man has ever produced. Microorganisms which utilize oil as food are responsible for preventing a major portion of this oil from being a problem today.

Regulations

The use of dispersants is tightly controlled by the United States Government. Under Subpart H of the present National Contingency Plan, the use of dispersants may be authorized by the government on-scene coordinator only to prevent or substantially reduce hazard to human life or limb or to substantially reduce explosion or fire hazard to property. In other situations, the Environmental Protection Agency's Regional Response Team member can authorize the use of dispersants to reduce environmental damage. This division of authority over the use of dispersants could at times create confusion.

Only chemicals accepted by the EPA can be authorized for non-emergency use. Such acceptance requires that extensive data, including chemical composition as well as toxicity and effectiveness tests, be submitted.

The reluctance to use dispersants in the United States probably originated from overuse of early dispersing agents during the 1967 Torrey Canyon disaster. The dispersants used in the disaster were highly toxic to marine life, and caused more damage than the oil itself when they were used excessively. Less toxic dispersants have subsequently been developed. Furthermore, the effectiveness of these second generation dispersants has been improved.

Effectiveness

The effectiveness of modern dispersants has increased almost as rapidly as their toxicity has decreased. The original agents were able to break up about ten parts of oil per one part of dispersant in salt water. Newer concentrated dispersants can reputedly disperse about 50 parts of oil per one part of dispersant in salt water. Under ideal conditions factors such as oils with high wax or asphalt content, very low temperatures, thin or scattered oil slicks, and lack of agitation can increase the amount of dispersant needed by three or four times.

Equipment

Equipment for application of dispersants has two primary functions: to operate under a wide range of conditions with limited personnel, and to reliably deliver the correct chemical dosage. Various types of equipment include: hand sprayers, boat spray arm systems, and aircraft spray systems.

Collecting Agents

Another aid to controlling oil spills is the collecting agent. Surface collecting agents are those chemical agents which are a surface film forming chemical for controlling oil layer thickness. They are considered to be generally acceptable provided that they do not in themselves or in combination with the oil increase the pollution hazard. Like dispersants, the use of collecting agents must be approved by the government on-scene coordinator.

The best known commercially available collecting agents include various herding agents. They are best applied in a straight stream with a sprayer on the water surface adjacent to a spill. They should not be applied directly to the oil slick or in a fine mist. Helicopters are usually best for this service. It is of prime importance to carefully plan the use of any collecting agent. The first rule is to apply them only when you are ready to remove the oil. If collecting agents are applied prematurely their effectiveness is gradually lost and the oil may spread again. The agents do not herd the oil against wind or tide but only against the natural spreading action of the oil. Hence, collecting agents have a limited use and work best under static conditions. The maximum recommended application rate is two gallons of agent per mile of spill perimeter. The agent can be re-applied, if needed, every six hours to a maximum of three applications in any 24 hour period.

Collecting agents are most effective in restricting spills to be picked up immediately, for spraying booms, and for decreasing movement to critical areas such as beaches, marshes, or marinas where collection may be difficult. Dispersants and collecting agents are not compatible and should not be used on a spill at the same time. It is practical to apply a collecting agent and, after the slick is compressed, to pick it up with sorbents.

Fire Prevention and Suppression Chemicals

When a potential fire situation exists, prevention is the best cure. Response personnel should be kept upwind and all unneccessary personnel should be removed from the area. Evacuation may be needed.

Chemicals used in fire situations can be classified into fire suppression chemicals or vapor controlling foams. Fire suppression chemicals, such as dry chemical and carbon dioxide extinguishers and some oil spill dispersants, can be used to extinguish hydrocarbon fires. Water spray and water fog systems can be used on small or large hydrocarbon fires. However, vapor controlling foams may be most effective. Appendix 1 provides more detailed information on firefighting foams. Appendix 2 details the use of dispersants for vapor suppression and as wetting agents.

Summary

Sorbents are useful for cleaning up small spills and for large spills in difficult to reach areas such as beneath piers and in swamps. Sorbents are not recommended for large open spills that could better be recovered by skimming.

Sorbents are available in mineral, natural organic, and synthetic forms. Although organic straw is usually available and the least expensive, its use in a loose form over water spills is not recommended. On open water, it is impractical to use straw blowers and loose sorbents. Synthetic sorbents are usually the most effective and are available in shapes that can be easily distributed and recovered.

Most synthetic sorbents can be reused; the decision to do so usually rests with the on-scene coordinator. Many sorbents are used once and then disposed of in an approved manner.

Chemical agents as well as biological agents should not be used without prior approval of the appropriate authorities. Dispersants can be effective in open waters, but their usage has been restricted by the EPA in the U.S.A. Collecting agents can be useful for open water spills and are often approved for use by the government.

For small fires, dry chemical and carbon dioxide extinguishers can be used. For larger fires, the use of foams and films, water spray, and water fogs can be used. Foams and films can prevent fires by suppressing the vapors, cooling fuels, and separating flames from fuel and reducing oxygen over the fuel.

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APPENDIX 1. FOAMS FOR CONTROL OF HAZARDOUS CHEMICAL VAPORS

I. Foam is a mass of gas-filled bubbles formed either through a chemical reaction or by the mechanical mixing of air and a foaming agent. The foam bubble functions as a vehicle for carrying and dispensing water.

All foams extinguish fires by:

1. smothering - preventing air from mixing with vapors
2. suppressing the release of flammable vapors
3. separating flames from fuel
4. cooling fuel and surrounding surfaces

II. There are a number of types of foam commonly available, each with certain advantages and desirable characteristics applicable to hazardous materials incidents.

1. Protein foam - natural proteinaceous polymers, metallic salts for strength in heat and flame, and organic solvents for foamability. Dense, viscous foams, highly stable, highly heat resistant, resistant to burnback.

2. Fluoroprotein foam - similar to protein foam except that it contains fluorinated surface active agents. Able to shed fuels so that foam may be injected into tanks or plunged into fuel. Superior sealing and burnback resistance to protein foam.

3. Aqueous film-forming foam (AFFF) - fluorinated hydrocarbons and polymers. Forms water solution films on flammable liquid surfaces. Low viscosity, fast spreading, and develops continuous aqueous layer of solution on fuel surface to cool and suppress vapors. Aqueous film layer can spread over surfaces not fully covered with foam, is self healing, and continuous as long as there is a foam reservoir. This film, however, is produced at the sacrifice of the burnback resistance and cooling ability of the foam.

4. Alcohol-type foam (ATF) - developed for fuels which are water soluble or polar solvents. These substances ordinarily will cause the rapid deterioration of other foam types. Consists of a protein base with a polymeric additive to form an insoluble chemical film between the foam bubbles and fuel surface. This "plastic" barrier prevents the fuel from destroying the foam bubbles. Most alcohol-type foams must be applied gently and not submerged in the fuel to preserve the barrier.

Manufacturers are now producing combination foams so that at one concentration an aqueous film-forming foam is produced and at a higher concentration an alcohol-type foam barrier is formed. These foams can be used with a greater variety of chemical classes.

5. <u>High expansion foam</u> - consists of synthetic hydrocarbon surfactants which produce large volumes of foam with a small amount of mixing energy. The foam is capable of expanding from 100-1000 to 1. High expansion foam has been used for total flooding of confined spaces and for displacement of vapors, heat, and smoke. It is suitable for confined areas but natural forces such as wind may limit its use outdoors. This foam, under suitable conditions may be built up to very thick layers.

III. Most protein, fluoroprotein and AFF foams are available in 3 percent and 6 percent concentrations. Alcohol foams are available in 6-10 percent (some may be used as AFF at low concentrations and ATF at higher concentrations). High expansion foams are used in 1.5-2.0 percent concentrations. The percentage indicates the number of foam liquid parts to be mixed with water for a 100 percent solution.

IV. Foams are in widespread use for controlling releases of flammable or combustible liquids. Foams are able to suppress vapors, extinguish fires, and can fill pockets or enclosures where vapors would collect. The effectiveness of foams for the suppression of toxic vapors, however, has not been fully investigated. M.S.A. Research Corporation and the U.S. E.P.A. have conducted studies in an attempt to determine some of the capabilities and limitations of common foam types on hazardous substances other than flammable liquids.

APPENDIX 2. DISPERSANTS (WETTING AGENTS) AS FIRE SUPPRESSION AND PREVENTION AGENTS

I. Dispersants are surface-active agents that contain an oil-compatible and a water-compatible chemical group. Because of this characteristic, when applied to a hydrocarbon spill on water, dispersant molecules orient themselves at the oil-water interface. By this orientation, the dispersant lowers the interfacial tension and greatly enhances droplet formation of the hydrocarbon in water.

Wetting agents are a particular type of dispersant formulation that lower the surface tension of the water whether or not a hydrocarbon is present. This tends to increase the amount of free water surface available for absorption of heat, thus increasing the efficiency of the extinguishing properties of the water.

II. Dispersants may not be used on spills without the consent of the Federal on-scene coordinator. The law does make special provisions for possible fire situations, and approval can be obtained if in the judgment of the on-scene coordinator use of a dispersant is justified.

III. Dispersant usage to suppress or prevent fires is best accomplished through the use of an educator system like that used for firefighting foams. Application rates vary according to the manufacturer. Usual dilutions are 1-2 percent in water. Mixing energy is essential, and fine mists or sprays will not provide effective dispersion.

IV. Dispersants are used on shallow spills such as those on roadways which are not amenable to pumping or other recovery. Foams should be used on spills where pumping can be accomplished.

V. All dispersants are not designed to be used for fire suppression or as wetting agents. Flashpoint of the dispersant is usually the determining factor. If the dispersant is combustible, it will probably not be an effective extinguishing agent.

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DEBRIS DISPOSAL

When an oil spill occurs, the primary consideration is for minimizing damage and removing the spilled oil from the environment. Hasty action on cleanup has resulted in large quantities of debris needlessly removed and transported to a disposal site. Lack of pre-planning has allowed transport of debris to distant disposal sites when local disposal sites were available. The choice of inappropriate cleanup and disposal techniques without adequate planning increases problems and costs in a spill.

Generally, oily debris comes in two types: oily liquids and oily solids. What can be done with these materials will depend on the condition of oil, oil processing equipment availability, and government regulations (federal and local).

The first consideration in debris disposal should be consolidation of debris types. Generally, this will require debris storage, oil/water separation, oily liquid pumping, and debris transport. Oily debris can be stored in a wide variety of containers, from plastic bags to oil storage tanks (Table 1). In most cases, the container type chosen will depend on availability and cost. Further, several container types may be needed. Some containers can also be used as oil/water separators.

Separating the water from oil will reduce the amount of liquid to be transported to a disposal site and improve the oily liquid's acceptability to be refined. Some containers are already equipped to separate the water from oil, such as tank trucks. However, not all tank trucks have this ability. Mechanical separators can be purchased to separate liquids. Many have moving parts and heating

TABLE 1
TYPES OF CONTAINERS FOR SPILLED OIL AND DEBRIS

Container	Comments
Drums	1) May require drum handling devices 2) Can be used on liquid and solid material
Tank Truck[1]	1) Consider road access 2) Full tanks of water may overweight axle loading 3) Requires more permanent oil storage container 4) Liquids only
Dump Trucks Flat Bed Trucks	1) Requires impermeable barrier to hold dripping oil 2) Consider flammability of vapors at mufflers 3) Solids only
Railroad Tank Car	1) Consider rail access 2) Liquids only
Barges	1) Consider venting of tanks 2) Liquids only in tanks
Oil Storage Tanks	1) Consider problems of large quantities of water in oil 2) Liquids only
Bladders	1) May require special hoses or pumps for oil transferral 2) Liquids only
Earthen Dikes[1].	1) May require impermeable liner 2) Liquid or solid material

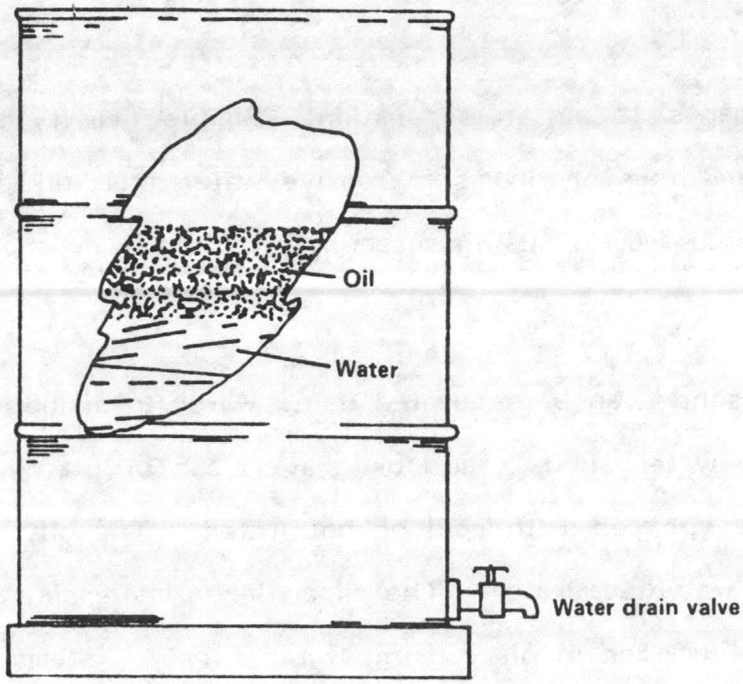
[1] Can be made into oil/water separators

heating elements to aid in separation. Simple gravity separators can be made using earthen dikes or drums to remove water from oil (Fig. 1). Floating solids can be removed from oil using screens, pitchforks, or shovels with oil drain holes in the blade.

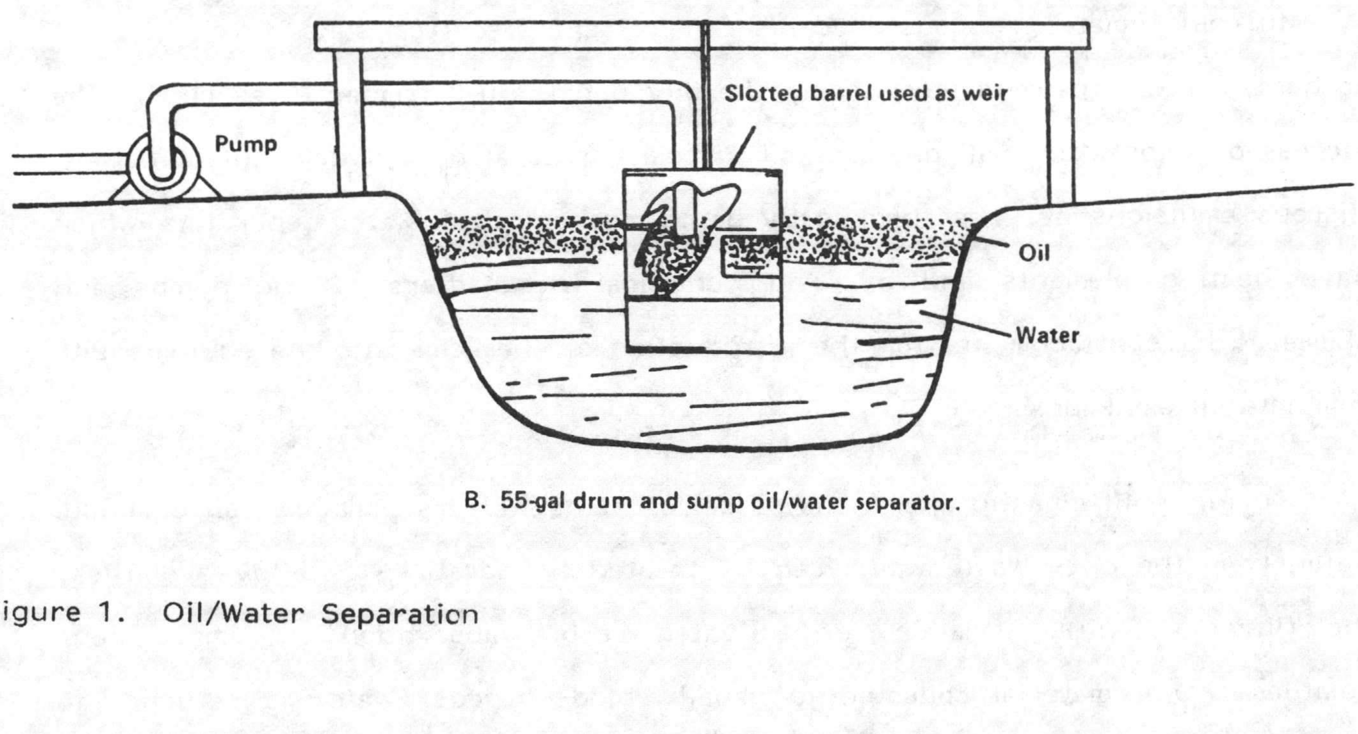
Oil on solids can be separated using water to dislodge the oil from the solid. Heavier than water solids (sand or gravel) can be placed in shallow pools and oil floated when sprayed with cold or hot water. The oily liquid can be separated using an oil/water separator. The oil on large materials, such as logs and rocks, may best be removed in place using water spray or steam cleaners using sorbents to collect oil. For solids that float (organic debris), the material should be placed on grating or an inclined surface (preferably concrete) to allow oil to wash away from debris. If oily solids are coated with light products such as diesel or number 2 fuel oil, mixing the material with hot sand can vaporize the oil and separate the oil from the solid.

In cold climates, viscous oil spills can be separated from solid debris such as sorbents, if time permits, by storing the oily debris until temperatures rise. The increased temperature will decrease oil viscosity so that oil will drip out of debris. Viscous emulsions are best broken by using mechanical oil/water separators which have heating elements and by using chemical demulsifiers. Some pumps and skimmers have attachments for the introduction of chemicals into the equipment to eliminate oil emulsions.

During spill cleanup operations, a series of oil/water separators can eliminate water from the oil. Waste water can be treated by aeration to remove volatiles, the filtration, ultra-filtration, or activated carbon absorbtion to remove non-volatiles. Oily material collected is usually biodegraded. Water is returned to the environment.



A. 55-gal drum oil/water separator.



B. 55-gal drum and sump oil/water separator.

Figure 1. Oil/Water Separation

Choosing a pump to transfer oil should be carefully considered. Some pumps may emulsify the oil and water picked up while other pumps may not work well against a strong back pressure. A general description of pump types follows:

Centrifugal Pumps

Can pump at very high rates.

Simple, rugged, inexpensive, and easy to repair.

Best suited for pumping water or low viscosity oil.

Will emulsify oil and water if pumped together.

Sensitive to debris, especially stringy material.

