Coping With an Oiled Sea

March 1990

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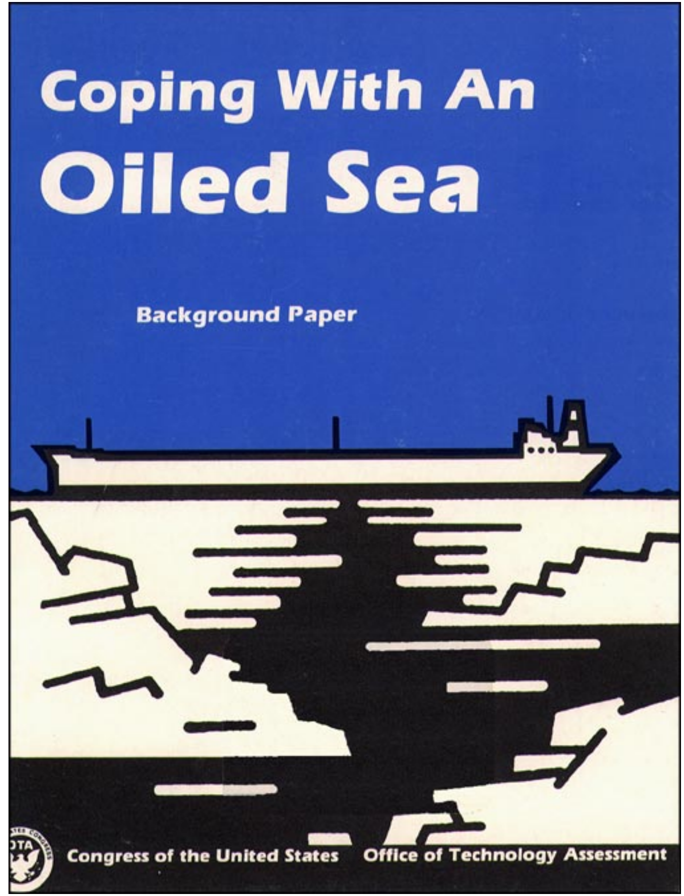

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Foreword

In the aftermath of the Exxon *Valdez* oil spill in Alaska in March, 1989, a myriad of investigations were initiated to evaluate the causes of that accident and to propose remedies. The Office of Technology Assessment was asked to study the Nation's oil spill clean-up capabilities and to assess the technologies for responding to such catastrophic spills in the future. The request for this study came from Senator Ted Stevens, a member of the Technology Assessment Board, and from Congressman Billy Tauzin, Chairman of the Subcommittee on Coast Guard and Navigation of the House Committee on Merchant Marine and Fisheries. This background paper presents the results of OTA's analysis. It discusses the current technologies and capabilities in the United States and abroad and evaluates the prospects for future improvements.

Cleaning up a discharge of millions of gallons of oil at sea under even moderate environmental conditions is an extraordinary problem. Current national capabilities to respond effectively to such an accident are marginal at best. ***OTA's analysis*** shows that improvements could be made, and that those offering the greatest benefits would not require technological breakthroughs –just good engineering design and testing, skilled maintenance and training, timely access to and availability of the most appropriate and substantial systems, and the means to make rapid, informed decisions. One must understand, however, that even the best national response system will have inherent practical limitations that will hinder spill response efforts for catastrophic events– sometimes to a major extent. For that reason it is important to pay at least equal attention to preventive measures as to response systems. In this area, the proverbial ounce of prevention is worth many, many pounds of cure.

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Chapter 1
Overview

The March *24, 1989 Exxon Valdez* oil spill in Prince William Sound, Alaska dramatically illuminated the gap between the assumed and actual capability of industry and government to respond to catastrophic oil spills. There are many reasons why this gap wasn't better appreciated before March 24: elaborate oil spill contingency plans had been prepared and approved; oil spill equipment had been developed and stocked; major damaging spills had occurred infrequently, and almost never in the United States; and a nebulous faith had existed that technology and American corporate management and know-how could prevent and/or significantly mitigate the worst disasters.

The *Exxon Valdez* accident shattered this complacency. In the aftermath of the spill a small army of people has been put to work around the country studying how the United States can do a better job preventing spills and how it can be better prepared to fight one that does occur. In this background paper, OTA examines the state-of-the-art of oil spill technologies and response capabilities. On an encouraging note, it appears that improvements can be made in oil spill cleanup technology and, perhaps even more, in the way we organize ourselves to apply the most appropriate technologies to fight oil spills. Such improvements should result in a reduced risk of significant damage from a major spill in the future.

However, the unfortunate reality is that, short of eliminating oil transportation at sea entirely, there is no perfect solution to offshore oil spills. **It is certain that oil spills will occur again.** If improvements in prevention technology are made, the frequency of major spills may decrease, but improvements are unlikely to eliminate oil spills entirely, and a very large spill under adverse conditions could still overwhelm our capacity to respond effectively. Even using the best technology available and assuming a timely and coordinated response effort, it is not realistic to expect that a significant amount of oil from a major offshore spill could be recovered, except under the most ideal conditions. **Historically, it has been unusual for more than 10 to 15 percent of oil to be recovered from a large spill,** where attempts have been made to recover it. With improvements in technology and response capability, it should become feasible to do much better, but it is unlikely that technical improvements will result in recovery of even half the oil from a typical *large* spill.

It is not feasible to be prepared for all contingencies: each oil spill is unique in terms of location, weather, oceanographic conditions, time of occurrence, characteristics of the oil, equipment available, and experience of response personnel. Accidents are unpredictable. They may be caused by "acts of God" or human error, both of which are impossible to fully anticipate or control. The ideal conditions in which cleanup technology would be most effective rarely occur in the real world.