Cannot pump against high back pressure.

Diaphragm Pumps

Simple, one moving part construction.

Handles thick slurries and debris without stalling.

Lends itself to ultra-safe, compressed air operation.

Moderate tendency to emulsify oil and water.

Cannot pump against high back pressure.

Gives pulsating flow - undesirable for weir skimmers.

Positive Displacement

Handles extremely high viscosity slurries or emulsions.

Can pump against extremely high back pressure.

Can pass debris up to 2 inches in diameter or more.

Only slight tendency to emulsify oil and water.

Generally more difficult to repair in the field than other type pumps.

More expensive than centrifugal or diaphragm of equal capacity.

Vacuum Systems

Extremely gentle treatment of the fluids handled.

Handles all kinds of debris up to several inches in diameter and several pounds in weight.

Can pick up "chocolate mousse" in thick or thin layers from water or land surfaces.

Cannot lift a water column more than 30 feet.

Vacuum pump is usually large and expensive.

Usually requires a large integral storage vessel to contain the recovered fluid.

Transportation of liquid debris is usually by barge, tank truck, or railroad tank car. However, trucks with sealed drums can also be used. If using a tank truck, the size of tank truck chosen can depend on weight limiting roadways or bridges near the spill scene. For solid debris, the main problem has been oil dripping out of flat-bed or dump trucks. As oil solids warm, oil drips off of the solids and onto the truck bed and onto roadways or parking areas, causing driving hazards and more cleanup problems. Plastic sheeting should be used in truck beds to reduce this problem.

The second consideration involves disposal options in the spill area. Generally, the options used to dispose of oily debris are:

1. Reuse of oil
2. Controlled burning
3. Biodegradation
4. Landfill
5. Burial

Reuse of Oil

There are several possibilities for reuse of oily debris. Oiled sand and gravel can be used in road construction. However, the oily aggregate should be checked for leachability of toxic compounds. The materials can be stabilized by mixing the oily aggregate with a binding agent, such as lime. Oily liquids have been used in road construction, as well as in dust suppression on gravel and dirt roads. In coal burning power plants, oily liquids can be sprayed on coal piles to suppress dust. Some power plants can burn waste oily liquids with their other feedstock.

Another reuse possibility is recycling oily debris into waste oil reclamation facilities. Their acceptance process of an oily liquid may depend on the percentage of water in the liquid and the amount of other material in the liquid (leaves, sand, etc.).

Controlled Burning

Open burning of oily debris can sometimes be handled at the spill site after receiving approval from appropriate regulatory agencies. This is particularly true for small spills in remote areas. It is best to hire local volunteer fire departments to monitor and control the fire if a large area is to be burned. The main problem arises from smoke and particulate matter which may cause respiratory ailments in some people. Smoke and associated particles have been known to travel up to 50 miles from the burn site.

Burning oil on water is difficult, if not impossible, as (1) oil may be hard to ignite, (2) burning oil heats the slick and causes it to spread, (3) wicking agents may be needed, (4) unburned residue remains (sometimes more toxic than oil), (5) burning creates hazards near population centers, and (6) burning is not effective on weathered or emulsified oils. However, burning oil between ice sheets where oil is several inches thick is feasible. If oil is removed from the water, controlled burning can eliminate large quantities of oil debris. A rotary kiln incinerator has been developed which can pick up oiled sand, burn oil off of sand, and drop sand back on the beach. Industrial incinerators can also be used to burn oil debris (Fig. 2). This incinerator uses a blowing overfire air source to recirculate smoke through the fire to obtain a clean burn.

Burners mounted on skimmer vessels similar to burners used on offshore oil well testing can burn 50-50 mixtures of oil and water. Also, fireproof boom development will facilitate burning oil that congregates in thick pools.

Biodegradation

Bidegradation of spilled oil on water is usually not a disposal practice due to the length of time needed to degrade the oil. However, oil can be degraded on land. The biodegredation rate is dependent on temperature, pH of soil, and oxygen, water, and nutrient availability. In the biodegredation process, bacteria, fungi, and yeasts break down the oil components piece by piece.

In land farming, the oily material must be small in size and degradable such as waste oil, oily organic matter, and salt-water free oil. Land farming can be practiced at existing sites or by preparing a site so that oil applied to the soil does not run off or leach into surface or subsurface waters.

First, oily material is applied to the site. In cool climates, such as southern Canada, 1 to 2 inch thick oil layers are added to a site, while in warmer climates, such as southern United States, 3 to 4 inch thick oil layers are added to a site.

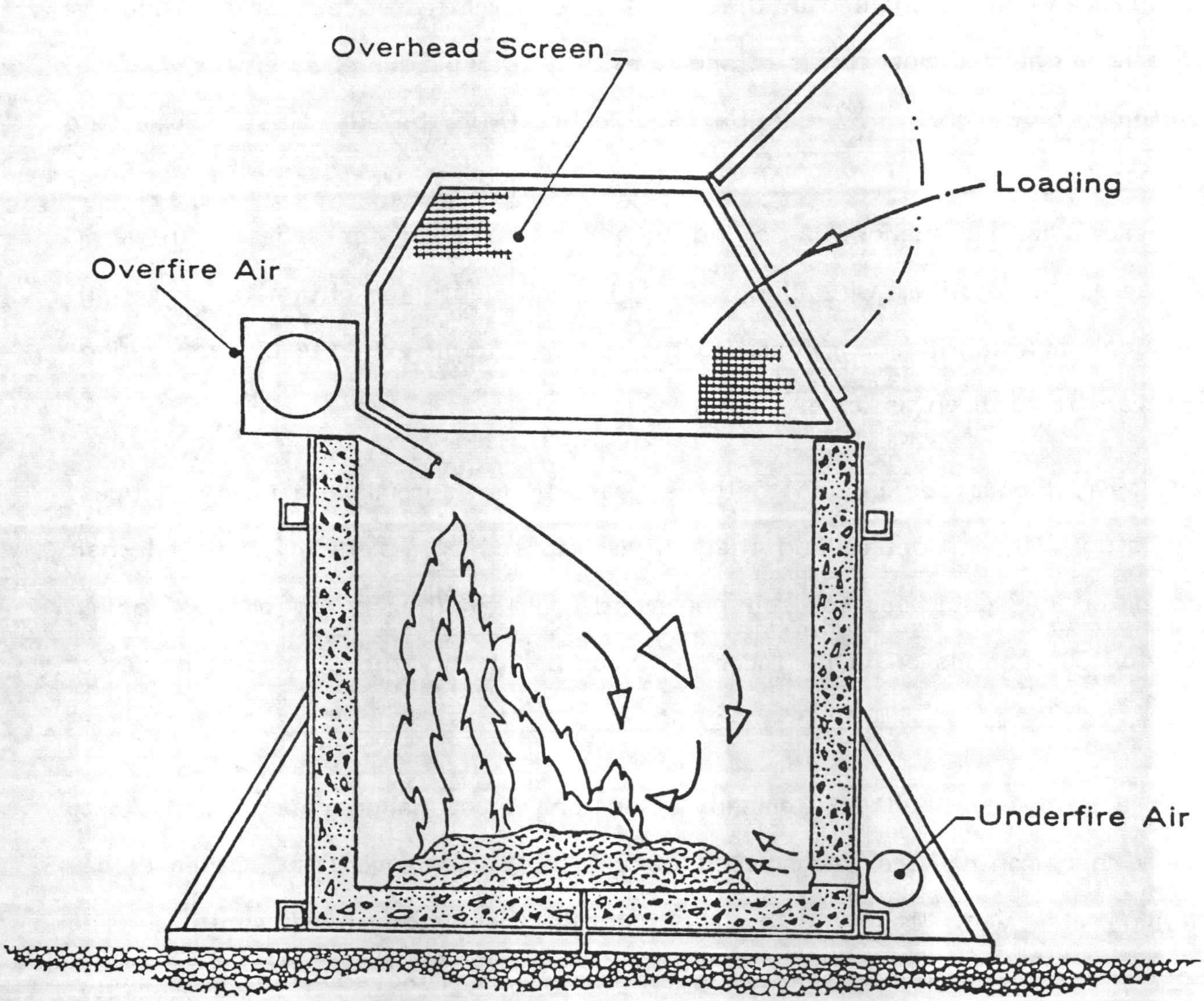


Figure 2. Air Portable Incinerator Schematic

These estimates will vary with soil type, temperature, oil type, and oil amount previously in soil.

Water and short-chained hydrocarbons are permitted to evaporate while the surface is slippery. Once the site allows a tractor to be driven over the surface, a rototiller, plow, or harrow can be used to break up the oily crust. Some land farm operators claim that deep plowing to a 6 inch depth works best, while other operators claim that shallow harrowing to a 2 inch depth works best. In warm, humid areas, a rototiller will allow a 8 to 14 inch depth for oily material mixing. Subsequent mixing will add oxygen to the soil which will expedite biodegradation. Mixing can be as often as once a month.

Oil may biodegrade in one to three years under normal land farm practices. In one study, it was determined that oil decomposed at a rate of about one-half pound of oil per cubic foot of soil per month. In another study oil was applied at 500 to 1500 barrels of oil per acre per year using only the upper six inches of soil.

In a study by Shell Oil Company (Houston) 3,000 gallons of refinery waste per acre per month were decomposed during the summer months. Other biodegradation rates vary from 0.1 to 22 percent of the oil degraded monthly. The use of fertilizer and weekly soil tilling (aeration) was employed to increase biodegradation rates.

In some cases the biodegradation rate has been doubled by adding fertilizer at the same application rate as used for corn. Some land farm operators claim that the cheapest high nitrogen fertilizer is the best fertilizer.

Generally, oily waste changes from an oily, black liquid to a black surface sludge to a dry, cakey soot-like matter that crumbles in the hand. The soil changes also. An alkaline bentonite-like clay soil that was a very hard cake when dried changed to a soft loam soil after land farming, presumably due to the addition of organic matter. Other changes in most oil-conditioned soil are increased soil moisture retention and increased vegetation growth.

Composting is not a standard disposal practice in the United States. However, in some countries, oily organic matter has been added to waste garbage sites. Since biodegradation results in the release of heat, temperatures can increase which will decrease oil viscosity. This may increase oil penetration in the ground. Oily debris can easily be over applied to a garbage site. Proper application degrades most of the oil in a few to several months, depending on the temperatures.

Landfilling and Burial

The main difference in landfilling and burial is that landfill sites have been established before the oil spill and oil debris can be mixed with other waste in disposal, while burial sites are established after the oil spill and oil debris may or may not be mixed with other waste. Both techniques require approval from the government agency in charge of landfills.

Oily liquids can be stabilized to reduce oil leaching into the ground by the addition of chemical binding agents, such as quick lime. The chemical will react with the oil to produce a practically insoluble powder or block.

Site choices should be determined prior to a spill when prices can be agreed upon in a relaxed climate. Contract disposal services should be investigated to determine if the firm is financially responsible, technically capable, protected by insurance, and reputable. Local air or water pollution control officers may be able to recommend contractors that meet state requirements.

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Past experiences in

Spill cleanup

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PAST EXPERIENCES IN SPILL CLEANUP

One good way to learn is by doing something, making mistakes, and correcting those mistakes. Unfortunately, this type of learning can be expensive. A second method is to study the mistakes and successes of others and learn from their experiences. The purpose of this section is to take the second course of action by studying different types of spills and learning how the cleanup activities were conducted.

Lake Champlain Spill[1]

The Lake Champlain spill occurred on March 23, 1971, at a terminal on the frozen shores of Lake Champlain at Plattsburgh, New York. A pumper began transferring No. 6 fuel oil from a holding tank to a working tank at 10:30 a.m. Because of the low temperature and slow pumping, the transfer was allowed to proceed for the rest of the shift. At 10:30 p.m. the pumper remembered that the transfer pump was still on. He returned to the terminal and discovered that approximately 1,000 barrels of No. 6 fuel oil had been pumped over the top of the tank. Oil had spilled down the side of the tank, over the ground, into a drainage ditch, then into a stream and into Lake Champlain.

The pumper and others from the terminal constructed temporary dikes around the tank and in the ditch and spread straw over the spilled oil. Unfortunately, most of the oil reached the ice-covered lake where it melted down through five feet of ice. The oil cooled and remained trapped under the ice but on top of the water.

The next day the company constructed a temporary stem line down to the lake and added a number of secondary lines at the end header. Secondary lines were submerged under the ice and in the oil and hot air blowing units were used at the mouth of the suction hose to make the oil easier to pump. Vaccum trucks were used to remove the oil from the lake. This proved to be a slow process because of the viscosity of the oil and the high suction lift.

To prevent oil from spreading under the ice, an open water ditch was constructed around the spill by sawing and removing blocks of ice. A wooden boom of 4 X 8 foot sheets of marine plywood was nailed to railroad ties. The boom was lowered into the ditch. During the night, the water froze and held the boom in place. Test borings showed that oil did not migrate past the boom.

Oil was recovered from beneath the ice on a 24-hour basis. Straw was used in the drainage ditch and stream bed to sorb the oil. Oiled straw was handled by pitchfork and placed in large boxes to be carried up the steep hills to dump trucks (one of the few instances where the use of straw would be recommended).

Six days after the oil was spilled, the cleanup operation was completed. Although about 1,000 barrels of oil were spilled from the tank, about 5,000 barrels of oil and water were removed from the lake for separation. After the spill, the company constructed a system of dikes to prevent other spills. Drainage from the diked areas was directed to a new oil-water separator.

St. Louis Bay Spill[2, 3]

A pipeline metering device ruptured on October 31, 1981, at Superior, Wisconsin. About 94,500 gallons of gasoline leaked into a creek, through a culvert and into a boat slip on St. Louis Bay. Upon receiving a report of strong gasoline fumes from local citizens, the U.S. Coast Guard located a large slick and traced its origin back to the boat slip, the culvert, and to the pipeline. Upon checking the metering devices, the pipeline company reported that the oil had been flowing for about eight hours.

Meanwhile, the USCG deployed 75 meters of boom at the boat slip. The local fire department requested nearby industries and the railroad to cease operations. The police closed off a two-block area near the culvert. The electric utility turned off electricity to the slip area. The oil company hired a local contractor to recover the product within the boom. Weir type skimmers were used to remove the product into tank trucks; the USCG used fire boat water jets to disperse the sheen on the bay.

In the creek, an underflow dam was constructed near the pipeline to contain any leaching oil. A polyethylene-lined liquid containment pit was constructed next to the transfer station to collect water during a recent flushing operation. Collected water was filtered through activated charcoal. A sub-contractor was hired to test groundwater by drilling two to three meter deep monitoring wells. Wells were checked by hydrocarbon sniffers and by visual inspection. No gasoline was found. About 25,000 gallons of gasoline were recovered.

Ruffy Brook and Swamp Spill[4]

On July 21, 1982, over 540,000 gallons of light crude oil flowed from a ruptured pipeline, down a hill, and into a creek and adjacent swamp in Minnesota. After a local farmer reported the spill, pipeline workers constructed a series of siphon dams and a sorbent filter fence in the creek. About 160,000 gallons of oil were recovered from the creek; a small amount escaped after a rainfall on July 23.

An estimated 300,000 gallons of oil remained in the grassy swamp. Due to the thick vegetation, manual and mechanical cleanup were not attempted. Instead, the oil was burned. The burn thinned out the grass, leaving heavy unburned oil residue. The oil, ash, and burned grass were removed by a local contractor. Water samples were taken for hydrocarbons, heavy metals, and pH changes. No changes were noticed. No fish kills or wildlife deaths were reported.

Sautali Marsh Spill[5, 6, 7]

The Sautali Marsh spill occurred on September 2 and 3, 1982, at a refinery on the island of Guam. Apparently a metal pipeline elbow broke under stress, and about 30,000 gallons of oil flowed down a ridge and into a marsh. Oil in the marsh drained through a culvert into the river and harbor. Initially the spill was believed to have come from a Navy vessel in the harbor. The Navy deployed booms, a skimmer, vacuum trucks, sorbent booms, and sorbent pads. They estimated recovering 10,000 gallons. However, the boom skirt was not of sufficient depth to hold oil during tidal changes. Furthermore, heavy rains helped flush oil out of the marsh.

When later estimates claimed 500,000 gallons of oil were spilled into the marsh, the USCG Pacific Strike team was called in November. The culvert from the marsh was cleared and modified for draining oil into a collection point. Nine smaller channels were constructed to aid oil drainage out of the marsh. Due to all the liquid being pumped out of the marsh, water from adjacent marshes was pumped into the oiled marsh. As of January, about 185,000 gallons of liquid had been recovered, with about 200,000 gallons of oil remaining in the marsh. The cleanup should require several more months, with oil leaching out of the marsh through the next year. Although no biological damage has been noticed due to the oil, a biologist will begin a thorough study.

Long Island Tank Truck Spill[8]

On June 12, 1981, a car went out of control on the Long Island Expressway, hitting a wall, crossing three lanes, and colliding with a tank truck. About 2,500 gallons of No. 6 fuel oil flowed onto the highway. A local contractor and the New York Sanitation Department cooperated so that the 3000 gallons left in the tank were off-loaded. Oil on the road was removed from the highway by using 24 inch neoprene squeegees and vacuum trucks. Oil in catch basins was recovered using vacuum turcks. Residual oil on the highway was treated with sawdust which was later removed. Two lanes were reopened in about four hours, and the third lane was reopened within eight hours.

Tank Farm Spill[9, 10, 11]

A ruptured fuel tank at Wilmington, North Carolina spilled about 2,000,000 gallons of diesel fuel on January 10 and 11, 1982. Although the oil flowed into the diked containment area, a network of storm drains and sewer pipes running within the hilly terrain complicated spill cleanup.

A contractor was hired to clean up the spill. Heavy equipment was used to construct dams in two nearby drainage ditches. Collected oil was pumped back to the diked enclosure and into tank trucks. Booms were placed in the river as a precautionary measure.

Heavy rains caused dams to fail. Oil and water were pumped into railroad tank cars and taken to an oil/water containment tank. A few days later the containment tank cracked, respilling oil into a drainage ditch. A dam was constructed in the ditch to contain the oil, and the oil and water were pumped back into tank cars. By January 26, 4 barges, 50 rail cars and 90 tank trucks of liquid had been recovered, or about 1,950,000 gallons.

The remaining oil apparently seeped into the ground. On January 19, oil was found at two sewer pump stations. Sorbent booms and skimmers were deployed to collect oil in pools. Subsequent investigation of underground pipes and drains found contaminated lines. Sewer lines were blocked to contain the oil. Monitoring wells were drilled to determine the direction of oil movement. Wells near the storage tanks failed to collect oil. There was no estimate of cleanup completion by February 7.

Brooklyn Undergound Oil Spill[12]

On September 2, 1978, oil was observed in a creek by USCG personnel. Although it appeared to come from a storm sewer outfall, oil was found to be seeping out from a bulkhead. Booms and vacuum trucks were deployed to recover the oil.

Test boring in the area revealed oil underground. Sumps and a recovery well were installed near the sewer outfall. Local investigations for the spill source at bulk oil and gasoline facilities were inconclusive. As the amount of oil recovered increased, large scale testing was initiated.

At least 191 test wells were drilled by the government and various oil companies, most by hollow-stem auger. Most wells were four inches in diameter, using PVC slotted pipe, capped at ground level to prevent vehicular damage. On the average, three wells were damaged or destroyed each week.

Data was collected to determine oil layer thickness and shape. The spill was estimated to cover 52 acres with about 17 million gallons of oily product. Oil and groundwater varied from 7 to over 40 feet below the land surface. Since there were no active public water wells in the area, pumping out water and oil would not be a major problem. Also, the product did not appear to threaten any populated areas, as most of the entire area was industrial or commercial property.

Oil recovery at the initial recovery site averaged about 18,000 gallons for several months, and slowly decreased to about 2,000 gallons in May 1979. Subsequent recovery wells were installed, particularly on oil company property to collect oil. Many systems installed included groundwater depression pumps to increase the oil recovery rate. Several years of recovery may remove 50 percent of the product.

The product appears to have originated from a former refinery. The product may have been in the ground as much as 30 years and may include leaded gasoline, kerosene, No. 2 fuel oil, solvents, and refinery fuel. Cleanup costs are expected to total $4,000,000.

Summary

The spills described represent many different situations, but some conclusions can be reached which are common to all. In each case, it was necessary to clean up the spill in a manner that was compatible with the equipment and manpower available at the site. Proven cleanup techniques worked at each spill.

Innovation was necessary to match the unique circumstances of each spill to the cleanup effort. Weather played a signficant part in some cases. Each cleanup effort clearly showed the necessity of preplanning cleanup activities.

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Response Team

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RESPONSE TEAM EQUIPMENT

RESPONSE TEAM EQUIPMENT

In minimizing the effect from oil spills, equipment must be usable and readily available. The equipment type needed in a spill response will depend on many factors. Among these are spill location (land, water, or both), product type, and weather conditions. Specific considerations for equipment should include equipment portability, spill cleanup effectiveness, maintenance, and cost. One way to simplify choosing equipment for an oil spill is to determine the equipment needed at different stages of an oil spill. The equipment may be classed into the following categories:

1. Investigation equipment
2. Initial response equipment
3. Standby equipment

Investigator's Equipment

In investigating a suspected spill, the intitial investigator should carry various items to communicate his findings to his operations center, to act as company liasion with local authorities, and to aid in providing safety at the spill scene to the public and to the initial response crew. To accomplish these objectives the following equipment may be included:

1. Portable two-way radio (to communicate with operations center)
2. Hydrocarbon monitor/gas detector/combustible gas indicator (to identify hazardous areas)
3. Protective clothing (to protect investigator)
4. Warning signs and lights (to define hazardous areas)
5. Rope or plastic barrier tape with stakes and hammer (to define hazardous area)

6. An intrinsically safe light

7. Writing materials (to document spill conditions)

8. Maps (to aid in investigating location)

In some response packages, investigators equipment is included with the initial response equipment.

Intitial Response Equipment

The initial response equipment should be packaged ready to be transported to the spill scene on a moment's notice. Generally, equipment should be capable of handling the most probable spill type and size. The equipment quantity and type may also depend on how the equipment will travel to the spill site. Large quantities of equipment can be carried easily in semi-trailers. However, in rough terrain equipment is easier carried in small trailers or by helicopters. On rivers or lakes, boats may be the mode for equipment transport.

Another consideration is spill control policy. Some initial response crews' primary objective is to contain the spill and minimize damage, while other initial response crews may be called to contain, recover, and restore an oil spill site. Obviously, the former initial response crew would need less equipment than the latter response crew. Some examples of initial response equipment show a variance in equipment chosen (Tables 1 and 2).

The River Spill Containment Trailers (Table 1) have a supply of boom for lakes, streams, and slow current rivers. With an additional trailer and boat a four to eight man response crew could deploy the equipment. Additional manpower and recovery equipment would be sent after the inititial response crew.

The Spill Containment and Recovery Semi-Trailers (Table 2) consist of two semi-trailers requiring an 8 to 16 man response crew. One trailer holds basic boom deployment and skimmer equipment, while the second trailer holds sorbents, boom lines, and various tools. Although a variety of equipment has been chosen to respond to a range of spills, the equipment placement could be reorganized by placing all necessary boom deployment equipment on a single trailer to avoid potential problems with response trailer accessibility. Furthermore, by exchanging the boom accessories in the second trailer with some skimming equipment in the first trailer, the second trailer would be equipped to respond to land spills by carrying sorbents, hand tools, skimming equipemnt, and mesh wire to make sorbent fences.

These examples represent equipment chosen for initial response. They may not be ideal for all situations. In choosing what is needed for initial response, the Oil Spill Equipment List (Table 3) shows equipment types that have been used in past oil spills.

TABLE 1. RIVER SPILL CONTAINMENT TRAILER

1 - 27' pup trailer containing the following:

950' - 18" River boom
700' - 12" Bennett boom
1 - 8" Pedco Skimmer
300' - 12" Bennett Inshore Boom
1 Aluminum weir box
Anchors, ropes, buoys, and tools
Diesel driven skid mounted capstan

TABLE 2. SPILL CONTAINMENT AND RECOVERY SEMI-TRAILERS

Item	Description	Quantity
Trailer	25' X 8' Fitted	1
Boom	20"/7" Sanivan	3000 feet
	14"/4" Sanivan Shore Protection	2000 feet
Paravanes	18" Sanivan c/w beacons	30
Anchors	100# Navy	30
	50# Navy	6
Buoys	12" Anchor Markers	30
Skimmers	Oil Mop, CSI c/w 1000' 9" Rope	1
	Morris, MI-30	1
	Slurp	2
	Pedco	3
Pumps	Spate	1
Hose	3" Suction 2 X 60' and 3 X 10'	150 feet
	3" Discharge 2 X 50'	100 feet
Generators	Onan c/w cable and portable lights	2
Portatanks	1000 gallon	6
	Trailer 25' X 8' containing:	1
Sorbents	Boom 8" X 10' Bundles of 4	55
	Blanket Rolls 36" X 150'	2
	Oil Snare 15# Cartons	52
	Speedy Dry 50# Bags	25
Anchor Lines	5/8" Polypad X 100'	30
Towing Lines	5/8" Polypad X 250'	12
Marker Lines	5/8" Polypad X 50'	30
Loud Hailer		1
Pitch Forks		12
Shovels		12
Rakes		12

TABLE 2. (continued)

Item	Description	Quantity
Chain Saw		1
Weed Cutter		1
Sledge Hammer		1
Tool Box	c/w Small Tools	1
Snow Fence	50' X 4' c/w 7' Stakes	50 feet
Chicken Wire	150' X 24" c/w 7' Stakes 50' X 24" Roll c/w Cable	150 feet 1
Plastic Batts	H.D.	100
Stretchers	Telescopic	1
Flashlights	H.D.	4
Hip Waders		12
Boats	Various types with trailers	-

STANDBY EQUIPMENT

Choosing standby equipment will depend on locally available equipment from contractors and equipment suppliers. Some equipment such as heavy road machinery (bulldozers, belly scrapers, dump trucks, etc.) as well as vacuum trucks, vac-alls, or other suction trucks will most likely be obtained locally. Other equipment that may not be easily obtained during a spill or that may dramatically increase in price during a spill should be stockpiled. Generally, the equipment used most often during spills should be stockpiled (sorbent, gloves, plastic bags). The Oil Spill Equipment List (Table 3) shows the equipment types used in oil spills.

TABLE 3. OIL SPILL EQUIPMENT LIST

Two-way radios	Hydrocarbon monitor
Protective clothing, boots, gloves, self contained breathing apparel	Boom
Skimmer	Boom accessories (rope, stakes, sledge hammer, end connectors, paravanes, anchors, buoys)
Pump	Hoses
Storage tanks, barrels, buckets	Sorbents
Plastic bags and sheeting	Emergency lighting with generator
Intrinsically safe flashlight	First aid kit
Fire extinguisher (dry chemical)	Trailers
Boots	Boat hook
Fuel (gasoline and diesel)	Funnel
No Smoking/Fire Hazard warning signs	Flashing warning lights
Boundary rope and plastic tape	Small tools
Tool box	Wrenches (various types)
Pliers (various types)	Screw drivers (various types)
Hammer	Pocket knives
Nails (assorted)	PVC adhesive tape
Axes	Wire (assorted) and wire cutters
Saw (wood)	Shovels, spades
Pitchforks	Rakes
Brooms	Squeegees
Weed cutter	Sand Bags
Rags	Hand Cleaner
Writing material	Maps

Although this list includes only containment and collection equipment, specific oil spill control operations will require special equipment (Table 4), particularly during medium and major spill events. Table 4 lists some spill operations and equipment that should be considered during a spill. The use of any or all equipment for a spill operation will vary with the situation.

TABLE 4. SPECIFIC OIL SPILL CONTROL OPERATIONS AND EQUIPMENT

A. LAND AND SHORELINE CLEANUP

Graders
Tractors with and without carts
Front-end loaders
Dump trucks
Honey wagons/vacuum trucks
Sorbents
Garbage cans
Booms
Hand tools (shovels, rakes, hoes, pitchforks, brooms)
Protective clothing
Flatbed trucks
Hoses
Plastic bags
Industrial waste container units and pickup units

B. ROCK, BULKHEAD, AND DOCK CLEANING

Tank trucks
Vacuum trucks
Chemicals
Fire and foam trucks
Sorbents
High pressure washers
Generators
Hoses
Plastic bags
Steam cleaners

C. STORAGE

Backhoes
Cranes
Liners
Floodlights
Chemicals
Bulldozers
Dump trucks
Sorbents
Pumps

D. TRANSPORTATION

Buses
Pickup trucks
Tank trucks
Railroad cars
Vessels
Flatbed trucks
Dump trucks
Vacuum trucks
Pumping systems
Boats, airboats
Helicopters

E. SURVEILLANCE AND COMMUNICATIONS

Aircraft
Communications base station
Helicopters
Portable radio system

F. SUPPORT FACILITIES

Repair stations
Cleaning chemicals
Cleaning machines
Office facilities
Telephone systems
Warehousing
Lighting facilities
Firefighting equipment
Repair tools (automotive, electrical, carpenter, etc.)
Protective clothing (hats, gloves, boots, goggles, etc.)
Miscellaneous tools (ladders, ropes, jacks, come alongs, buck oxes)
Fuels and lubricants

G. PERSONNEL SUPPORT FACILITIES

Potable water
Sanitary facility
Medical facilities
Cleaning locations
Housing
Food

TABLE 4. (continued)

H. SCIENTIFIC AND DOCUMENTATION

Current meters	Photography equipment
Meteorological station	Television
Chemistry laboratory	Surveying equipment
Sampling equipment	

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DESCRIPTION:

Communications

Equipment

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COMMUNICATIONS EQUIPMENT

Introduction

Experience has shown that an effective communications system is one of the keys to an efficient oil spill cleanup operation. Activities within each segment of the overall cleanup operation must be coordinated. Moreover, cross communications must also exist between each distinct segment. Without such overlapping communications, cleanup operations management is severely restricted.

Alerting Systems

When an oil spill occurs, members of the response team must be alerted in order to begin cleanup operations.

The most common means of alerting response team members is by telephone. Radio paging may be used where a paging system is in operation for other purposes. Telephone alerting systems are ineffective unless response team members are convenient to their phones. Radio paging has the advantage of reaching response team members wherever they are--at lunch, the movies, or on the golf course--when they are needed, thereby reducing response time.

It must be remembered, however, that pagers only provide one-way communication. These units are valuable at facilities where telephones are nearby, but they must not be depended upon for communications with personnel at the spill site. One can never be sure that contact has been made with the intended person due to interferences, noise, or an inoperable unit. On-site cleanup operations necessitate a dependable two-way communications system.

Two-way Radio Communications

When response teams have been assembled, an effective two-way radio system will be needed to coordinate their activities. For small spills, a single frequency communications network may be sufficient. For major spills and/or cleanup operations covering several miles, it may be advantageous to set up an "operations" network and a "logistics" network.

The operations network requires effective planning because of the heavy workload imposed upon it. The operations network must provide the on-scene cleanup commander and response team with reliable communications. Each team member must be free to move about, so a reliable network utilizing portable radios should be established.

While the cleanup team is busy coordinating on-site cleanup operations, a logistics network is needed to coordinate all support activity. Generally, the logistics network will utilize base stations or mobile command posts instead of portable radios. The logistics network should be designed for wide-area coverage. To facilitate this coverage, it may be necessary to establish a repeater system (see "Repeater Systems"). The logistics network should "tie together" the cleanup operation with support activities such as staging areas, disposal sites, and support-related locations that provide equipment and materials such as sorbents, boom, skimmers, vacuum trucks, and tugs.

Although marine radio facilities are often helpful in cleanup operations, marine channels should not be utilized as an integral part of the operations or logistics network described earlier. Marine channels will generally be required to handle marine traffic unrelated to the cleanup operation.

Careful attention must be given to the technical design concepts of the communications system. Equipment size, cost, and power do not necessarily guarantee satisfactory service. A qualified communications expert should be employed for designing and purchasing the communications system.

Preplanning and coordination are essential for any workable system. Standardization of overall networks is essential. Borrowing radio units from charitable neighbors usually is unsatisfactory. Indiscriminately borrowed units generally are not compatible and are therefore ineffective. If the borrowed units are in working order, they may have the wrong frequencies for use within the network. Therefore, the contingency plan for communications must carefully predesignate the sources from which radio units can be obtained in an emergency.

Radio units that have been shelved for long periods often fail to work when they are pressed into emergency service. However, like firefighting equipment, when emergency equipment does not get a normal daily workout it is essential that it be periodically inspected and tested. The complete system should be tested at least every 90 days.

A license is required before radio transmitters can be legally operated. The licensing agency in the United States is the Federal Communications Commission (F.C.C.). The Federal Department of Communications (D.O.C.) is the licensing agency in Canada. The license required for normal operations does not require an examination. Normally, a station license is issued rather than licenses for individual radio operators. In Canada, each radio requires a license. Personnel who are issued two-way radios should be trained in proper radio procedures, including how to identify the station by call sign. Personnel should be cautioned not to use obscene, indecent, or profane language on the air.

While at first glance an adequate communications system may seem extremely expensive, when cost effectiveness is reviewed it becomes obvious that during a large spill the system will pay for itself quickly through effective coordination of manpower and equipment. It has been estimated that during the Oakland Estuary cleanup (see "Past Experiences in Spill Cleanups") the communications system paid for itself in less than one day through optimum coordination of cleanup activities.

Small portable radios, commonly referred to as walkie-talkies, are the backbone of the operations network. They can be put into operation quickly and have a range of from one to five miles, depending on local conditions. The range of these units can be extended to cover wide areas through the use of a repeater system. The cost of dependable, high quality portables ranges from $1000 to $2000 each.

Lightweight, solid-state portables allow response team members to move about with a minimum of restrictions. Addition of a remote speaker/microphone attachment is desirable because the user does not have to remove the radio from its carrying case for operation. This reduces the chances of dropping the unit, an important consideration when working around water. The remote speaker/microphone also helps to free hands and to provide better listening capability (in noisy areas, the speaker may be clipped to the individual's lapel or collar). Where high ambient noise may be present, consideration should be given to purchasing headset equipment.

Unless a repeater system is to be used, high power units should be purchased. Six-watt units are slightly more expensive than two-watt models, but they offer much better coverage.

Portables with multi-frequency capabilities should be purchased (despite, perhaps, present intentions of using only one frequency) to allow for future expansion, such as adding a co-op frequency without having to purchase new radios. Multiple frequency units also provide capability for operating either two frequency simplex (with a repeater), or single frequency simplex (unit to unit).

Portables should be equipped with a high capacity, rapid recharge, nickel cadmium battery. (Note: If working in hazardous atmospheres, be sure that the battery is approved by the regulatory agency having jurisdiction, i.e., U.S. Coast Guard for docks, barges, etc.) At least one spare battery per radio should be on hand. Exchange or recharging of batteries will be required after approximately eight to ten hours of use. The on-site command post trailer is an ideal location for a multi-unit rapid charger and spare batteries.

Portables should be intrinsically safe to facilitate usage in explosive atmospheres.

When purchasing portable radios, be sure that nationwide service will be available for the brand purchased.

Communications Command Post

With medium and large spills, it is helpful to set up a small office trailer or motor home at the spill site to serve as a command post and communications center. The trailer should be equipped with telephones and arrangements for making emergency telephone connections at or near spill cleanup sites should be made. The telephones will be used to order material and manpower and to talk with company officials and government representatives. The communications command post will also contain radio equipment to communicate with both the operations and logistics segments of the cleanup operation.

Command post radios should be at or near the maximum allowable wattage allowed by the regulatory agency having jurisdiction (D.O.C. may allow a 60-watt maximum for base stations, while F.C.C. may allow 110 watts). Command post radios should be solid state and capable of operating from a 110-volt AC or 12-volt DC power supply. This will allow limited emergency operation from a 12-volt DC auto battery if the 110-volt AC power supply should fail. The command post should be equipped with a 110-volt power plant of sufficient capacity to provide electricity for base stations, battery charger for portable radio batteries, lights, and any accessories associated with the post.

Pre-installation of a mobile antenna on the command post trailer can get the base on the air quickly. If extended range is needed, the use of a portable telescoping radio tower, capable of extending to elevations of 35 or 40 feet, should allow the command post to communicate with portables over a range of 2 to 15 miles, and with high power boat and auto radios 20 to 40 miles, depending on terrain and other local conditions.

It has been said that "a chain is no stronger than it weakest link." An efficient antenna system can be the "weakest" link in an otherwise efficient system. It is essential that the proper type antenna be selected for the command post. In addition the command post should be equipped with a programmable monitor/scanner for monitoring the weather frequency and the frequencies of support related activities.