The U.S. industry has concentrated its efforts in developing technology to fight the numerous small spills in harbors and protected waters. On the one hand, industry has oversold its ability to fight major spills, and the government has largely relied on private capabilities; on the other, the public's expectation about what can be accomplished once a major spill has occurred has been too high. *Prevention* of major spills, although beyond the scope of this study, must be a high priority.[2]

[1] For the purposes of this report the terms "catastrophic," "major)" and "large offshore" spills refer to discharges in excess of 1 million gallons of oil that occur in open waters subject to rough seas, high currents, or other adverse environmental factors.

[2] For a detailed discussion of prevention measures, see U.S. Congress, Office of Technology Assessment, *Oil Transportation by Tankers: An Analysis of Marine Pollution and Safety Measures* (Washington, DC: U.S. Government Printing Office, July 1975).

It is important to put the environmental impacts of a major oil spill into perspective. Such a spill is indeed a catastrophe, but oil spills are not the worst type of pollution with which Federal and State authorities have to deal. In terms of threats to human health and persistence in the environment, spills of hazardous chemicals or radioactive waste can be far larger problems, and accidents involving dangerous materials can cause significant loss of life. Nevertheless, it is a serious problem when a large quantity of oil is spilled in a coastal or near-coastal area. The public is particularly concerned about large spills in sensitive areas because the effects on the local ecosystem are acute, often initially devastating both to biota and economic activities. Oil can be toxic to organisms that come into contact with it and can cause major problems with recreational or other uses of coastal regions, such as commercial fishing in Alaska. If large amounts of oil reach the shore, the oil may persist for long periods, even though natural degradation mechanisms do assist recovery.[3]

As bad as the *Exxon Valdez* accident was, it could have been far worse: **only about one-fifth of the crude oil the tanker was carrying was released.** Fortunately, the rest was off-loaded. The Amoco Cadiz did spill its entire cargo off the coast of France in 1978, a cargo roughly the same size as that carried by the *Exxon Valdez*.[4] Significantly, neither the oil industry, the Federal Government, nor the State of Alaska were prepared to deal with a spill the size of the *Exxon Valdez* spill. It was fortunate, in a sense, that the spiller in this incident was a major international oil company capable of marshaling significant resources, rather than a small tanker company.

[3] In 1974 *the* supertanker *Metula* spilled some 16.2 million gallons of oil after grounding in the Strait of Magellan. Essentially, no cleanup occurred and at least half of the oil lost washed onto about 50 miles of shoreline. A study by the National Oceanic and Atmospheric Administration about 6 years after the spill concluded that much of the oil remained in sediments, along beaches, and in marshes. In heavily oiled, sheltered areas, it seems likely that the oil will persist for more than 100 years.

[4] The *Amoco Cadiz* spill released 66.4 million gallons of light crude oil off the Brittany coast in France. Prevailing winds kept the slick near the coast for 1 month, eventually oiling about 200 miles of coastline. In a 19S5 report, *Oil in the Sea,* the National Research Council estimated that it would take decades before the environment recovered.

Chapter 2

Findings

The Exxon *Valdez* accident was the largest spill (about 10.8 million gallons or 35,000 tons) in U.S. history. Not since the Santa Barbara oil spill 20 years earlier has as much public concern been voiced about the inability of government and industry to respond effectively to large oil spills. Although such spills have occurred worldwide at the rate of 3 to 5 per year since the *Torrey Canyon* accident off England in 1967, many of these (table 2-1) have escaped U.S. attention. This OTA study is *not* directed at an evaluation of what went wrong with the *Exxon Valdez* but is focused on the response capabilities (or lack thereof) that were brought to bear in the Exxon *Valdez* spill, as well as in other large offshore spills.

Two factors are important to the question of why public and private oil spill response capabilities seem so limited today. First, very large accidents and catastrophic oil spills have not occurred very often in U.S. waters. The last major tanker spill near the United States was the *Alvenus* spill off the Gulf Coast in 1984. It was about one-third the size of the *Exxon Valdez* spill, and, even though a large portion of the 2.7 million gallon spill was deposited on Texas beaches, the type of oil and the local conditions were such that beach cleanup was reasonably effective. Second, many believed that the responsible industry and government agencies were prepared. The exhaustive contingency plans appeared to be evidence of the preparation and demonstration of adequate capabilities.

In the light of actual events, the response capabilities of both government and private entities proved inadequate for an *Exxon Valdez* type of accident. It is also clear that the few other large offshore spills that have occurred in U.S. coastal waters in the past 10 to 15 years have mostly escaped public attention, largely because natural events dispersed or mitigated the impacts. One spill caught fire, burning most of the oil; others happened where favorable winds and currents carried and dispersed most of the oil to the open seal

Photo credit: U.S. Coast Guard

The Exxon Valdez, flanked by two tugboats, in Prince William Sound.

Many people have asked how can we be so ill-prepared for massive oil spills in the modern world of high technology. Perhaps the United States has not given attention to developing appropriate technology in this arena; maybe we haven't made needed investments in research; or maybe management of the response was just inept.

This OTA study addresses the question of technological promises and limitations. The technology now available for oil spill cleanup in the United States and overseas has many limitations affecting capabilities in real world situations. This has resulted in only very small percentages of actual cleanup for almost all past major ocean spills. Some sources claim that the most oil that can be recovered

I In the *Burmah Agate* accident off the Gulf Coast in 1979, the oil caught fire and resulted in most of the spill burning up. In the *Argo Merchant* spill off New England in 1976, the offshore winds carried almost all of the oil out to sea and it was dissipated in the open ocean.