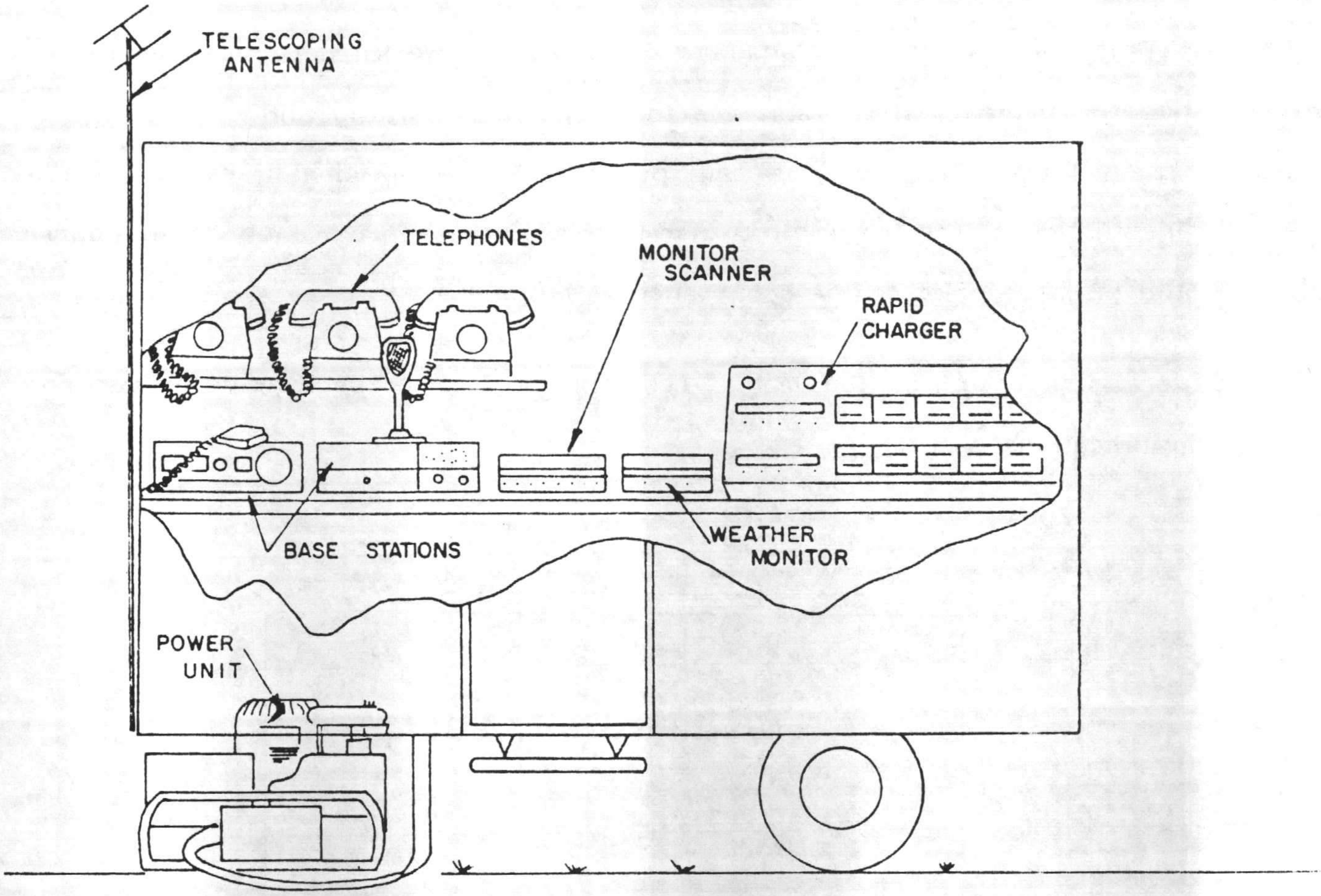

Figure 1. Portable Trailer for Spill Control Communications

Mobile Radios

Cars and trucks used during the cleanup operation may be equipped with portable radios for short range communications. The portable's efficiency may be increased by using an optional console accessory which will connect the portable to a vehicle mounted antenna and an audio amplifier.

For increased range, mobile radios should be installed. The smaller units (below 45 watts) are easier to install. These units can be equipped with a cigarette lighter plug for power supply and are small enough to be mounted under the dash of most vehicles. For maximum range, it may be necessary to install a 110-watt unit (not allowed in Canada). The more powerful sets must be wired directly to the vehicle battery and are too large for mounting under the dash or seat of the vehicle. Normally the main power unit is mounted in the auto trunk. Proper installation of the larger units normally requires approximately three hours and should be made prior to the occurrence of a spill.

Several briefcase mounted mobile command posts may be useful for certain spill communications needs.

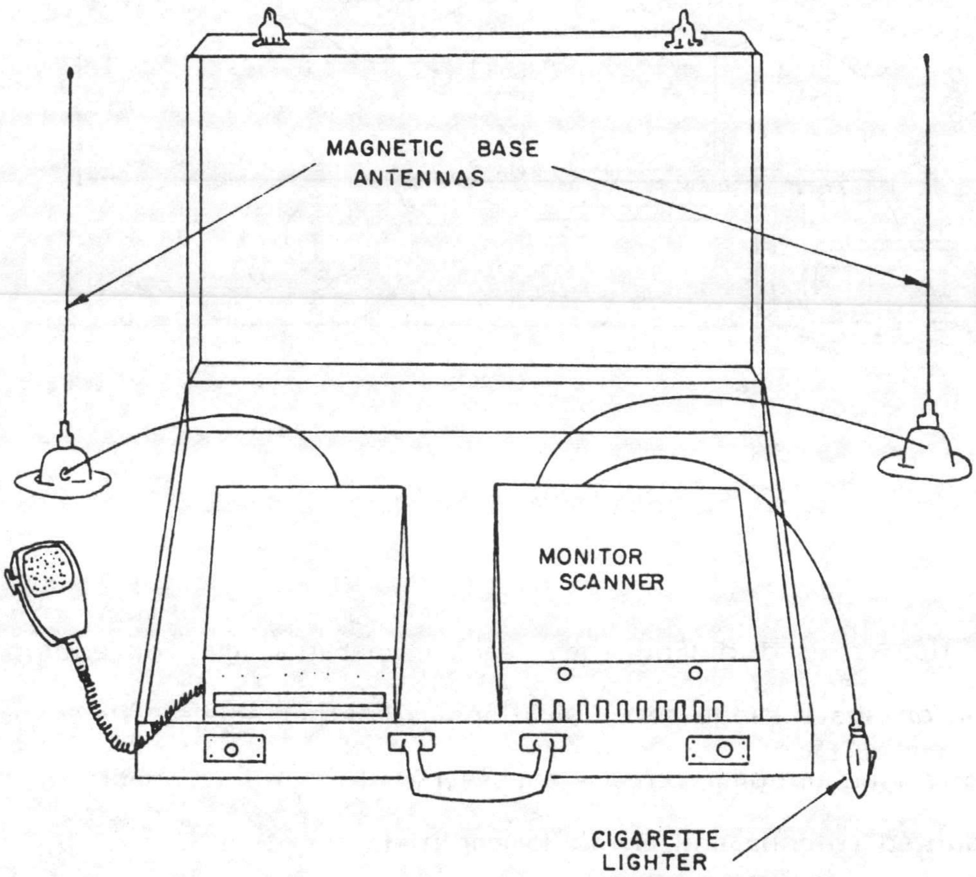

Figure 2. Mobile Command Post

The mobile command post contains a 25-watt solid state multifrequency FM radio equipped with scanner attachment, magnetic antenna, and cigarette lighter power plug. A monitor scanner can also receive weather forecasts and monitor radio transmissions of others involved in the spill cleanup.

Aircraft Radio

Aircraft radios are VHF AM radios used for communicating with airport control towers and other aircraft. These units operate on frequencies designated for the aviation radio service and are not available for use in coordinating clean-up operations. Mobile radios on petroleum service frequencies may be very difficult to install in aircraft and must be installed by an approved aircraft mechanic. In the United States, the F.C.C. limits aircraft radio power output to 10 watts. For most aerial surveillance, a six-watt portable radio on the operations frequency should be carried in the aircraft. Boats and vehicles should be identified by some marking visible to aircraft. Masking tape, four inches wide, can be used for temporary numbers.

Special Oil Spill Cleanup Frequencies

In the United States, the American Petroleum Institute (A.P.I.) and the Oil Spill Control Association of America petitioned the F.C.C. to allocate certain frequencies in the petroleum service band for oil spill containment and cleanup operations and for training and drills essential in the preparation for the containment and cleanup of oil spills. In Canada, the Petroleum Association for Conservation of the Canadian Environment (PACE) requested the Federal Department of Communications (D.O.C.) to allocate the same frequencies.

The following frequencies were allocated:

VHF	150.980 MHz	(Base or Mobile)
	154.585 MHz	(Mobile Only)
	158.445 MHz	(Mobile Only)
	159.480 MHz	(Base or Mobile)
UHF	454.000 MHz	(Base or Mobile)
	459.000 MHz	(Base or Mobile)

In allocating these exclusive frequencies, the regulatory agencies (F.C.C. in the United States and D.O.C. in Canada) have indicated that communications related to oil spill cleanup and containment should be carried out on these frequencies.

Repeater Systems

When spill cleanup operations cover a large geographical area or when the spill is in wooded or hilly terrain, it may be necessary to use a mobile relay system, usually called a repeater.

A repeater is a two-way radio which will receive a weak signal from a portable (or mobile) radio on one frequency and retransmit it on another frequency with increased power.

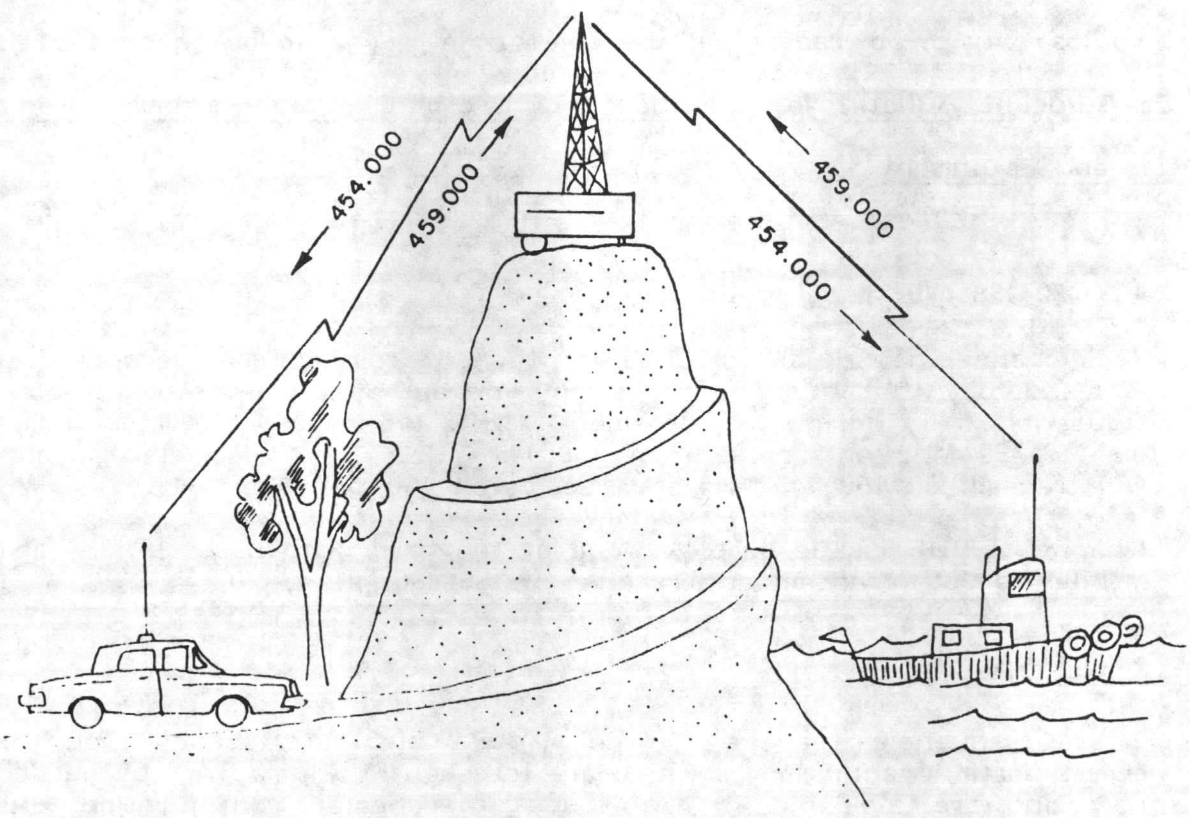

Figure 3. U.H.F. Repeater System.

The repeater should be centrally located at a favorable vantage point such as a high hill. Using a repeater system allows personnel with low powered portables (walkie-talkies) to communicate through obstructions with other operational team members such as shoreline supervisors and boom deploying boats.

While land based repeaters can sometimes be designed to cover a large anticipated spill cleanup area, there are many areas where this may not be practical, necessitating portable repeaters. These may be either trailer mounted units complete with batteries, chargers, and telescoping antennas or units transportable by helicopter with battery supply suitable for long periods of unattended operation.

PACE has recommended that standardized channel pairing be used so that borrowed radios and co-op radios will be compatible. The following excerpt is from PACE Guideline Bulletin #6, Directions For Use of Oil Spill Emergency Radio Frequencies and Equipment.

> 159.480/158.445
>
> This channel pairing is assigned for the site-commander's network. It is mandatory that this channel pairing be equipped. In repeater configuration it is designated Channel 1 VHF, the repeater is to transmit on 159.480 MHz and receive on 158.445 MHz. The associated mobiles will transmit on 158.445 MHz and receive on 159.480 MHz.
>
> Channel 2 VHF is the simplex mode of the pair, with base stations and mobiles to both transmit and receive on 159.480 MHz.
>
> 150.980/154.585
>
> These frequencies have also been made available. Depending on the communication requirements which are foreseen, they may not be needed now but are available if required. In repeater configuration this channel pairing is designated Channel 3 VHF, the repeater is to transmit on 150.980 MHz and receive on 154.585 MHz. The associated mobiles will transmit on 154.585 and recieve on 150.980 MHz.
>
> Channel 4 VHF is the simplex mode of the pair, with base stations and mobiles to both transmit and receive on 150.980 MHz.

454.000/459.000

This is the only UHF channel pairing available; in some United States' cooperatives it will be used for the site-commander's network. In repeater configuration it is designated Channel 1 UHF, the repeater is to transmit on 454.000 MHz and receive on 459.000 MHz. The associated mobiles will transmit on 459.000 MHz and receive on 454.000 MHz.

Channel 2 UHF is the simplex mode of the pair, with base stations and mobiles to both transmit and receive on 454.000 MHz.

In Canada, the predominant use of UHF will be on Channel 2 UHF, simplex communication between hand-held portables in local work crews. However, all UHF radios in the Canadian system should include Channel 1 UHF in the event a repeater configuration is used in conjunction with U.S. cleanup operations.

Checklist for Communications

Some important points that should be remembered when setting up a communications center are as follows:

1. Attempt to keep one or more telephone lines unlisted for emergency use,
2. have a number of lines available for normal communications,
3. keep a line open for communications with the on-scene coordinator,
4. determine how company communications equipment can mesh with the on-scene coordinator's equipment,
5. say nothing over the radio that would not be appropriate for publication (reporters also buy radios),
6. obtain competent help for setting up the communications networks, and
7. have cleanup communications operations well described in the contingency plan.

Summary

An effective communications system for oil spill cleanup should include integrated radio and telephone systems. Experience has shown that for major spill cleanup operations both "operations" and "logistics" radio networks may be necessary in order to effectively coordinate the cleanup.

The largest potential spill should be determined and a communications system designed accordingly. The time to develop a communications system is before a spill occurs.

Considering the sophistication of today's radio equipment, the assistance of a communications expert will be required to develop an effective communication system.

Further Reading

Leigh, J. T. and W. C. Park III. 1983. Mobile Command and Communications System. In: Proc. 1983 Oil Spill Conference. pp. 111-114. American Petroleum Institute, Washington, D.C.

PACE. 1980. Radio communications for major oil spills. Petroleum Association for the Conservation of the Canadian Environment (PACE) Bulletin No. 6. 19 pp.

[illegible] Mot[illegible] Command and [illegible]
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CONTRACTORS

CONTRACTORS

Numerous contracting companies have been formed in recent years to assist in oil spill cleanup operations. These companies range in size from the very small organization with limited equipment to large well-staffed and well-equipped companies capable of handling major spills. The services of general contractors not necessarily in the oil spill cleanup business are also important during cleanup operations. In all cases, the function of a third party contractor is to assist a company in cleaning up a spill.

Contracting Services Available

Oil spill contractor services can range from furnishing equipment items, such as vacuum trucks or pumps, to providing complete cleanup of a spill on a turn-key basis. The more limited assistance of providing equipment can usually be arranged through heavy equipment contractors in most parts of the country. Contractors that offer the service of turn-key oil spill cleanup are usually located near major petroleum production, manufacturing, and distribution centers.

A company may find its needs served best by prearranging for the services of a number of contractors in their area. For example, a company may have an agreement to rent heavy equipment with operators from a highway contractor, small equipment such as pumps, chain saws, and portable lights from a contractor supply firm; helicopters from an aircraft company; boats from a barge company; and cleanup services from several oil cleanup contractors.

Some specific services that can be obtained from an oil cleanup contractor include:

1. spill-response units on call 24 hours a day that include well equipped trucks and trained personnel to combat a spill in the initial stages;

2. backup manpower and equipment for large spills;

3. large, offshore or bay-type self-propelled skimmers;

4. warehouses stocked with sorbents and booms;

5. rental agreements with other contractors to bring in additional vacuum trucks and other equipment;

6. experienced personnel to assist in supervising cleanup operations;

7. commercial disposal sites for oily debris; and

8. oil reclamation facilities for recovered oil.

Manpower Supply

One of the most important contract services is to provide a nucleus of trained supervisory personnel. It is essential that enough trained supervisors be available to prevent individuals from becoming overextended and unable to direct the work properly.

No one would expect a contractor to keep more than a skeleton crew available at any time for a spill, so provisions must be made to greatly expand the contractor's force as required. The contractor should have files on potential workers and may make public appeals for labor. These people will be inexperienced and must have careful supervision. One contractor in New York believes that this is best solved by operating a union company and hiring workers from the union hall. This can have its disadvantages by raising the price for unskilled as well as skilled workers.

A large contractor in the Houston area built his business from a waste oil hauling and disposal operation. He is capable of expanding to a 100-person oil spill labor force, because of drivers available for his trucking operation. This method of expanding his labor force has proven valuable.