Table 2-1 -Large Oil Spills: A List of 66 Spills Greater Than 2 Million Gallons, 1967 to Present

No.	Date	Spill	Location	Volume (millions of gallons)	Ref(s)
1	1979-1980	Ixtoc 1, Well Blowout	Mexico	139-428*	abgh
2	1983	Nowruz Oil Field, Well Blowout(s)	Persian Gulf	80-185	ab
3	1983	Castillo de Beliver/Broke, Fire	South Africa	50-80'	abe
4	1978	Amoco Cadiz/Grounding	France	67-76	abfhm
5	1979	*Aegean Captain/Atlantic Empress*	Off Tobago	49*	abl
6	1980-1981	D-103 Libya, Well Blowout	Libya	42	a
7	1979	Atlantic *Empress/Fire*	Barbados	41 .5*	abl
8	1967	*Torrey* Canyon/Grounding	England	35.7-38.6*	bcf
9	1980	*Irenes Serenade/Fire*	Greece	12.3-36.6*	am
10	1972	*Sea* Star/Collision, Fire	Gulf of Oman	35.3*	bf
11	1981	Kuwait Nat'l Petroleum Tank	Kuwait	31.2	a
12	1976	Urquiola/Grounding	Spain	27-30.7'	bf
13	1970	Othello/Collision	Sweden	18.4 -30.7	bcf
14	1977	*Hawaiian* Patriot/Fire	N Pacific	30.4*	bf
15	1979	*Independents*	Turkey	28.9	a
16	1978	*No.* 126 Well/Pipe	Iran	28	a
17	1975	*Jakob Maersk*	Portugal	25*	f
18	1985	BP Storage Tank	Nigeria	23.9	a
19	1985	Nova/Collision	Iran	21.4	a
20	1978	BP, Shell Fuel Dept.	Zimbabwe	20	a
21	1971	Wafra	South Africa	19.6*	cf
22	1989	Kharg 5, Explosion	Morocco	19	g
23	1974	Metula/Grounding	Chile	16	cf
24	1983	Assimi/Fire	off Oman	15.8*	a
25	1970	*Polycommander*	Spain	3-15.3	c
26	1978	Tohoku Storage Tanks, Earthquake	Japan	15	a
27	1978	*Andros Patria*	Spain	14.6	a
28	1983	*Pericles GC*	Qatar	14	a
29	1985	Ranger, TX, Well Blowout	Texas	6.3-13.7	bk
30	1968	*World* Glory/Hull Failure	South Africa	13.5	bcf
31	1970	*Ennerdale/struck* Granite	Seychelles	12.6	cf
32	1974	Mizushima Refinery, Tank Rupture	Japan	11.3	cdf
33	1973	*Napier*	SE Pacific	11*	f
34	1980	*Juan A. Lavalleja*	Algeria	11	a
35	1989	*Exxon* Valdez/Grounding	Alaska	10.8	i
38	1978	Turkish Petroleum Corporation	Turkey	10.7	a
37	1979	Burmah Agate/Collision, Fire	Texas	1 .3-10 .7*	abc
38	1971	*Texaco Oklahoma,* 120 mi. offshore	North Carolina	9.2-10.7	cf
39	1972	*Tinder*	Mediterranean	10.4	f
40	1976	*St. Peter*	SE Pacific	10.4	f
41	1977	*Irene's Challenge*	Pacific	10.4	f
42	1972	*Golden Drake*	NW Atlantic	9.5	f
43	1970	*Chryssi*	NW Atlantic	9.5	f
44	1969	Pacocean/Broke in two	NW Pacific	9.2	f
45	1977	*Caribbean Sea*	E Pacific	9.2	f
46	1976	*Grand* Zenith/Disappearance	NW Atlantic	8.9	f
47	1976	Cretan star	Indian Ocean	8.9	f
48	1969	Keo/Hull failure	Massachusetts	8.8	bf
49	1969	Storage Tank	New Jersey	8.4	b
50	1977	Ekofisk Bravo, Well Blowout	North Sea	4.6-8.2	bf

a. A List of the 20..., 1989.
b. Reuters, 1989.
c. Van Gelder-Ottway..., 1976.
d. A Basic Spill..., 1981.
e. Lord et al., 1987.
f. Butler, 1978.
g. Woods and Hannah, 1981.
h. Teal and Howarth, 1984.
i. Caleb Brett, 1989
j. Ganten, 1985.
k. Quina et al., 1987.
1. Horn and Neil, 1981.
m. Bao-Kang, 1987.
n. Tracey, 1988.
0. Ocean Industry, 1980.
p. NRC, 1975.
q. Journal of Commerce, 1/4/90.

Tinker spills from the Iran/Iraq war were not generally available

• Fire burned part of spill

SOURCE: Exxon Corp and Office of Technology Assessment

Table 2-1- Large Oil Spills: A List of 66 Spills Greater Than 2 Million Gallons, 1967 to Present (Continued)

No.	Date	Spill	Location	Volume (millions of gallons)	Ref(s)
51	1972	*Giuseppi Guilietti*	NE Atlantic	8	f
52	1977	Venpet and Venoil/Collision	South Africa	7.4-8	ef
53	1976	Argo Merchant/Grounding	Massachusetts	7.7	bfh
54	1967	Humble Oil Pipeline, Offshore Leak	Louisiana	6 7	n
55	1973	*Jawacta*	Baltic Sea	6.1	c
56	1967	*R.C. Stoner*	Wake Island	6	c
57	1970	*Marlena*	Sicily	4.3	c
58	1970	Pipeline	Saudi Arabia	4.2	c
59	1971	Oil Well	Persian Gulf	4,2	c
60	1980	Tanio/Broke amidships	France	4.2	j
61	1988	Ashland Storage Tank, Rupture	Pennsylvania	3.8	b
62	1969	Santa Barbara Channel, Well Blowout	California	1.4-3,4	dfp
63	1970	Arrow/Grounding	Nova Scotia	1.5-3.1	ch
64	1970	Storage Tank	Pennsylvania	3	c
65	1984	Alvenus/Grounding	Louisiana	2.8	b
66	1970	Offshore Platform, Well Blowout	Louisiana	2.7	c

a. A List of the 20..., 1989.
b. Reuters, 1989.
c. Van Gelder-Ottway..., 1976.
d. A Basic Spill..., 1981.
e. Lord et al., 1987.
f. Butter, 1978.
g. Woods and Hannah, 1981
h. Teal and Howarth, 1984.
i. Caleb Brett, 1989
j. Ganten, 1985.
k. Quina et al., 1987.
I. Horn and Neil, 1981.
m. Bao-Kang, 1987.
n. Tracey, 1988.
0. Ocean Industry, 1980.
p. NRC, 1975.
q. Journal of Commerce, 1/4/90.