The Contractor as an Oil Spill Equipment Sales Outlet

Many contractors double as oil spill cleanup equipment sales outlets. This gives them an opportunity to diversify and to obtain equipment at discount prices. Because these companies also use their products under actual spill conditions, they are in a good position to evaluate the equipment. A number of contractor-sales operations sell booms stamped with their own name. The boom is made by a manufacturing company, but often to a particular contractor's specifications. Some of their changes may be extra handholds, anchor points, or additional reinforcement.

Preventing Conflicts with Contractors

Some conflicts between companies and cleanup contractors in the past have originated from disagreement over charges for equipment and manpower. To prevent problems, a cleanup supervisor should be assigned to each contractor to carefully follow the operation. The supervisor should keep a daily log of all contractor operations and have a meeting each afternoon with the contractor superintendent to discuss what was accomplished, what needs to be done the next day, what equipment will be charged to the job, and the number and classification of labor hours that will be charged for the day. If charges for each day's operation are agreed to by the company and the contractor, fewer problems should arise when invoices are received.

Some specific points to discuss with the contractor include:

1. What equipment at the job site is being charged to the project but is no longer required?
2. What is the procedure for charging overtime for personnel?
3. At what rates are overtime charges made?

4. Are living expenses charged to the job?

5. Are protective clothing and hand tools charged to the job?

Contractor rates should be agreed on before a spill occurs, not during a spill. Participants in this course should determine if their company and its contractors have mutually approved a rate schedule that can be employed for oil spill cleanup. Because of inflation, the contractor will probably specify an expiration date on the rate sheet. If this is the case, a new rate sheet should be obtained as prices expire.

Who Does the Contractor Work For?

Depending on the spill, the contractor may work for the company responsible for the spill or for the government. In some cases a contractor may initially be hired by the spiller, but if cleanup costs become prohibitive, the government may assume cleanup responsibility and directly supervise the contractor.

Contractors' Problems

Contractors often encounter difficulties collecting payment for their services. Many ship company spills are paid through insurance claims and the insurance companies tend to pay only a portion of the contractor's cost. The contractor is expected to keep hundreds of thousands of dollars worth of specialized equipment ready to go at all times backed by an army of well-trained laborers. This is not economically practical and companies should not expect this type of service without paying for it. A company that wants to continue to have the services of a competent contractor will see that all bills are verified and paid as expeditiously as possible.

Preplanning Cleanup Operation with the Contractor

If a company expects to rely on a cleanup contractor for a significant portion of the operation, the contingency plan must be developed around the contractor. Since oil will often move great distances after a spill occurs, the expected response time of the contractor is an important consideration for preplanning cleanup operations. The company developing the contingency plan must know how the contractor will respond when called, i.e., how long it takes, what equipment will be moved in on initial call up, and what manpower will respond to the spill. Arrangements must be made for early communication between the company and the contractor.

Contractors can assist in determining recovery locations that will be adequate for their equipment and in obtaining disposal sites for debris and waste oil. The contingency plan should be developed as a team effort between the contractor and company, and the plan must be updated as required.

Summary

Becoming acquainted with area contractors, their capabilities and services can result in an improved contingency plan. Information regarding what equipment contractors have available to them, where they obtain their labor,and what their limitations are as far as numbers and experience should be obtained. The company should determine if a contractor has something special to offer, such as an oily water disposal system or a solid waste land fill. Rates and responsibilities should be agreed on before a spill occurs. A company representative should be assigned to follow the contractor's work, and charges for the amount of manpower and equipment used each day should be determined during a meeting with the contractor at the end of the day.

Typical Contractual Agreement Outline

All segments should be written by company personnel who are experienced with writing contracts. A typical contractual agreement between an oil cleanup contractor and a company should contain the following:

1. name, address, and telephone number of contractor to perform services;
2. name of company to receive services;
3. purpose of agreement;
4. where the services will be performed;
5. details of services to be performed and unit cost of each service;
6. statement on the liability of all services provided by the contractor;
7. what the company will provide;
8. statement on the liability of the company;
9. how work will be supervised by the company;
10. when and how payments will be made to the contractor;
11. dates the agreement will be in effect;
12. statements on dissolving the contract and/or obtaining compensation upon failure by the contractor to act or, in the event he acts, in some manner not in the interest of the company;
13. signatures of each party; and
14. date signed.

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DESCRIPTION:

Training Program for

the response Team

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Confidential Records Management, Inc.
New Bern, NC
1-888-622-4425
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TRAINING PROGRAM FOR THE RESPONSE TEAM

Experienced, well-trained people are essential for successful implementation of an oil spill contingency plan. Training sessions must be held on a regularly scheduled basis since persons on the response team will be continuously changing, new equipment will be acquired, and the oil spill contingency plan will be modified as more experience is gained. For a good training program to exist, it must have the support of the company. The supervisor of the oil spill response team is responsible for the team's continued training.

Purpose of the Training

The objective of the response team is to clean up an oil spill efficiently and quickly with a minimal adverse effect on the environment. The purpose of the training program is to prepare the response team to meet this objective. The training program should be divided into quarterly meetings which can be devoted to classroom exercises, field training, and response drills. The specific goals of the training program are to teach the response members to:

1. use oil spill cleanup equipment safely,
2. identify cleanup sites,
3. utilize the oil spill contingency plan,
4. handle the respective duties of a response member, and
5. critically review and upgrade the contingency plan.

Responsibilities of Response Team

Each member of the response team should be familiar with all aspects of the oil spill contingency plan. This includes how to use the notification system for reporting spills and the call-up procedure for activating the response team. Each member of the response team should have a folder with the following information:

1. organization chart of response team with the names of people assigned to the various positions,

2. notification plan with phone numbers of all members of the team,

3. map of plant area showing:

   a. potential spill sites

   b. environmentally sensitive areas

   c. boom deployment sites

   d. access roads to deployment and waste disposal sites,

4. description of each deployment site, and

5. complete job description for each response team member (the job description will help new members become oriented).

Members of the response team in the procurement group must periodically check to ensure that their lists for furnishing personnel, equipment, and supplies are current.

The Training Program

Most of the training program should be oriented around drills and demonstrations rather than formal classroom instruction. However, certain aspects of the training program can be covered efficiently in group training classes. Training sessions should be held regularly, perhaps for a few hours each month, and large-scale exercises should be held once or twice each year. A suggested list of topics for response team meetings is included as Table 1.

Training is time consuming and expensive. Like any other expenditure, it must justify the overall program. Whenever possible, consideration should be given to holding joint sessions with other plants in the area. A local spill cooperative can provide a valuable service organizing and coordinating training sessions.

Vendors are often willing to put on demonstrations of their equipment or materials. However, although observing demonstrations are worthwhile, it is not a substitute for actual first-hand practice with one's own equipment.

The practical field work required to contain and clean up an oil spill should be broken down into a series of elements. Each element should be practiced separately before a full-scale exercise is attempted. A full-scale exercise can be a chaotic experience and wasteful if it is not well planned and organized.

Classroom instruction should include the following:

1. discussion of new ideas, equipment problems, and results of field exercises;

2. movies on new equipment and its use, oil spill cleanup operations, and drills;

3. instruction on boom theory, day and night navigation, oil movement, water current measurements, and cleanup techniques;

4. status reports on equipment and inventory of supplies; and

5. reviews of the oil spill contingency plan, responsibilities of individual members, characteristics of various deployment sites, water currents about the plant site, and use of equipment.

A general guide for evaluating the contingency plan is given in Table 2.

Summary

Training must be regularly scheduled since persons on the response team will be continuously changing, new equipment will be acquired, and the oil spill contingency plan will be revised regularly. Training should be such that each team member knows exactly what to do in case of a spill at any time. Each member of the team should be issued a folder with information detailing his role in the cleanup organization, a notification plan, and various maps of the area locating potential spill sites, boom sites, and access roads.

Training sessions should emphasize hands-on experience with specific pieces of equipment. Limited classroom discussions can consist of equipment status reports and review of the contingency plan. A full-scale exercise of the response team should be held one or two times each year.

TABLE 1

SUGGESTED TOPICS FOR REGULAR RESPONSE TEAM MEETINGS

I. <u>Drills</u>

Provide working experience and practice with specific pieces of equipment or operations. Introduce competition between small groups or teams to simulate urgency.

A. Set up and operate:

1. electrical generator and light set

2. pumps and skimmers

3. communications system - radios and telephones

B. Connect boom sections on land and in water

C. Launch boom from dock and from beach or river bank

D. Boat handling - launch boat, tow sections of boom, set boom anchors

E. Spread and recover sorbents - loose (to demonstrate the recovery problems), pads, and rolls

F. Dry run on emergency telephone call list, i.e., in-house, cooperative, contractors, and governmental agencies

II. <u>Demonstrations</u>

A. Equipment manufacturers

B. Material and chemical suppliers

C. Observe training exercises conducted by others in the area including other companies, local cooperatives, cleanup contractors, and governmental agencies

III. <u>Instruction</u>

A. Boom theory

B. Oil skimmer performance

C. Small boat handling

D. Oil movement on water - effective wind and current

E. Oil movements in soil

F. Shoreline and land cleanup techniques

IV. <u>Review the Oil Spill Contingency Plan</u>

A. Inventory of potential spill sites

B. Review characteristics of various deployment sites

C. Inventory of environmentally sensitive areas

D. Review water currents about the plant site

E. Review response team organization and notification procedures

F. Review responsibilities of individual members

G. Review the use and limitations of various equipment and cleanup techniques

H. Review sources of equipment, supplies, and personnel to ensure sources are up to date

V. <u>General</u>

A. Discuss results of any field exercise

B. Report status of equipment and supplies

C. Discuss new ideas

D. Case histories: view movies or discuss published reports on oil spills

E. Outside speakers from other plants, EPA, and Coast Guard

TABLE 2

CONTINGENCY PLAN EVALUATION

I. General

A. Does the plan emphasize the importance of spill prevention?

B. Is the problem described?

C. Are possible spill locations listed and described as to action to be taken?

D. Does the plan specify action to be taken in case of a spill?

E. Are there extraneous and superfluous materials included in the plan?

F. Is there provision for posting information as well as submitting the plan?

II. Equipment and Manpower

A. Does the plan indicate that the spill will be recovered without the use of spill-handling equipment?

B. Does the plan specify what manpower and equipment are available and how they are to be used? If a contractor is to be called in does the plan list the spill handling equipment the contractor has?

C. Is spill-handling initiating responsibility specified?

D. Does the plan include a list of sources of boats, planes, materials, and so forth?

E. Is there evidence that neighbors would be willing to help, and does the plan describe the action to be taken when a neighbor needs help?

F. Does the plan state if and when chemicals may be used?

III. Notification

A. Is there a logical notification procedure?

B. Is there a description of the services that public relations men will be able to perform? How is insurance to be notified?

C. Does the plan fall apart if the supervisor is on vacation?

IV. Procedures

A. Is there evidence that fire protection is to emphasized?

B. Is there provision for an alternative action to be taken in adverse weather and water conditions?

C. Does the plan provide for personnel safety such as life jackets and fire extinguishers?

D. Does the plan emphasize the shutting off of the spill source?

E. Is there a provision for making a written report of the spill and maintaining a log of action taken?

F. Does the plan provide for disposal of recovered oil and oil-soaked spill-handling mate ials?

V. Limitation of Liability

A. Does the plan fulfill legal requirements?

B. Does it meet with government approval? Do the interested agencies know of the plan?

C. Does the plan include use of police, fire departments, and disaster units when they would be of help?

D. Does the plan include steps to be taken to protect potential victims' property, people, fish, and birds?

VI. Oil Spill Cooperatives

Cooperatives convenient to company operations are in the best interest of all concerned. If no cooperative group has been organized and such a group is feasible, the company should be encouraged to initiate action to form a cooperative.

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Reporting oil spills

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REPORTING OIL SPILLS

Spilling oil is illegal. The quantity considered illegal is that amount that will cause a sheen on the surface of water or cause a sludge or emulsion to be deposited beneath the surface of the water or on adjoining shorelines. The amount necessary to cause a sheen can be less than a teacup full.

Another qualification is that the oil must be spilled in a location that could result in the oil reaching navigable waters. Navigable waters have been defined by federal courts as "waters of the United States" which means almost any watercourse, including intermittent dry creeks.

There are several federal laws concerning the discharge of oil, but Public Law 92-500, Section 311, also known as the Federal Water Pollution Control Act Amendments of 1972, is probably the most important and explains the rules for oil spill occurrences. Section 311 is included at the end of this section.

Reporting Spills

When an oil spill occurs, the person in charge of a vessel or an onshore or an offshore facility must immediately notify the appropriate federal agency. The maximum fine for <u>failing to report a spill</u> is $10,000 and/or one year in jail. The appropriate agency is the U.S. Coast Guard. For inland spills, the EPA should also be notified. Some states also require notification. Determine if this is the case for your state and also report to that agency. The EPA or U.S. Coast Guard on-scene coordinator should know what other federal or state agencies should be called. But find out before you have a spill.

Even when a spill is properly reported, there can be a civil penalty assessed against the owner or operator of up to $5,000. The Coast Guard has the authority to compromise the severity of penalties. It should be kept in mind that the penalties above are on the national level and states may have additional penalties matching or exceeding federal penalties. This is not considered double jeopardy because more than one law may have been broken. For all practical purposes, if an employee follows company procedure when a spill occurs, he personally should be protected from legal action. However, if it is clear that an employee has deliberately or maliciously spilled oil, legal action may be brought directly against the employee. The person may also be subject to company discipline.

Federal Goverment Involvement After a Spill

The federal government has overall responsibility to see that an oil spill is cleaned up properly. If the spiller does not take steps to remove the oil to the satisfaction of the federal on-scene coordinator (OSC), the federal government can take over the management of the spill and arrange for the removal of the oil. Any costs incurred after the federal OSC takes over will be submitted to the spiller for reimbursement. For this reason most companies prefer to handle their own cleanup operations.

For most inland (onshore) spills, the federal OSC will be from the EPA. Exact boundaries between the USCG and EPA responsibility for responding to spills have been established by memorandums of agreement between these two agencies. Any storer, transporter, or producer of oil should identify these boundaries for local contingency plans.

Although the OSC means the federal official predesignated by the EPA or the USCG, a state official may act as the OSC when he is acting pursuant to a contract or cooperative agreement with the federal government. Any potential spiller should also be aware that many other federal agencies could be involved. These could include the Corps of Engineers, the Bureau of Land Management, the

Mineral Management Service, the Bureau of Indian Affairs, the National Park Service, and the National Oceanographic and Atmospheric Administration (NOAA) as well as others. Below the federal level will be state department of environment agencies, or commissions that have state jurisdiction over oil spills. Within their boundaries, state and local laws will be discussed later.

For onshore or offshore facilities that discharge oil, the limit of liability is $50,000,000. There is no limit of liability where the discharge is proven to be the result of willful negligence or misconduct. Exceptions which remove the owner or operator from liability include an act of God, an act of war, negligence on the part of the United States government, or an act or omission of a third party. If it appears that the spill falls under one of these exceptions, contact the company supervisor immediately.

Owners and operators of vessels and facilities must comply with regulations for the removal of oil, implementing local and regional contingency plans, procedures to prevent discharges and inspections of vessels containing oil. Those who do not comply with the regulations are liable to a civil penalty of $5,000 per offense.

State and Local Laws

State and local regulations must be followed in addition to the federal regulations regarding oil pollution, spills, and cleanup. The more important state requirements will often be found in the respective Regional or Local Pollution Contingency Plan.

In Texas, for example, the two state agencies involved in discharges of oil are the Texas Water Quality Board and the Texas Railroad Commission. Any oil spill in Texas must be reported to one of these agencies. The Texas Water

Quality Board has developed regulations which require their approval or the approval of the Texas Parks and Wildlife Department before oil cleanup chemicals are used.

Most state laws now follow closely the same general policies, laws, and regulations found in the federal statutes and regulations. However, there are occasions when state or local requirements differ or exceed federal laws. The most notable example was when Florida passed legislation that provided for unlimited liability for recovery of cleanup costs for oil spilled in Florida waters. This provision was challenged in American Waterways Operators vs Askew. However, the Supreme Court upheld the Florida law. Florida has recently amended the law, however, and presently has the same limits on liability as the federal government.

Other Regulations

In the federal regulations there is an exception for discharges of oil from a vessel's engine; however, the exception does not extend to oil accumulated in bilges. There is a specific prohibition against adding dispersants or emulsifiers to oil to be discharged in an attempt to circumvent these provisions. Demonstrations or research projects such as those that may be involved with this course are exempted from the prohibitions on discharges of oil.

Cleanup Costs

There is a revolving fund authorized in the amount of $35,000,000 to provide for cleanup costs that the federal government may incur. The fund is administered by the U.S. Coast Guard. According to the regulations, only costs for response Phase II (Containment and Countermeasures) and Phase III (Cleanup and Disposal) actions under the National Contingency Plan or the Regional or Local Plans may be reimbursed. If the Coast Guard or EPA uses the revolving fund in a cleanup the government will attempt to reimburse the fund by collecting from the spiller. In most cases, the spiller will notify the appropriate agencies and pay a contractor or will utilize his own forces to cleanup the spill.

Summary

Any oil spill that can reach navigable waters (waters of the U.S.) must be reported to the U.S. Coast Guard. Failure to do so may result in a $10,000 fine. Various state agencies also require reports of oil spills and may levy fines.

Most oil spills are cleaned up and paid for by the company responsible for the spill. But, a company's exposure for cleanup cost is sometimes limited by insurance and/or government regulation. If possible, spills by unknown parties should be handled under the direction of the government on-scene coordinator.

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DOCUMENTING AN OIL SPILL

Accurately documenting an oil spill cleanup operation is an important job for the cleanup supervisor. Documentation is necessary for protection in the event of lawsuits and should be valuable as a tool to improve the management of cleanup operations and thus reduce expenses. By studying well-documented histories of past oil spills, one can also use the information to improve the facility's oil spill prevention program.

The Daily Log

A log of daily events should be kept from the time a spill is first noticed until cleanup operations are complete. One person should be delegated the responsibility of recording all data pertaining to the spill on a daily basis. For legal purposes, bound volumes with consecutively numbered pages should be used rather than looseleaf notebooks. Records kept in looseleaf notebooks could be subject to claims that information was purposefully removed or added. Each entry should record the date, time, place, action, and signature of the witness(es). Because of its value, particularly as potential legal evidence, the log must be kept in a secure place.

Any information that could be of importance should be recorded while the spill is in progress. Small, portable tape recorders allow a supervisor to verbally document operations as he views them from the air, water, or land. Tapes should be transcribed daily and not be reused or thrown away. Large spills may necessitate each supervisor to keep a personal log. Entries from such logs should be consolidated and recorded into the headquarters log. Information should be as complete as possible.

Some of the more important points to document include:

1. The limits of the spill (did the oil reach a certain intake, marina, beach, or marsh?)
2. Damages resulting from the spill (were warnings issued?)
   a. Property
      1. Boats - names and registration numbers
      2. Other
   b. Life
      1. Human injury or death - names, addresses, extent of injuries
      2. Livestock - number of, owner(s), address(es)
      3. Wildlife - number of oiled birds collected, number cleaned, number surviving
3. Prior condition of the area and property if known
4. Cleanup operations
   a. Equipment and manpower available (cooperatives, contractors)
   b. Actions taken (equipment and techniques employed, chemicals used, etc.)
   c. Assessment of effectiveness/recommendations

Because the spiller is officially responsible to the government on-scene coordinator, the spiller should be careful to record all orders and directions from the on-scene coordinator in the log. After recording the information the coordinator should be asked to sign the log book next to the spiller's signature to ensure that both parties understand what has been said. This can be particularly important when an on-scene coordinator's representative approves a cleanup area, but the on-scene coordinator overrides the subordinate's decision. This procedure will also help ensure that orders from the on-scene coordinator are clear. However, in some cases, this procedure might be impractical or may not work for a specific cleanup operation.

Contractors should be required to submit time sheets each day listing manpower, equipment, and materials used. These documents should be signed after the close of each working day by a representative of the company and the contractor. The contractors should understand that only charges so verified and authorized will be accepted for payment. This will help avoid disagreements at the completion of the job.

Photographs

Color photographs should be taken to record the source and the extent of the spill and the cleanup effort. A 35 mm camera is recommended for documentation. The following information should be recorded at the time each picture is taken:

1. name and location of the vessel, facility, or site,
2. date and time the photograph was taken,
3. names of photographer and witnesses,
4. description of what is being photographed, and
5. reference to outstanding landmarks.

In addition, lawyers often want information on shutter speed, f-stop, type of film used, and details of film processing. A Polaroid camera can be useful by providing the photographer with an immediate visual record, allowing a scene to be reshot if needed to obtain an acceptable photograph. For large spills, a professional photographer should be hired to handle photographic documentation. The professional photographer will require information regarding what is to be photographed. The photographer's name and number should be in the contingency plan.

Oil Sampling

Oil sampling is an important part of documenting a spill. The government on-scene coordinator will sample the oil, and the party presumed responsible for the spill will want to verify the analyses by also taking samples. An oil spill can result in a lawsuit, so all the facts of a spill should be available from the beginning of the spill to its cleanup completion.

Methods of identifying particular oils essentially match samples based on the assumption that no two oils have identical compositions unless they have identical histories. This relationship has been termed the "fingerprint principle" because, in theory, every oil is unique. It should be emphasized that this is a theory since weathering will tend to alter the composition of an oil, making it more difficult to trace. Co-mingling with other products and contamination are also significant problems in fingerprinting.

Sampling Procedures for Oil Spills on Water

At the present, there is no standard procedure for oil sampling, although the EPA, U.S. Coast Guard, and ASTM are expected to publish methods soon. Until then, the following procedures should be considered.

The objectives of oil sampling are:

1. to obtain a quantity of oil that makes identification possible (one pint sample, or more, if possible);
2. to obtain a true representation of the oil;
3. to handle the sample properly so that it is not contaminated or altered in any way; and
4. to protect the legal validity of the sample identity and subsequent analyses.

As a part of the planning procedure, a sampling kit should be assembled which includes the following items:

1. spatula,
2. note pad,
3. pen with indelible ink,
4. sample bottles, glass or Teflon, with lids (pint, wide-mouth bottle, and Teflon-lined lid),
5. labels to identify location,
6. packing material or appropriate case to prevent breakage of sample bottles during shipping,
7. pads of some type of sorbent material to pick up rainbows,
8. rags for cleanup of personnel, and
9. plastic or rubber gloves.

The recommended sample size varies, but generally one pint is sufficient. Many of the procedures used for identification require only a small amount of material, so a sample should be taken even if a full pint cannot be obtained. Duplicate samples should be taken from each area so that one bottle can be sent to the labortory for analysis and the other retained as a reference. Glass and Teflon are the only two types of containers recommended for oil spill sampling. Glass containers are most frequently used because they are less expensive and more available. Care should be taken in packing glass containers in dry ice. For this duty it is better to use Teflon containers. A Teflon-lined top should be used, but any non-metallic closure is acceptable. Unused containers are preferred, although previously used containers that have been cleaned with a strong detergent and thoroughly rinsed are acceptable.

Sampling a slick is a simple procedure, but care must be taken to get a true representation of the spill. When the oil is several inches thick the person taking the sample can skim a sufficient amount from the top. However, when the oil is thin this is not possible. Plenty of samples should be taken when there is enough available and the excess should be stored as duplicates. It is best to keep the samples cold to prevent biological and chemical degradation.

To obtain a large enough sample from a thin layer of oil, first skim as much oil into a jar as possible. Then turn the bottle upside-down (with the cap screwed on) and slowly unscrew the cap. Let the water run from the jar but tighten the cap before the oil escapes. Repeat this procedure several times until a reasonable oil sample size is obtained.

When oil layers are so thin (rainbows) that a sample cannot be obtained using the upside-down method, absorbent pads may be used. Several types are available and may be cut to size. Glass fiber insulation material is used by some Coast Guard offices to take samples. This material has a special coating that does not contaminate the sample. Pads used in gun cleaning also work well. The pad should be placed in an appropriately sized bottle after it is well oiled. Several pads should be oiled to obtain enough oil for analysis and placed in a sample bottle. The bottle should be labeled as to the type of pads used. Other acceptable pads are sheets of Teflon, polypropylene fiber, rayon waste, and polyurethane foam. Another sampling device that is used fairly frequently is aluminum foil. A sheet of heavy-duty foil is skimmed along the surface of the spill and placed into a jar.

Soil Sampling

Oil spill samples on dry land can be collected by picking up oil-coated soil and transferring it to containers. Oil on rocks or debris can be scraped into containers with a spatula.

Reference Samples

Reference samples are taken to determine the source of the spill in question. They are important because oil identification is basically accomplished by matching the oil sample with the reference to determine the oil's origin. Reference samples should be taken from every possible spill source in the area even though some may appear to be no way involved with the spill. The references should be properly labeled and described in a log as to location, nature, and why they were selected. All facts pertaining to the reference samples must be in writing and witnessed to be legally valid.

Underground leaks from service station tanks present some different sampling problems. Gasoline may seep through the ground and float on the water table, traveling several miles underground. For this reason, it is important to obtain reference gasolines from all possible seepage sources, even though they may not be in the immediate vicinity of the spot where the leak was discovered. This would include service station underground tanks, surface storage tanks, and pipelines. It may be difficult to match a sample with a source because many materials in the soil are soluble in gasoline.

Sample Analysis

As part of the oil spill cleanup preparation, arrangements should be made with an analytical laboratory to analyze oil samples. After samples are collected and witnessed, the person handling the sampling should oversee the packaging and shipping. The person in charge should state in a letter that he observed the samples being packaged and that he took the package to the carrier, who received it and marked it in some distinctive way (i.e., adhering a numbered form to it). He should also state that he requested the carrier to return to him evidence that the package was delivered to the addressee. He should attach to the letter the carrier's receipt for the package and follow up to see that the package was delivered.

When samples reach the laboratory, chemists have several analytical methods at their disposal to identify the sample. The most commonly accepted methods are gas chromatography, atomic absorption spectrophotometry, and infrared analysis. These methods utilize various characteristics of the oil to identify it. Gas chromatography is used to characterize the organic components such as isooctane and propane. A small quantity of the sample is injected into a carrier gas and enters a small diameter column, usually several feet long, filled with a chemical packing material. The column is heated to control the rate the sample fractions move through the column. The small molecules travel at a faster rate than the long chain molecules and are detected at the end through a flame measuring technique or by other methods. Standard pure organic samples are also injected in the column. The readout oil sample is compared to the readouts for standards. The device can determine quality and quantity of different fractions of oil.

Atomic absorption spectroscopy is used in oil identification to determine the nickel/vanadium ratio of oils. This procedure is based on the premise that the nickel/vanadium ratio is unique to a particular oil and does not change significantly during weathering. In atomic absorption spectrophotometry, a light beam is directed through a flame that is burning the sample, then the light from the flame passes through very small grids and onto a detector that measures the amount of light. The wavelength of the light beam is characteristic of the metal being determined, and the amount of light energy absorbed by the flame is a measure of the concentration of that metal in the sample.

Infrared analysis is useful in oil analysis because nearly all chemical compounds show marked selective absorption in the infrared regions. It has been found that infrared spectra are very complex, making it improbable that any two compounds will have identical curves. The instrument is capable of generating light over a range of wavelengths in the infrared region. The sample is placed in a glass vial and infrared light passed through. Absorption of the infrared radiation displaces the atoms from their normal positions and causes them to oscillate. The remaining light passes on to a photocell and results in a reading on a graph.

Summary

One of the most important tasks of the cleanup operation is to accurately record the history of the oil spill. The purpose of documentation is to protect the company, minimize expenses, and use the log as a basis for critiquing the spill prevention and cleanup programs. It is important to record the extent of the spill, orders that were received from the government on-scene coordinator, major orders given to others, and an assessment of the cleanup activities each day. Because one does not know what may be important at the time, it is necessary to take many more pictures, take more samples, and record much more written information than one may believe necessary.

The spilled oil should be documented by taking samples of unspilled oil for reference and spilled oil for comparison. The sampling program and arrangements for sample shipping and chemical analyses should be preplanned.

Further Reading

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Security, Damage claims,

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SECURITY, DAMAGE CLAIMS, AND PUBLIC RELATIONS

SECURITY, DAMAGE CLAIMS, AND PUBLIC RELATIONS

When a spill occurs it will affect people socially and/or economically. Some are affected directly, such as property owners, resort personnel, and spill response personnel (cleanup crews, and government personnel - federal, state, local). Others are affected indirectly, such as individuals, private interest groups, and public groups interested in property or resource use and the aesthetic value of scenic and recreational areas.

Improper handling of people can affect public opinion by:

1. Not providing information
2. Proving misinformation
3. Improper security etiquette

This can result in adverse publicity, and as a worst case, lead to a loss of product sales or cause a postponement of planned facilities by the spiller.

Security at the Spill Scene

Security must be maintained at the scene of an oil spill to provide public safety and avoid equipment loss from theft. Public access can be reduced by limiting land, water, and air vehicle traffic where possible to control the public for their own safety and to ensure the safety of the cleanup operation. Visitors should be personally escorted by security personnel to and from the spill scene. Although security personnel can patrol equipment stores, identification of company employees, contract laborers, and visitors with colored armbands, nametags, colored hardhats, or hardhat stickers can facilitate security.

Equipment most subject to theft are pumps, hand tools, chain saws, outboard motors, and radios. Equipment trailers, portable sheds, and lighting systems are useful in abating security problems. A security patrol should be established for the spill site, particularly at night.

If a contractor is hired to clean up the spill, he should be responsible for his own security. However, responsibility for company equipment lies with company personnel and can be conveniently divided by assigning each person a specific item. In obtaining spill security the services of law enforcement agencies, the Federal Aviation Agency, the Coast Guard, and/or off-duty law enforcement officers may be needed.

Damage Claims

When a company is involved in an oil spill, specialists will probably handle damage claims. However, one should be familiar with company policy as the claims specialists may require assistance. The daily log and photographs are useful documents providing a reference as to the kind of work done in the area and the extent of damages. These documents are particularly important on small or medium spills when the claims adjuster is not called for several days after the spill. For the claims adjuster it is best to settle claims as soon as possible to promote good public relations and to minimize expense. If a property owner believes a company is not acting in good faith, he may turn to an attorney to collect for damages, which will cause unnecessary delays and expense. Above all, every claim should be treated equally; one property owner should not be paid more than another for equal damages. If payments are not consistent, citizens who receive less are apt to hire lawyers to collect additional money. By treating every person fairly, this can be avoided. Without good documentation denial of fradulent claims cannot be supported. Table 1 lists a variety of damage claims situations that the spill supervisor(s) should be aware of to reduce costs of claims.

TABLE 1. POSSIBLE DAMAGE CLAIMS AFFECTING SPILL COSTS

Property Loss	1. Loss of structural integrity 2. Use loss (recreation or aesthetic) 3. Value diminution
Personnel Injury	
Water User Cost	1. Contamination of sensitive areas (wildlife refuges, parks, etc.) 2. Increased cost to purify public drinking water 3. Increased cost to purify industrial water supply (especially power plants)
Resort Areas Related Cost	1. Increased cost of user to find equivalent facility 2. Reduced income for tourist trade dependent businesses 3. Reduced income for secondary tourist businesses (suppliers) 4. Reduced public revenue due to reduced public area use
Traffic or Navigation Blockage Cost	1. Cost to reroute traffic (auto or ship) 2. Cost to stop traffic (especially ships)
Aquatic Losses of Economically Important Species or Areas	1. Wildlife kills 2. Destruction of food value (taste, odor) 3. Loss of productivity to breeding, spawning, or fishing areas

Public Relations

Handling Sidewalk Superintendents and Volunteers

The cleanup crew will do a better job if it is unhampered by curious onlookers. Unfortunately, oil spills often bring the same attention that a fire does in some parts of the country. Security personnel should be stationed around the spill area to keep the public from getting in the way. The police, Coast Guard, and fire department may be able to help in this capacity. All personnel involved with the spill should be instructed to treat the public politely, but not to discuss the spill; the public relations department will handle this detail.

If the spill is large or draws much attention, concerned people may volunteer to help. In most cases, volunteer help should be discouraged. Although these people are well motivated, they are usually untrained and may slow down cleanup operations. During past spills, companies have provided food or protective equipment to volunteers working near company personnel. Cases in which a volunteer later claimed to be an employee have resulted in the courts awarding full pay for such effort. Thus, volunteers should not be encouraged unless a company is prepared to be responsible for them. It is recommended that all volunteers be directed away or to the governmental on-scene coordinator.

Public Relations Information About the Spill

While containment and cleanup are the major priorities at a spill site, a prompt, accurate, and cooperative public information program is essential. Public relations must be considered from the outset in dealing with a spill. In fact, the first reports from the scene will generally be vital in placing the incident in perspective, lessening the spread of misinformation and setting the tone of continuing media coverage. It cannot be emphasized enough that failure to provide pertinent information to the public and the media as quickly as possible will create unnecessary headaches in dealing with a spill incident.

General Public Relations Preparations

Efficient public relations can help by making sure the public gets facts instead of speculation and by freeing the technical people responsible for cleanup to devote their attention to the spill. Good public relations can also protect the company's legal position with respect to liability.

To handle this phase of the operation, the contingency plan for public relations should designate appropriate spokespersons, define the kind of information that may be provided, outline procedures for passing on information, and designate a public relations program for the facility.

An oil spill almost automatically creates the following audiences either at the scene or anywhere that people may hear about the incident.

1. The local population - Homeowners, residents, farmers or others directly affected by the spill have a specific need for information since the spill may present harm to life or property. They become sources of information for media representatives who may come to the site or who seek information by telephone.

2. The media - Even if the site is remote, it is certain that a newspaper, radio, or television representative will be there soon, depending on the severity of the spill. Any company, group, or agency identified with the spill will also be queried by the media at regional or main offices.

3. Assisting forces - Police or fire departments, municipal emergency crews, government agencies, or others who would normally be directly or peripherally involved in an incident of this nature have a need for information.

4. Special interest groups - Environmentalists, citizens groups, municipal government representatives, insurance agents, and politicians are often attracted to the scene.

5. Any company involved in the spill and concerned about liability, image, or other considerations, may be present to protect its interests.

Preplanning is vital to ensure that designated persons in positions of responsibility have the opportunity to speak to the audiences and are familiar with the procedures for gathering and disseminating information. Normally, the spokesperson will represent the company with the responsibility for directing cleanup. The answer is to develop a central information source as quickly as possible. The cleanup supervisors should have a clear channel for feeding information to the central information source.

The First Company Person On-Scene

The first company person on the scene may have to deal with one or several of the audiences. His primary job is to assess and report, but he should also use courtesy and tact in dealing with requests for information. While he will probably not be in a position to answer all requests for information, he should ensure the information will be provided as soon as possible and pass these requests to the appropriate spokesperson.

The urgency of the situation may restrict his role in providing public information to little more than an honest promise to have the information provided. He also has to be fully aware of the dangers of providing anything more than the bare facts initially (see fact sheet at end of this section). It is imperative to refrain from comments on the cause, extent, damages, or responsibility for a spill.

The Government On-Scene Coordinator

The designated on-scene coordinator will normally take over the public relations responsibilities as soon as possible. He will generally appoint a spokesperson who will be an agency official at the site to keep the spokesperson informed.

The on-scene coordinator will remain as the source of information and, depending on the circumstances, will be funneling data to his superiors and then to a public relations representative. The on-scene coordinator will have the final judgement on what information may be released. Press conferences should be called once a day.

The Public Relations Representative

Ideally, a public relations representative, because of his familiarity with media, should handle the information function either at the scene or from the central office. One of his functions is to assist the on-scene coordinator in the preparation and release of information. The public relations representative should have a procedure established in the event of a spill which includes a clear-cut channel for receiving notice of a spill and obtaining continuous data on the spill, plus a plan for disseminating information to the various audiences.

A Suggested Fact Sheet

At the end of this section is a fact sheet that suggests a format for use in answering typical questions. Initial statements must be confined to facts that will not be in dispute, such as:

1. identification of the location, name of installation or carrier involved,
2. time of accident,
3. type of oil or products spilled, and
4. action being taken to combat the spill.

It must be stressed that information released about an oil spill may be used in legal action against the company involved. Although the main questions initially will be "How much was spilled? How serious is the incident?", initial estimates are often erroneous and should not be given until an accurate figure is available and approved for release. In most cases, no attempt should be made to explain tha cause of the spill or to estimate the costs of cleanup or other costs associated with the spill, until such data has been approved for release. In some cases, such as a tank truck overturning, the cause may be evident and could be readily released, but the reason for the cause may be obscure until proven.

Spokespersons should be careful not to speculate about any aspect of the situation, especially liability or cause. If an answer is not known, the spokesperson should say so and add nothing more.