Tanker spills from the Iran/Iraq war were not generally available

• Fire burned part of spill

SOURCE: Exxon Corp and Office of Technology Assessment

after a major spill is 10 to 15 percent.[2] OTA obtained data from several documented open ocean large tanker spills that show the actual oil recovered at sea hasbeen less than 10 percent of oil discharged –usually much less. Probably between 6 and 8 percent of the oil spilled by the Exxon *Valdez* was recovered at sea,[3] although, as of this writing, Exxon is still in the process of developing a recovery estimate. Under the best conditions, with the best technology, with technology that is immediately available, and with the ablest organization, cleanup capabilities could be substantially improved. However, technical experts have widely ranging views on the magnitude of potential improvements, mainly because the best conditions seldom occur in the real world.[4]

Many claim that techniques other than mechanical recovery could be used to mitigate the effects of a large offshore oil spill without actually picking up the oil. These techniques include use of dispersants and burning. In fact these other techniques have seldom been used successfully. In some cases public concerns about side effects have prevented their use (these include possible toxic effects of dispersed oil and air emissions from burning oil). In other cases, sea conditions or the condition of the spilled oil have resulted in poor performance of these techniques.

[2]U.S. General Accounting Office, Adequacy of Preparation and Response to *Exxon Valdez* Oil Spill, October 1989.

[3]Walter Parker, Alaska Oil Spill Commission, personal communication, Feb. 12, 1990.

[4]At OTA's Oil Spill workshop in August 1989, several experts agreed that the high end of recovery capabilities for large ocean spills might hypothetically reach more than 30 percent with the best technology.

The main question, therefore, is what improvements could be expected if new technologies or techniques were employed in the future. This OTA study has concluded that improvements could be made and that the most obvious improvements would not require any technological breakthroughs-just good engineering design and testing, good maintenance and training, timely access to the most appropriate systems, and rapid, informed decisions. The improvements that can be made, however, also have limitations, and the inherent practical difficulties of recovering oil from the ocean will always hinder spill response efforts, sometimes to a major extent.

The key findings from this OTA evaluation are summarized below:

- Mechanical containment and recovery is the primary U.S. oil spill response method. The technology currently available for mechanical oil spill cleanup has many limitations, and only very small percentages of oil have been cleaned up from most major spills. While new designs have appeared over the years, the basic technology has not changed in the past decade.
- Current mechanical containment and recovery technology (especially that available in the United States) is not usually effective in waves greater than 6 feet, winds greater than 20 knots, and currents greater than 1 knot (perpendicular to a boom). Wind and current conditions in U.S. port areas, not to mention offshore areas, often exceed these limits, leaving little margin for the effective use of existing mechanical equipment.
- Improvements in mechanical recovery technologies that can be expected from stepped-up research and development efforts are unlikely to result in dramatic increases in total oil recovered from a catastrophic spill. In general, the improvements that are likely to offer greater effectiveness for large offshore spills involve larger, more costly equipment, strategically located for quick response.
- One prospect for reducing the high cost of more effective containment and recovery equipment for large spills is to employ dual purpose vessels. Army Corps of Engineers' dredges, for example, could be designed or retrofitted with oil spill recovery equipment, and be on call to fight spills as needed. Commercial barges, Coast Guard vessels, and other vessels of opportunity may also be employed. Such an approach may also offer the advantage of keeping more equipment in strategic locations.
- Dispersants, like mechanical cleanup methods, have their place as an oil spill countermeasures tool. Greater use of dispersants has been hampered in part by concerns about toxicity and in part by concerns about effectiveness. Currently available dispersants are less toxic than the oil they dispersers but dispersed oil can be toxic until it breaks down or is diluted sufficiently, and it will impact a greater fraction of the water column (or the sea bottom if used in shallow water) than undispersed oil. Dispersant use may involve a trade-off between the environmental effects of a treated oil slick with the shoreline impacts of an untreated one.
- The effectiveness of dispersants is perhaps of more concern than their toxicity. A number of experts disagree about the effectiveness of dispersants, and there is as yet no reliable method to test effectiveness in field operations. Although

[5] National Research Council, *Using Oil Spill Dispersants on the Sea* (Washington, DC: National Academy Press, 1989), p. 3.

some currently available dispersants have proved effective in ideal situations, ideal conditions rarely exist in the real world. Research to improve dispersant effectiveness is continuing and appears to be producing some encouraging results.