Methods of Passing Information

A number of means of passing information to the various audiences can be used, as follows:

1. <u>Verbal</u> - The first person on the scene and the on-scene coordinator may verbally explain what is happening to those members of the general public who are directly affected and to media personnel who appear on the scene. The spokesperson must remember to use care when being quoted or recorded. Adequate, accurate information is important; conjecture and general comments could be dangerous. Verbal dissemination of information should be done with caution. Written information is preferable.

2. <u>Written</u> - A written release on what has happened is essential and should be prepared as soon as possible by the public relations representative, approved by management, and transmitted to the media quickly. Depending on the severity of the spill and the duration of cleanup operations additional interim releases may be required, and should be concluded by a final report to the media after the spill has been cleaned up. Releases may be given to media representatives, read to them over the telephone, transmitted by news or commercial wire services, or distributed by couriers.

3. <u>Telephone</u> - Access to a telephone is important, but company radio equipment may be the only on-scene means of contact. As the cleanup continues, on-scene media will need access to communication equipment and should be assisted in that respect.

4. <u>The Press Briefing</u> - It is valuable to provide a press briefing when time allows and sufficient data has been obtained so that a statement can be made. This may not be prudent until the public relations representative's advice has obtained or he is at the scene. The press briefing may take place away from the scene using relayed information.

5. <u>The Press Room</u> - Should a spill be of substantial size and the cleanup of long duration, it is valuable to have a central location at the scene for press information. This would normally be staffed by a public relations representative. Up-to-date information should be provided, as well as telephones and other press equipment. Staff should be available for conducting tours of the scene for media and VIP visitors. The press room should have maps of the area available.

Special Considerations

Landowners, residents, curious onlookers, cottagers, and fishermen have a need for information that partially will be met through media coverage. However, they may require additional data. A danger of fumes or fire may require a house-to-house notice which the on-scene coordinator coordinates with local police, fire departments, and company forces. Loud hailers and vehicle-mounted speakers may be necessary. A close contact with the local radio station is invaluable.

Local police forces will be necessary to deal with any crowds that may gather and to control traffic in the area. Police or other civil authorities should be versed in the broad outlines of the situation so they may answer casual questions and avoid rumors or panic. Distribution of an approved fact sheet to local authorities would be of benefit. In particular, persons whose property has been damaged will need special assurance to prevent them from becoming vocal critics.

Ambulance personnel or other civil authorities normally deal with the treatment of injuries or death. The matter of making names public may be left with the local police, if available, or representatives of the company involved. The fact that there have been injuries or deaths should be confirmed to media, if known by the responsible spokesperson, and the media referred to the correct source for further information.

Efforts should be made by responsible public relations representatives to conduct a continuing public relations and governmental relations program designed to establish the procedures that would be followed in the event of a spill and to maintain the credibility of the company concerned with such a spill.

In some instances it may be valuable to hold seminars with local media to explain what procedures would be followed. Provisions of an up-to-date emergency contact list would be valuable for the media.

Pre-spill Public Relations

A wider application of preplanning could include speeches and presentations to community groups on what is being done to avoid spills and what would take place if an accident occurs. Public relations representatives should have a good knowledge of their area, media needs, and personnel. In addition, prepared fact sheets on pollution cleanup equipment and other technical data about the procedures should be available. This data must be kept current.

Contingency plans for specific events should be made (i.e., what would happen if the tank farm sprung a large leak near a subdivision; what takes place if a ship is damaged in the harbor). The most important part of preplanning is to have all personnel who would be participating in a containment and cleanup program aware of the public relations aspects of the situation. Designation of a spokesperson is vital. A contact list should be established for company personnel.

Problems of Media Representatives

Media representatives at the scene of an oil spill face particular problems. An understanding of their job will assist in meeting their needs as follows:

1. Knowledge - In most cases, media representatives should not be expected to understand the technical aspects of what has occurred and what is taking place. They will rely on empirical information: What does it look like? Is anyone injured? What are people saying about it? How serious is the spill? What is being done to clean it up?

2. Method - Media representatives will attempt to gather information from any source they can. These sources will include anyone standing around at the scene, as well as anyone affected by the spill such as landowners or cottagers. The newsperson will actively seek someone in authority. It is the responsibility of the person in authority to be available to the media.

3. Needs - News representatives basically need fast, accurate information as well as a means of getting the information to their media. They may have communication equipment of their own or seek to use the company telephone or other communications equipment. Where possible they

should be assisted. A radio reporter will want to send back data as soon as possible. A newspaper reporter will want pictures. Where photographs can be safely taken, assistance and a guide should be provided. (Some flashbulb equipment is dangerous and may create a spark). No one should avoid having his picture taken. It is to the company's advantage to have the responsible person cooperate. Photographers should not be barred from taking pictures of a spill. As long as the correct perspective is provided through an interview, it is prudent not to attempt to control picture taking.

Summary

Security has been a problem at a number of spills. The cleanup supervisor may buy hundreds of thousands of dollars worth of small equipment only to have it stolen. Favorite items include pumps, hand tools, chain saws, outboard motors, and radios. Some method of security at the spill should be devised. It is advisable for employees to learn the company's policy on dealing with damage claims and to assist in resolving claims by keeping a detailed and accurate record of spill activities. The use of volunteer help is discouraged because they are often untrained and unreliable. They can be more of a liability than an asset. A public relations person should be designated in case of a spill to answer all public inquiries. Pertinent information should be released to the public as quickly as possible. The company spokesperson should cooperate with the public and media and try to keep people clear of the cleanup operation.

Other employees involved in the cleanup operation should limit their conversations with the public to factual information concerning the location, time, type of product spilled, and cleanup action taken. No comment should be made on the amount spilled, the cause of the spill, or the damages involved.

Fact Sheet Format

Oil Spill Public Relations Fact Sheet

The following information will normally be requested as soon as possible by media, the general public, or other affected or interested in an oil spill. The first person on the scene and/or the on-scene coordinator should fill out this sheet or be aware of the data as soon as possible.

Name of installation or carrier involved ______________________________

____

Time and date of the accident ______________________________

Location of the spill ______________________________

____

Type of product spilled ______________________________

Action being taken to combat spill ______________________________

____

Personnel involved in the program ______________________________

____

Advise the public that additional information will be made available as soon as the facts are verified.

TAB PLACEMENT HERE

DESCRIPTION:

Course Evaluation

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Confidential Records Management, Inc.
New Bern, NC
1-888-622-4425
9/08

INLAND OIL SPILL

May 19-23, 1986

Bordelon, Randy
Boeing Petroleum Services
850 S. Clearview
New Orleans, LA 70123
504/343-5676
#85122

Breuer, R. W.
Amoco Oil Company
P.O. Box 160
Casper, Wyoming 82602
307/261-4233
#710066

Brown, Brian
Standard Oil Production Co.
Rural Route
Gorham, KS 67640
913/637-5290
#710075

Carrier, Colin J.
Amoco Production Co
1604 Calkins
Gaylord, MI 49735
616/922-5100
#710058

Crocker, David T
Mobil Oil Corp.
Joliet Refinery
P.O. Box 874
Joliet, IL 60434
815/423-5571
#710065

Crotty, Jim A.
Mobil Oil Corp
West Coast Pipelines
Rt.1, Box 200
Taft, CA 93268
805/765-2058
#710060

Cseresznye, Gerald
City of Austin
Electric Generation Division
P.O. Box 1088
Austin, Tx 78767-8816
512/397-1588
#710059

Guyote, Ramona Y.
Boeing Petroleum Services
850 S. Clearview
New Orleans, LA 70123
504/343-5676
#85122

Goolsby, J.R.
Chevron Pipeline Co
P.O. Box 156
Wortham, Tx 76693
817/765-3261
#710061

Greg Kucera
Chevron Pipeline Co.
P.O. Box 5241
Beaumont, Tx 77706
409/839-3100
#710068

Kurbel, Richard F.
Amoco Productions Co.
1015 Motz Rd.
Kalkaska, MI 49646
616/258-3510

Marder, Jack
Colonial Pipeline Co.
P.O. Box 5193
Beaumont, Tx 77706
409/832-4548
#710064

Martin, Manuel
Civilian Personnel Division
Marine Corps Base
Camp Lejeune, N.C. 28542
919/451-1539
#710067

Martinez, S. R.
Exxon Pipeline Co.
P.O. Box 4687
Corpus Christi, Tx 78469-4687
512/289-4111
#710063

McDonald, William
Buckeye Pipeline
24002 Allen Road
Woodhaven, MICH 48183
313/676-9339
#88617

INLAND OIL SPILL Cont.

Parker, J. M.
Amoco Oil Company
P.O. Box 160
Casper, WY 82602
307/261-4233
#710066

Sims, L.E.
Exxon Pipeline Co.
P.O. Box 4916
Corpus Christi, Tx 78469-4916
512/289-4147
#710063

OIL SPILL CLEANUP COMPANIES IN UNITED STATES AND CANADA

The following is a partial list of cleanup companies. Inclusions or ommissions are not intended to be a positive or negative endorsement by the Texas A&M University System. We reserve the right to revise the list without notification. Comments are encouraged.

AAA Environmental Industries, Inc.
Eldred Swanson
5544 West Forest Home Avenue
Milwaukee, WI 53220
(414) 541-1440

AAA Oil Pollution Specialists, Inc.
Edward Blendermann
40-10 Crescent Street
Long Island City, NY 11101
(212) 729-2122

Acme Products Co.
James Duncan
2666 Darlington Avenue
P.O. Box 51388
Tulsa, OK 74151
(918) 836-7184

AMO Pollution Services, Inc.
Robert Garza
RD #2, Box 311b
Canonsburg, PA 15317
(412) 921-8486

Anti Pollution, Inc.
Charles Cloutier
P.O. Box 885
Morgan City, LA 70381
(504) 384-9517

Associated Chemical and
Environmental Services
Larry Imely
876 Otter Creek Road
Oregon, OH 43616
(419) 726-1521

Atlantic Towing Ltd.
C. S. Brownell
300 Union Street
Saint John, New Brunswick
Canada E2L 1B6
(506) 652-3540

Byars Spill Control, Inc.
Fred Byars
P.O. Box 1578
Harvey, LA 70059
(504) 367-0993

Centrifugal Systems, Inc.
H. M. Rhodes
8319 Bauman Road
Houston, TX 77022
(713) 692-7722

Clean America, Inc.
Dorsey Fleming
9407 Thornewood Drive
Baltimore, MD 21234
(301) 354-0751

Clean Industry, Inc.
Tom Calter
170 Border Street
East Boston, MA 02128
(617) 567-6500

Clean Venture, Inc.
Gary Wagner
P.O. Box 936
Perth Amboy, NJ 08862
(201) 225-4130

Coastal Diver and
Pollution Control, Inc.
John Nasworthy
120 Brannen Drive
Savannah, GA 31410
(912) 897-2398

Creed Petroleum Equipment Maintenance
Roy Creed
23 Norwood Avenue
Charlottetown, Prince Edward Island
Canada C1A 6P7
(902) 892-6036

Crosby and Overton, Inc.
Joe Cemore
2971 Ventura Boulevard
Oxnard, CA 93030
(805) 487-3382

Crowley Environmental Services
Pat Sanborn
3400 East Marginal Way
Seattle, WA 98134
(206) 682-4898

Damco Sales and Service, Inc.
Brian McCarthy
128 23rd Street (Sharpsburg)
Pittsburgh, PA 15215
(412) 782-2987

East Coast Environmental Service
Leo Tancreti
454 Quinnipiac Avenue
New Haven, CT 06513
(203) 469-2376

Environcorp
Pierre Hardy
10700 Henri Bourassa East
Montreal, Quebec
Canada H1C 1G9
(514) 325-8810

Environmental Coastal Pollution
Cleanup Services, Inc.
Jim Weber
7158 Seminole Boulevard
St. Petersburg, FL 33542
(813) 391-9735

Environmental Emergency Services Co.
Roland Miller
P.O. Box 3320
Portland, OR 97208
(503) 285-9111 Ext. 341

Ergon Environmental Services
James Jones
P.O. Box Drawer 1639
Jackson, MS 39205
(601) 948-3472

Ferguson Harbor Service
William Ferguson
P.O. Box 8153
Nashville, TN 37207
(615) 8222-3295

Fourth Coast Pollution Control
Richard Mayette
P.O. Box 278
Waddington, NY 13694
(315) 388-5909

Giroux Enterprises Ltd.
Al Stackhouse
P.O. Box 1109
Saint John, New Brunswick
Canada E2L 4E6
(506) 693-7600

Goldston Corporation
Rick Duncan
P.O. Box 9668
Corpus Christi, TX 78469
(512) 289-1266

Great Lakes Environmental Services
Terry Begnoche
22077 Mound Road
Warren, MI 48091
(313) 758-0400

Halliburton Services, MRD
Tom Allen
P.O. Box 1431
Duncan, OK 73536
(405) 251-3619

H&H Ship Service Co.
Don McGregor
220 China Basin
San Francisco, CA 94107
(415) 543-4835

High Rise Service Co.
A. J. Simmons, Jr.
6317 Wrightsville Avenue
Wilmington, NC 28403
(919) 256-9921

Industrial Marine Service, Inc.
James Parker
P.O. Box 1779
Norfolk, VA 23501
(804) 543-5718

Inland Waters Pollution Control
Rick Prawdzik
4544 Webster
Ecorse, MI 48229
(313) 383-6310

IT Corporation
Paul Kaufman
4575 Pacheco Boulevard
Martinez, CA 94553
(415) 288-5100

Jet-Line Services, Inc.
Fred Wynn
441 Canton Street (rear)
Stoughton, MA 02072
(617) 843-2829

J&L Industries
James Szyman
6923 Ebenezer Road
Baltimore, MD 21220
(301) 488-0800

Marine and Environmental Services Ltd.
1516 Robie Street
Halifax, Nova Scotia
Canada B3H 3E4
(902) 423-2446

Marine Maintenance, Inc.
Otis Chambers
1802 Mechanic
Galveston, TX 77550
(409) 762-7785

Marine Pollution Control
David Usher
8631 West Jefferson
Detroit, MI 48209
(313) 849-2333

Marine Pollution Control
James Miller
460 Terryville Road
Port Jefferson Station, NY 11776
(516) 928-0048

Medallion-Ford Ltd.
Louis Vezina
195 Leonidas
Rimouski, Quebec
Canada G5L 2T5

Mid-Atlantic Refinery Services
Ben Santacroce
2301 Pennsylvania Avenue
Deptford, NJ 08096
(609) 589-5000

Midwest Pollution Control
Gerald Moravy
P.O. Box 530
Mt. Pleasant, MI 48858
(517) 773-6971

Moran-Crowley Environmental Services
Robert Loftus
1 World Trade Center
Suite 4971
New York, NY 10048
(212) 432-2680

Need-A-Diver Marine Service, Inc.
Thomas Pidgeon
P.O. Box 5436
Tampa, FL 33675
(813) 247-1146

New England Pollution Control
Ellie Varricchio
7 Edgewater Place
East Norwalk, CT 06855
(203) 853-1990

O. E. Durant, Inc.
Charles King
P.O. Box 673
Wilmington, NC 28402
(919) 762-7765

O. H. Materials
Robert Graziano
P.O. Box 551
Findlay, OH 45840
(419) 423-3526

Oil Mop, Inc.
Shaw Thompson
P.O. Drawer P
Belle Chase, LA 70037
(504) 394-6110

Olsen-Deane Co.
Billy Brown
1850 Walton Road
St. Louis, MO 63114
(314) 428-7870

Partridge Motorboat Services
Walter Partridge
P.O. Box 2434
Halifax, Nova Scotia
Canada B3J 3E4

Peterson Maritime Services, Inc.
Harold Pecunia
14101 Old Gentilly
New Orleans, LA 70129
(504) 254-3600

Petrochem Services, Inc.
Joseph Smith
1 West Stephens Street
Lemont, IL 60439
(312) 257-5875

Pollution Control and Ecology, Inc.
George Rezzo
P.O. Box 313
Oakmont, PA 15139
(412) 828-0670

Sam Vezina, Inc.
Jean-Paul Houde
C.P. 127
Quebec City, Quebec
Canada G1K 7A1
(418) 692-0348

Sanimobile, Inc.
J. A. Cote
666 Transcanada
St. David Levis, Quebec
Canada G6W 6M7
(418) 833-6840

Sanivan, Inc
Albert Daoust
1705 Third Avenue
Pointe-aux-Trembles, Quebec
Canada H1B 5M9
(514) 353-9170

Service Central de Reservoir, Inc.
Yves Lalonde
50 Chempetre
Montreal East, Quebec
Canada H1B 5J6
(514) 645-4543

Simpson Environmental Service
Scott Simpson
P.O. Box 903
Port Neches, TX 77651
(409) 722-9389

Spill Control Services, Inc.
Rustin Johnson
5802 River Road
Harahan, LA 70123
(504) 733-1947

Spill Recovery of Indiana
John Fetter
P.O. Box 34337
Indianapolis, IN 46234
(317) 291-3972

Sprayaway Marine Services Ltd.
Jim Gwin
5735 Dorset Street
Burnaby, British Columbia
Canada V5J 1L8
(604) 433-8020

Tricil Ltd.
Peter Colak
6785 Route 132
St. Catherine, Quebec
Canada J0L 1E0
(514) 632-6440

U.S. Pollution Control, Inc.
Mark Fuchs
2000 Classen Center
Suite 320 South
Oklahoma City, OK 73106

Vic Clouston 1982 Ltd.
Frank Armstrong
Box 9341
ST. John's, Newfoundland
Canada A1A 2Y3

Western Emergency Service
Denny Day
Box 189
Keller, TX 76248
(817) 654-5858

VECTOR ADDITION FOR

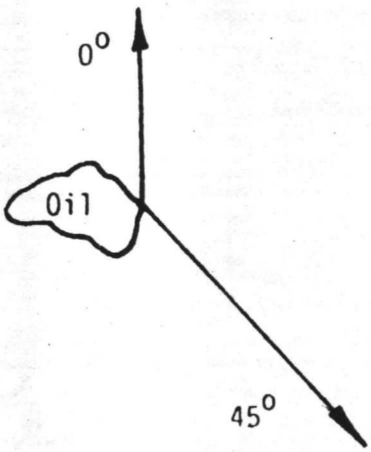
PREDICTION OF OIL SPILL MOVEMENT

1. Draw surface water current and wind vectors in their respective directions. The length of the vectors represents the velocity. Example: 0.5 knots = 1 inch

2. Draw a line parallel to the wind vector starting from the tip of the current vector and measuring the exact length of the wind vector (Figure 2, Line P).