- Abroad, some countries rely almost exclusively on mechanical cleanup methods (e.g., Norway and the Netherlands), while others (e.g., the United Kingdom) rely almost exclusively on dispersants. Some countries have much larger mechanical systems than those currently available in the United States (e.g., dual purpose dredges in the Netherlands) and thus have much greater capacities for high volume recovery. Different policies regarding the use of mechanical methods are due largely to different physical conditions in each country; different dispersant policies relate to varying perceptions about their effectiveness and toxicity.
- In situ burning of spilled oil appears to have merit in certain spill situations, especially if the oil can be contained and thickened with the use of fireproof booms. This technique is not currently an important oil spill countermeasure but is being investigated further in the United States. Some experiments have resulted in high burn percentages and thus high removal rates. Nevertheless, burning is probably also limited in its applications. Igniting and keeping a slick burning may be a problem in some circumstances; in others, burning may jeopardize the stricken vessel and any oil remaining on board– oil which might otherwise be off-loaded; and the resultant visible air pollution (which must, however, be balanced against the invisible air pollution caused by allowing evaporation of the toxic volatile components of the oil) may be unacceptable.
- Despite the shortcomings of all existing countermeasure approaches, each may have applications in certain situations. There is no one general solution to an oil spill. Many technologies may be very effective in certain applications but completely inappropriate in others. Regardless of the technique(s) employed, the effectiveness of the response will be greatly enhanced if there is a rapid response by a professional response team that understands which techniques are best under which conditions. The speed of a response is critical and is dependent on rapid decisionmaking, logistics, and training.

  Decisionmaking: If important decisions, such as how to deploy mechanical equipment and whether to use dispersants, are not made within the first few hours after a major spill, the spill may be beyond effective control. Rapid decisionmaking is difficult in the United States, in part because oil companies have the responsibility to clean up major spills but not the authority to use all means they deem appropriate. Rapid decisionmaking could be enhanced if the government were responsible for combating major vessel spills, as is the case inmost European countries; if authority within the government were more centralized; and if, through more thorough contingency planning, a greater number of decisions could be made without delay.

  – *Logistics:* Having the right equipment on scene when needed is essential to a rapid response. Equipment may either be strategically located or rapidly moved to the spill site, but in either case the recovery effort will only be as good as the weakest link in the system. Response system elements such as adequate ships or barges to accept recovered oil, temporary storage sites, and a means to dispose the recovered oil are often crucial to a successful operation and are often ignored.

– *Training:* A career track for oil spill response professionals does not now exist in the Federal Government. With the Coast Guard rotation system currently in effect, operational expertise is hard to come by, and even if developed, maybe lost before required. The establishment of a trained professional cadre to fight oil spills throughout the country (and perhaps abroad too) could make a significant difference in the government's ability to respond rapidly to spills. To be effective, professional training must include the conduct of periodic exercises and contingency plan testing.

- The response to a major spill would be more rapid and efficient if certain regulations could be waived or streamlined. Regulations that are appropriate under normal operating procedures but which may cause unnecessary delay in emergency situations include: 1) Clean Water Act restrictions that prohibit the decanting of oily water collected during cleanup operations, and 2) Jones Act restrictions that restrict the use of available foreign vessels without a waiver.

- The oil industry, through a new Petroleum Industry Response Organization (PIRO), proposes to establish 5 or more regional oil spill response centers and claims it could endow each with the capability to fight a 30,000-ton (about 9 million gallons) spill. In January 1990 the PIRO Steering Committee recommended adoption of this proposal with a 5-year budget of almost $400 million and membership by 20 oil companies. This is a worthwhile concept and could bring about a major increase in U.S. capabilities when implemented. However, industry and the appropriate Federal agencies must work together to devise an efficient, integrated approach to fighting major oil spills. The benefits of the regional center approach could be enhanced if the specific organization, function, and outfitting of each center were jointly determined. Also, if the government continues to rely on private resources for spill response, it must carefully monitor the availability and capability of those resources.

- Increased R&D on oil spill response technologies will likely yield incremental benefits. Important problems can be better understood, but technological breakthroughs that would result in major improvements in mechanical cleanup capabilities are unlikely. The most important problems have to do with 1) providing technical backup for decisions on use of techniques such as dispersants and other chemicals, 2) developing technical standards based on full-scale tests of capabilities of specific equipment, and 3) sound engineering design and construction of substantial and reliable systems in enough quantities to meet performance requirements for oil recovery under real world operating conditions.

- One aspect of future technical improvements – that of pollution prevention – may provide significant benefits to the overall oil spill problem. While many have advocated this as an area needing attention, it has not been included in the scope of this OTA study. A 1975 OTA study (ref. 2, chapter 1) addresses this issue and an on-going National Academy of Sciences/National Research Council study is investigating the current situation with regard to the double-bottom, double-hull issue.

- Given the difficulty of containing and cleaning up a catastrophic spill at sea, many have advocated more attention to techniques that would protect priority coastal areas (e.g., booms). OTA has *not* found evidence that shoreline protection has been effective except under ideal weather conditions. Efforts are probably needed, however, to improve capabilities of protective systems and to assure the availability of the best equipment.

Chapter 3
Oil Spill Response Technologies

INTRODUCTION

The capability to respond effectively to a major offshore oil spill is a combination of three principal factors:

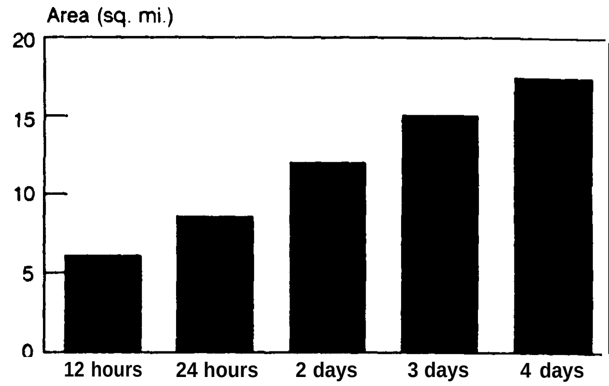
1. the physical conditions at the time of the accident or spill;
2. the suitability, capacity, and availability of the technology deployed to fight the spill; and
3. the skills, training, readiness, and decisionmaking capabilities of the organizations and people with responsibilities for combating the spill.

This OTA study focuses on the second factor while recognizing the major influences of the other two and how they interact.

Adverse physical conditions that may be present at any spill site always contribute to the difficulty of responding efficiently and effectively. Some of the key conditions that affect a response effort include:

Spreading of Oil. Oil spilled on the water spreads rapidly. The spreading rate depends on the type of oil, its volume, wind and sea conditions, and the amount of weathering that occurs. Figure 3-1 shows the effect of spreading for calm water conditions and uniform slick thickness–not necessarily real world conditions. It can be seen that, for an *Exxon Valdez* type of spill, the oil can spread over 6 square miles (almost 4,000 acres) during the first 12 hours.[1] The huge area encompassed by a large spill means substantial amounts of equipment are needed to respond. Spreading also enhances evaporation and solution of the oil by creating a large active surface area. In addition, an oil slick tends to fragment into a number of smaller patches with time, and thus, even larger total surface areas must be covered with any available recovery equipment.

Figure 3-1 -Spread of an Exxon Valdez-Sized Oil Spill



Note: Assuming no wind or current

SOURCE: Engineering Computer Optecnomics, Inc (ECO)

Composition of Oil. The viscosity of the oil can be a critical factor in the response effort. In addition, oil spills in rough seas quickly become emulsions as they mix with water and form "chocolate mousse, " a substance which is very difficult to pump. High viscosity oils are more difficult to recover mechanically and disperse than low viscosity oils. Also, weathering processes such as evaporation, water take-up, oxidation, and biodegradation will increase the viscosity. Certain crude oils (such as Alaskan crude) become very difficult to pump when temperatures reach about O to 5 degrees Celsius. In addition, the effectiveness of dispersants and the burning process decreases as viscosity and emulsification increase. Also, the total volume of oil/water emulsion (mousse) can reach several times the initial oil spill volume.

[1] If all of the containment boom in the U.S. Navy inventory could be deployed to this type of spill site within the first 12 hours, it would barely be enough to encircle such a spill. In fact, the U.S. Navy response was not even requested until more than 1 week after the *Exxon Valdez* accident.

Sea Conditions. Most existing mechanical equipment becomes much less effective in waves greater than 3 to 6 feet. In addition, small vessels cannot be used, and deployment of gear in rough seas can be difficult. Currents can cause oil to move in unpredictable directions, and booms become ineffective when current velocity exceeds about 1 knot perpendicular to the face of the boom.

Weather Conditions. Weather such as snow, fog, heavy rain, high winds, and low temperatures all adversely affect the deployment and operation of equipment.

Location of Spill. If the spill is near the shoreline and the drift is toward shore, it will be very difficult to prevent beach contamination, no matter how ideal the conditions. The more remote a spill, the more difficult it is to get equipment to the site quickly.

Logistics. It is critical to be able to move equipment and personnel to the spill site as rapidly as possible. Also, all aspects of the transportation network are important–barges and other support vessels are often overlooked or not available.

Safety. Response to a large spill must include consideration of fire and explosion potential of the slick under the right temperature and atmospheric conditions. The protection of people aboard the vessel and those working on clean-up operations is critical. The safety of the stranded vessel itself is also important, especially if part of the cargo can be recovered before it is all spilled.

The above factors affect the ability of any response effort to mitigate the effects of a large offshore spill. OTA has reviewed three major categories of existing technologies for oil spill response: mechanical recovery; dispersants; and burning, bioremediation, and other techniques. In general, none of the currently available technologies are adequate to respond to and mitigate major offshore spills of the *Exxon Valdez* type and size (over 10 million gallons).

In the United States, almost all of the existing technology in the private sector has been developed for use in harbors and other protected waters. The Coast Guard and the Navy have equipment in their inventory that was designed for offshore areas in terms of deployability and ruggedness, but it is limited to moderate sea states, low currents, and moderate-size spills. No private U.S. oil spill cooperative has the ability to deal with large, catastrophic spills. The few large cooperatives in the United States have equipment that is more appropriate for platform spills. The Coast Guard has only minimal equipment of its own and depends, in large part, on private industry to supply systems to respond to spills. The Coast Guard has not developed any new equipment in recent years, and the number of strike teams has been reduced from three to two. The Navy's spill response capability is probably more substantial than that of any other government agency, but its equipment has been designed to be air-transportable and, thus, is limited in size and capacity.

MECHANICAL SPILL RESPONSE TECHNOLOGIES

Mechanical recovery of spilled oilcan be accomplished by a variety of techniques. A large number of different systems have been designed and built over the last 20 years. The *World Catalog of Oil Spill Response Products,* for instance, includes hundreds of harbor, calm water, and offshore booms and skimmers designed for a variety of spills and conditions, in addition to hundreds of sorbants that soak up oil.[2] Oil spill containment and

[2] Robert Schulze (d.), *World Catalog of Oil Spill Response Products* (Baltimore, MD: Port City Press, 1987), 470 pp.

cleanup technology has improved marginally over the past two decades, but private and Federal research efforts in the United States diminished greatly in the 1980s. Mechanical spill response technologies can be divided into two major categories: containment booms and oil recovery devices. Several containment and cleanup devices are discussed below. More details are included in appendix A.

Booms

Booms range in vertical dimension from under 1 foot for protecting calm water areas to over 7 feet for offshore applications. Smaller booms are less expensive, lighter, and easier to deploy. Large offshore booms require larger boats, heavier equipment, and often specialized equipment to deploy and recover. Most booms, including large offshore booms as well as smaller booms, become ineffective in currents over 1 knot and wave heights over 6 feet. Systems designed for more severe conditions in the Norwegian sector of the North Sea are required by the Norwegian government to be effective in waves up to 9 feet and currents of 1.5 knots. However, in wave heights in the range of 6 to 9 feet, the efficiency of the equipment decreases as oil escapes the boom. In wave heights above 9 feet, oil is whipped into the water and splashed over the booms, and little recovery is possible.