3. Draw a line from the present slick position to the tip of Line P. This final line, called the resultant vector, gives the speed and direction of the oil slick movement. The speed is determined by the length of the resultant vector relative to the scale set in Step 1 and used in drawing the component vectors. The direction of predicted oil slick movement can be determined from compass headings.

FIGURE 1



Current 0.5 knots/hour

1 inch = 0.5 knots

Wind 20 knots/hour from NW

20 knots x 3.4% = 0.7 knots/hour

FIGURE 2

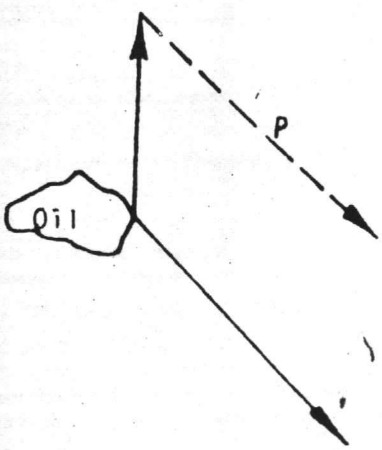
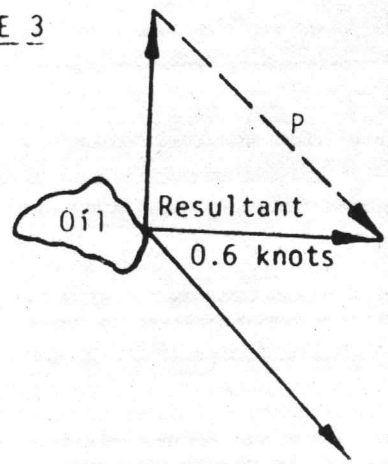


FIGURE 3



OIL AND HAZARDOUS MATERIAL CONTROL TRAINING DIVISION

Oil Spill Control Course

DAVID V. MORRIS:

EXPERIENCE:

Instructor, Oil and Hazardous Material Control Training Division 1980 through 1981. Inspector, City of Houston, Anti-Pollution Section, 1982 to 1985.

EDUCATION:

B.S., Agricultural Education, Biology (minor); Masters Degree in Agricultural Development, licensed by the Texas Department of Health in Wastewater Treatment and Water Purification. Numerous conferences and workshops relating to Oil Spill Control (API, EPS Canada) State of Texas training programs and Company training programs.

OIL AND HAZARDOUS MATERIAL CONTROL TRAINING DIVISION

Oil Spill Control Course

HARRY N. YOUNG, JR.

EXPERIENCE:

Program Coordinator, Texas A&M Oil Spill School, Galveston, Texas; Research Associate, Environmental Engineering, Texas A&M; Branch Chief of Environmental Protection Branch, U.S. Coast Guard Base, New Orleans, Louisiana; Expediter, Junior Buyer, Santa Barbara Research Center, Goleta, CA; Captain, U.S. Air Force, Procurement Officer; Lt. USCGR.

EDUCATION:

BBA, Finance: University of Miami, Florida, 1968. Coast Guard: Oil Sample Analysis, Marine Environmental Protection, Port Safety and Law Enforcement; U.S. Air Force: Procurement Officer Course, Small Purchase School, Government Contracts, Graduate Courses in Marine and Environmental area. Numerous conferences, workshops relating to Oil Spill Control including API, EPA, NOAA, and Company Training Programs.

MEMBERSHIPS:

National Environmental Training Association.

PETER F. OLSEN:

EXPERIENCE:

Instructor, Oil and Hazardous Material Control Training Division, 1980 to present. Marine Machinist Technician, Oil and Hazardous Material Control Training Division, 1977 to 1980. Guest Instructor, Fire Protection Training Division, 1977 to present. Island Marine Technician, 1974 to 1976. Power Generation Equipment Repairman, U.S. Army, 1969 to 1972. Student Teaching, 1968 to 1969.

EDUCATION:

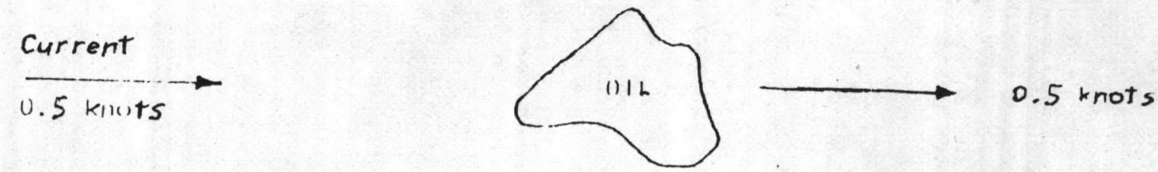
Presently enrolled - University of Houston at Clear Lake - Environmental Management. Texas A&M University - Ind. Education. Galveston College - Middle Management. University of Texas at Arlington - Civil Engineering. North Virginia Community College - Pre-Engineering. Numerous Conferences and workshops relating to Oil Spill Control including API, AMOP, MMS and various Oil Company training programs.

MEMBERSHIPS:

Hazardous Material Advisory Committee, City of Galveston; Troop Leader - Girl Scouts of America.

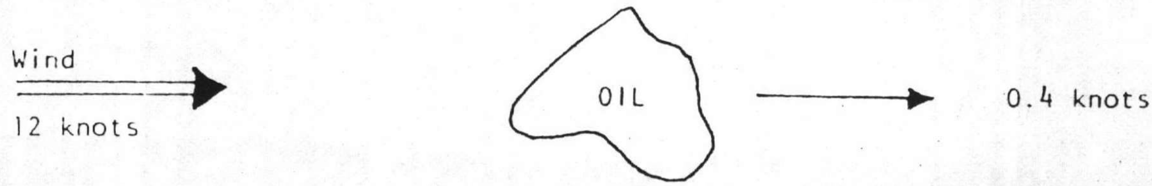
MOVEMENT OF OIL ON WATER

Example 1. Surface water currents only; no wind

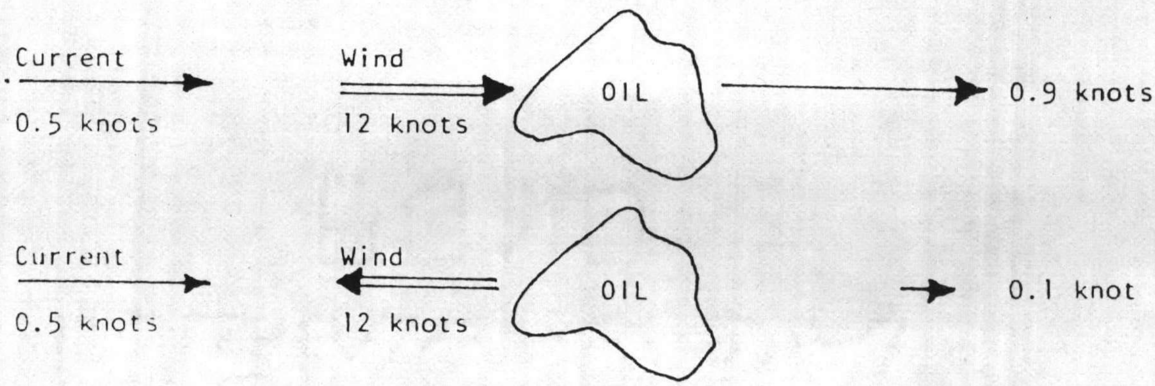


Example 2. Wind only; no currents.

12 knot wind X 3.4% = 0.4 knot wind effect on the movement of the oil



Example 3. Wind and water currents



Oil and Hazardous Material Control Training Division

C·O·U·R·S·E·S

Texas Engineering Extension Service

The Texas A&M University System

HISTORY

The Texas A&M University System became committed to oil and hazardous material control training in 1975 after receiving a grant from the American Petroleum Institute to develop a practical, hands-on oil spill control course. Since that time, the Oil and Hazardous Material Control Training Division of the Texas Engineering Extension Service has expanded its course offerings to include an Inland Oil Spill Control Course, Hazardous Material Control Course, and Tank Truck Rollover Training Course. In addition to these regularly scheduled programs, the division is also involved in site-specific extension training on both domestic and international fronts. Each course carries the appropriate number of CEU equivalents.

STAFF

All course offerings utilize highly qualified professional educators skilled in various aspects of oil and hazardous material control. Primary instructors are from the Oil and Hazardous Material Control Training Division of the Texas Engineering Extension Service. Programs are frequently augmented by guest lecturers from industry and governmental agencies.

BASIC PROGRAM PHILOSOPHY

Practical, hands-on experiences provide the underpinnings of these various training programs. It is generally acknowledged that course attendees learn and retain more through active participation. Curricula are designed to cover basic knowledge in a traditional classroom setting while field exercises provide realistic exposure to a wide variety of situations.

General Information

Tank Truck Rollover Training

Hazardous Material Control

Inland Oil Spill Control

Oil Spill Control

On-Site Extension Training

Course Schedules/Registration Forms

LOCATION

The 2½-day Tank Truck Rollover Training Course is offered regularly at Brayton Firemen Training Field in College Station, Texas. Training aids include a specially outfitted tank trailer, lifting bags, and numerous tank truck appurtenances designed to provide extensive hands-on training capabilities for each participant.

OBJECTIVES

The purpose of the Tank Truck Rollover Training Course is to provide participants with basic knowledge of the valves, venting systems, and appurtenances common to tank truck operations. Personnel safety, monitoring and detection equipment, and control and offloading strategies are emphasized. Basic information is covered in a classroom environment and reinforced through hands-on training and use of equipment, including a specially-outfitted tank trailer. Students learn proper techniques of offloading, stabilizing, and uprighting disabled vehicles in addition to spill containment and recovery operations. Following the completion of the course, each participant is awarded a certificate.

CLASSROOM SESSIONS

General Response Procedures
Tank Truck Construction and Design
Personnel and Site Safety
Valves, Venting Systems, and Tank Truck Appurtenances

FIELD OPERATIONS

Stabilizing Leaking Tank Trucks
Offloading Procedures
Protective Clothing
Emergency Containment Operations
Uprighting Disabled Vehicles

Tank Truck Rollover Training

Hazardous Material Control

Inland Oil Spill Control

Oil Spill Control

On-Site Extension Training

Course Schedules/Registration Forms

LOCATION

The five-day Hazardous Material Control Course is conducted throughout the year at special facilities at Brayton Firemen Training Field in College Station, Texas. Training aids and mock-ups such as railcars and tank trucks provide excellent hands-on capabilities during the training program.

OBJECTIVES

The purpose of the Hazardous Material Control Course is to provide participants with the basic knowledge and information necessary for responding to or assisting with the various operations surrounding a hazardous material incident. General concepts of hazardous material response are covered in a classroom setting. Through hands-on exercises and demonstrations, participants are given an opportunity to further enhance their skills under realistic conditions. On Thursday of each course week, participants organize their own response groups and respond to a simulated incident. The groups' actions are videotaped for playback in a later critique session. Following the completion of the course, each participant is awarded a certificate.

CLASSROOM SESSIONS

Properties of Hazardous Materials
Protective Clothing and Equipment
Monitoring and Detection Devices
Containment, Recovery, and Treatment of Hazardous Materials
Patching and Stabilizing Leaking Containers
Sources of Aid and Assistance
Chemical Agents and Sorbents for Controlling Hazardous Material Spills
Toxicology
Contingency Planning Problem Sessions
Orientation for Spill Simulation and Videotape Critique

FIELD OPERATIONS

Working in a Hazardous Environment
Self-Contained Breathing Apparatus and Encapsulated Suits
Control of Flammable Gases
Handling Pyrophoric Materials
Containment and Cleanup of Hazardous Material Spills
Decontamination and Overpack Procedures
Response to a Simulated Hazardous Material Spill

Hazardous Material Control

Inland Oil Spill Control

Oil Spill Control

On-Site Extension Training

Course Schedules/Registration Forms

6. preplan arrangements for additional support equipment and supplies not readily available;
7. establish plans for an effective communications network during a spill;
8. meet legal requirements for properly reporting oil spills;
9. effectively handle the public relations aspects and be aware of the legal implications at the spill scene.

Following the completion of the course, each participant is awarded a certificate.

CLASSROOM SESSIONS

Initial Spill Response
Reporting and Government Agencies
Properties of Oil that Affect Recovery
Containing Oil on Water
Recovering Oil on Water
Containing and Recovering Oil in Icy Waters
Shoreline Protection, Cleanup, and Restoration
Oil in Surface and Subsurface Soil
Oil in Groundwater
Physical and Chemical Treatment of Oil
Debris Disposal
Oil in the Environment
Documentation
Security, Damage Claims, and Public Relations
Contractors
Past Experiences
Training for Response Team

FIELD OPERATIONS

Initial Spill Response
Booms in Lakes and Streams
Booms in Rivers
Skimmer Operations
Moving Oil on Water
Sorbents and Chemical Agents
Recovering Underground Oil Spills
Oil Spill Simulation Exercise

LOCATION

The Inland Oil Spill Control Course is conducted at Brayton Firemen Training Field in College Station, Texas. The course emphasizes the control of oil spills in an inland environment and utilizes field facilities centered around a freshwater lake and a small running creek. Oil spills on open ground and into underground water supplies are also covered.

OBJECTIVES

The Inland Oil Spill Control Course is designed to provide participants with information and training necessary for handling an oil spill within the capabilities of available equipment and manpower. Students learn to work efficiently within the framework of the law, enhancing their effectiveness under various spill conditions and minimizing spill damage and expense. At the close of the course, each student should be able to:

1. recognize potential spill situations;
2. modify and update existing contingency plans to enhance their effectiveness;
3. establish a supervisory team to implement the contingency plan;
4. organize, train, and direct a response team;
5. recommend and direct the use of proper oil spill control equipment such as skimmers, booms, sorbents, and other tools;

Inland Oil Spill Control
Oil Spill Control
On-Site Extension Training

Course Schedules/Registration Forms

LOCATION

The five-day Oil Spill Control Course is conducted regularly at special facilities on Pelican Island in Galveston, Texas. This program, while covering oil spill control activities in general, utilizes a coastal marine setting for its actual field training.

OBJECTIVES

The Oil Spill Control Course is designed to provide participants with the information and training necessary to handle an oil spill within the capabilities of available equipment and manpower. Students learn to work efficiently within the framework of the law, enhancing their effectiveness under various spill conditions and minimizing spill damage and expense. At the close of the course, each student should be able to:

1. recognize potential spill situations;
2. modify and update existing contingency plans to enhance their effectiveness;
3. establish a supervisory team to implement the contingency plan;
4. organize, train, and direct a response team;
5. recommend and direct the use of proper oil spill control equipment such as skimmers, booms, sorbents, and other tools;
6. preplan arrangements for additional support equipment and supplies not readily available;
7. establish plans for an effective communications network during a spill;
8. meet legal requirements for properly reporting oil spills;
9. effectively handle the public relations aspects and be aware of the legal implications at the spill scene.

Following the completion of the course, each participant is awarded a certificate.

CLASSROOM SESSIONS

- Contingency Planning; Training the Response Team; Security, Damage Claims, and Public Relations; Movement, Containment, and Cleanup of Oil; Reporting and Documenting Oil Spills
- Communications Equipment
- Oily Debris Disposal
- Boom and Skimmer Design
- Oil Spill Cleanup Contractors and Cooperatives
- Aerial Surveillance
- Sorbents and Chemical Agents
- Properties of Oil Affecting Recovery
- Oil in the Environment
- Preventing Oil Spills
- Past Experiences in Oil Spill Control

FIELD OPERATIONS

- Boat Safety and Handling
- Boom Deployment
- Boom Tending
- Skimmer Operations
- Oil Sampling and Documenting Techniques
- Sorbent and Chemical Agents
- Moving Oil on Water
- Spill Simulation Exercise
- Methods of Recovering Underground Spills
- Oil Spill Simulation Exercise

Oil Spill Control

On-Site Extension Training

Course Schedules/Registration Forms

LOCATION

Special courses in Oil Spill Control, Tank Truck Rollover Training, and Hazardous Material Control are offered upon request on an extension basis both in-country and overseas. Courses have been conducted throughout the United States and in overseas locations, including Nigeria, Singapore, Rotterdam, England, and Malaysia.

OBJECTIVES

The primary objective of such site-specific programs is to provide practical training to personnel at their locations utilizing their available equipment and resources. This arrangement affords maximum benefits to personnel by training them within their usual working environments and under constraints typically found at their workplaces.

PROCEDURE

Each of the regularly offered courses is available on an extension basis. Special combination programs as well as other custom designed training activities are also available upon request.

Custom extension programs are usually conducted in three phases. First an actual on-site visit is conducted by the course instructor in an effort to evaluate the working environment and to gather specific information that will help in designing a special program for the personnel at that location. The second phase involves Oil and Hazardous Material Control Training Division personnel designing and developing a complete program (including curriculum, visual aids, and notebooks) subsequent to the preliminary site assessment visit. The third and final phase involves a team of instructors returning to the site to conduct the specially tailored training program. As with the regularly offered courses, certificates of completion are awarded for these extension programs.

On-Site Extension Training

COURSE SCHEDULES

TANK TRUCK ROLLOVER

HAZARDOUS MATERIAL CONTROL

Course Schedules/Registration Forms

COURSE SCHEDULES

TANK TRUCK ROLLOVER

1986

April 15	August 26
May 6	October 1
August 12	October 28

1987

January 21	June 3
February 2	June 29
February 18	August 19
March 30	September 23
April 13	October 7
April 22	October 28
May 13	December 14

HAZARDOUS MATERIAL CONTROL

1986

April 7	August 18
April 21	September 8
April 28	September 22
May 12	October 13
May 19	October 20
May 28	November 10
June 2	November 17
June 9	December 8
June 23	December 15

1987

January 12	June 15
February 9	June 22
February 23	August 10
March 23	September 14
April 6	September 28
April 27	October 12
May 4	October 19
May 18	November 2
May 25	November 16
June 8	December 7

INLAND OIL SPILL

1986

April 14
April 28
September 15
September 29
October 13
November 10

1987

February 23
March 23
May 4
June 1
September 28
October 26
November 9

OIL SPILL

1986

April 1
April 7
May 6
May 12
May 19
June 23
July 21
August 25
September 8
September 29
October 20
November 4
November 17
December 1

1987

January 12
January 28
March 2
March 30
April 13
May 11
May 18
June 8
June 23
July 6
July 20
July 27
August 3
August 18
September 21
October 5
November 2

Course Schedules/Registration Forms

College Station, Texas 77843-8000 • (409) 845-3418 • Telex 762966

COMMUNICATIONS

ALERTING SYSTEMS

TELEPHONE OR RADIO PAGING