One type of boom, designed for rapid deployment, is pumped full of air (in an upper flotation chamber) and water (in a lower ballast chamber) as it is pulled off a reel. Thus, one trade-off is between rapid deployment using continuous air inflation versus slower deployment but less reliance on continuously operating inflation equipment. Booms that can be deployed from a reel and do not require

Photo credit: Vikoma International, Lti.

A weir boom corralling an oil spill.

that sections be bolted together are generally easier to handle offshore. Future developments are not likely to be in the direction of greater ability to operate in harsher sea conditions but more toward ease of operation within the limits now attained.

Booms ranging from 18 inches to 80 inches were used at the Exxon *Valdez* spill in Prince William Sounds According to one spill response supervisor at the spill, the largest booms were no better at containing oil than booms in the 32 to 42 inch range, but the larger booms were useful to slow down the larger boats that could not otherwise tow slowly enough.[4]

[3]Engineering Computer Optecnomics, Inc. (EC! O), "Analysis of Oil Spill Response Technologies, " contractor report prepared for the Office of Technology Assessment, July 1989.

[4]Ibid.

Photo credit: Jim Mielke

Heavy-duty boom on reel at the Southampton, U.K. Oil Spill Service Centre.

Air bubble barriers are another type of containment device. If air is pumped into a perforated pipe below the water surface, the rising bubbles cause the surface water to flow away from the pipe. Air barriers are more effective in calm waters and when used at freed installations. An air bubble barrier was employed in the 1969 Santa Barbara spill with little success. This equipment requires large amounts of compressed air and presents logistical problems, which probably would make it unsuitable for remote areas.

A promising future addition to containment technology may be the high pressure water jet barrier. The water jet system is designed to herd oil, much like a barrier, but under a wide variety of operating conditions. It can be mounted on and used with oil recovery devices.

Skimmers

Several basic types of skimmers are available; some of the more common are suction and weir skimmers and skimmers with a moving surface such as a belt, oil-absorbent rope mop, or disks (see appendix A). Each has its strengths and weaknesses, and no single type is best for all situations or types of oil. Even the most effective skimmers have rarely accounted for recovery of more than a few percent of oil from large spills.

Suction skimmers generally have a fairly high oil recovery rate because of their high pumping capacity, but they do not discriminate well between oil and water and thus have a low recovery efficiency.[5] They are simple to operate but do not work well in choppy waves. **Weir skimmers** have the advantages of being simple and reliable, and they have a fairly high recovery rate. However, most (especially rigid types) do not work well in waves. Conventional weir skimmers also have problems in becoming clogged with debris. There are a variety of belt **skimmers,** some with belts of absorbent material, some without, and some that can be used either way. Belt skimmers with the belt inclined to the water and the upper surface moving upward can generally handle debris very well. They also can be expected to have a relatively high oil recovery rate and high efficiency. **Disk skimmers** rely on the adhesion of oil on rotating disks. Because of the large vertical dimensions of the disks, they are relatively more effective in waves, and the larger skimmers are effective in fairly high sea states. Disk skimmers have a high recovery efficiency, which can be a considerable advantage if storage volume is limited. Among their disadvantages are their vulnerability to becoming clogged with debris, their ineffectiveness with mousse, and their more complicated design (which makes them more likely to break down). Rope **mop skimmers** have a long loop of absorbent oleophilic (oil loving) material that floats on the surface of the water

[5]The oil recovery rate, measured in gallons per minute, is the rate at which pure oil is recovered. Recovery efficiency is the percent oil in the recovered mixture. Robert Schulze (cd.), *World Catalog of Oil Spill Response Products* (Baltimore, MD: Port City Press, 1987), p. 213.

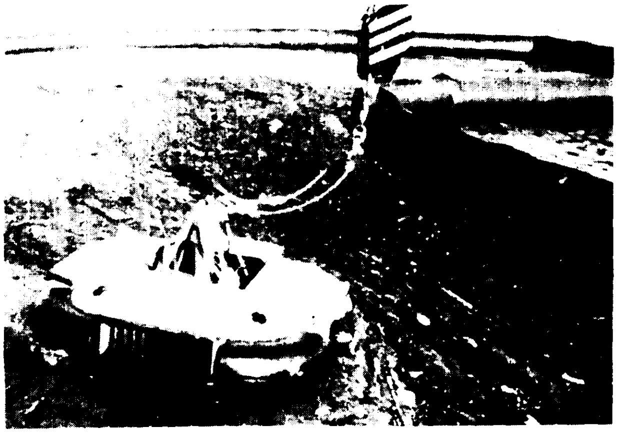


Photo credit: Vikoma International, Ltd.

A disk skimmer deployed behind a boom. This model has the capacity to recover about 50 tons of oil per hour.

and is then pulled through a wringer to remove oil. These skimmers have a high recovery efficiency, are easy to deploy off the side of a vessel, and are relatively easy to maintain.

Evaluation of Capabilities

In wind and currents, a boom must be designed with proper ballast to remain vertical and to maintain an effective height in the water. Other problems of containing oil in a current are related to the hydrodynamics of oil in moving water. As an oil slick increases in thickness against the boom, the oil extends deeper into the water. Only about 10 percent rises above the waterline. In other words, an oil slick floats in much the same way as an iceberg. As current velocity increases, more oil is driven against the barrier. When a critical velocity for the depth of the barrier is exceeded, oil will migrate down the barrier and escape underneath. Another problem is entrainment or dispersion of oil droplets in the water as it flows past oil held against a barrier. The rate at which droplets of oil enter the water and flow beneath the barrier depends on the current speed (or the relative velocity between the barrier and the water if the barrier is being towed) and properties of the oil itself. Both entrainment and migration of the slick under a barrier become significant problems at current speeds in excess of 1 knot perpendicular to the boom face.[6] Badly designed booms may fail below this current speed. The difficulties in handling barriers in open ocean waters are compounded by the fact that ships towing booms must navigate at very slow speeds where it is difficult to maintain steering control.

Booms have probably reached their practical limits in terms of the maximum wind and wave conditions in which they can be expected to retain oil. Additional improvement will most likely result from advances in ease of deployment and possible development of new, lighter weight, durable materials.

Skimmer performance varies widely depending on the viscosity of the oil being recovered. Most skimmers have a range of viscosities in which they work best and can be roughly grouped according to the oil viscosity in which they are most effective. A generalized grouping of skimmer performance according to oil viscosity is shown below.

Light Oil
Weir
Suction
Submersion belts
Submersion plane

Medium Oil
Disk
Rope mop
Sorbent belt
Sorbent lifting belt
Sorbent submersion belt
Boom-skimmer
Vortex

(continued)

[6] 1 knot equals 1.2 miles per hour.

Photo credit: Jim Mielke

A "Foxtail" rope mop skimmer deployed in a Norwegian test tank.

Heavy Oil
- Paddle belt
- Sorbent lifting belt disc (large offshore types only)
- Rope mop (high viscosity, but not Bunker-C)
- Weir with progressive cavity pump

In general, even the most rugged mechanical containment "and recovery equipment is limited in effectiveness to waves of less than 6 feet, winds of less than 20 knots, and currents less than 1 knot. Average wind and current conditions in many U.S. port areas come close to these limits leaving little margin for effective use of mechanical equipment. Thus, it would be normal to expect periods when weather conditions would preclude operation of mechanical containment and recovery equipment in any U.S. port area.

Even under ideal conditions, with equipment and trained personnel nearby and good weather, it is not realistic to expect to recover more than 30 percent of the oil from a major spill. Probably less than half that amount is more likely. The rapid spreading and fragmentation of oil that occurs after a spill has made cleanup of large percentages of oil exceedingly difficult. Historically, recovery from major spills has amounted to only a few percent, if there was any attempt at recovery at all.

Mechanical Cleanup Enhancers

A number of products have been marketed to assist in the recovery of spilled oil. One chemical that has undergone preliminary testing and appears to offer some promise is a nontoxic polymer, polyisobutylene, which comes in the form of a white powder and renders oil visco-elastic. This change makes the oil adhere to recovery surfaces, thereby greatly increasing the effectiveness of oil skimmers, particularly rotating disk and drum types. Rope mop type skimmers do not appear to be well suited to the use of this treating agent because the increased visco-elasticity makes the squeezing of the rope more difficult. This material has also been shown to be effective at treatment ratios as low as one part in 1,000.[7] It does not appear to reduce spreading or increase thickness sufficiently to assist in situ burning. One potential problem may be applying and mixing it with oil in large, spread-out spills.

Other chemicals have been developed to break or prevent emulsions. These products have the ability to convert the water-in-oil emulsion to two separate phases. The advantage of doing this is that the oil can then be

[7] Merv F. Fingas, "Chemical Treatment of Oil Spills," Alaska Arctic Offshore Oil Spill Response Technology Workshop Proceedings, U.S. Department of Commerce, National Institute of Standards and Technology, NIST Special Publication 762, April 1989, p. 33.

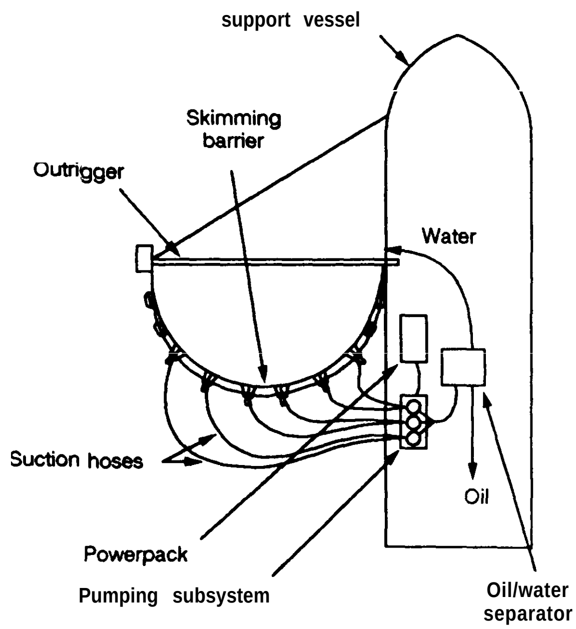
recovered more efficiently or dispersed or burned more successfully. Most of these products are hydrophilic (water-loving) surfactants. The problem with these surfactants is that the surfactant is more soluble in water than in oil and will quickly leave the system if there is sufficient water. One product being tested by Environment Canada is a demoussifier – a mixture of long-chain polymers that does not have the drawback mentioned above. Although not yet available, laboratory tests show this material will prevent the formation of water-in-oil emulsions at treatment ratios as low as 1:2,000. As with other treating agents, application and mixing in large spills may be difficult. Like dispersants, mechanical cleanup enhancers require certification before they can be considered for use.

Integrated Systems and Deployment

The difficulties encountered in spill responses with respect to obtaining and deploying boom and skimmer handling vessels and oil storage vessels have led to the propositioning of chemicals and equipment and development of integrated systems that are equipped to perform all the functions of the mechanical recovery process. Integrated systems fall into three categories: vessel-of-opportunity systems; single purpose, specially designed oil spill response vessels; and multiple purpose vessels, of which one of the purposes is oil spill recovery. These systems use conventional skimmer techniques to recover the oil and are subject to the efficiencies and shortcomings of those systems. However, they also have the advantage of being independent of other supporting equipment in their recovery process, until their storage capacity is exceeded.

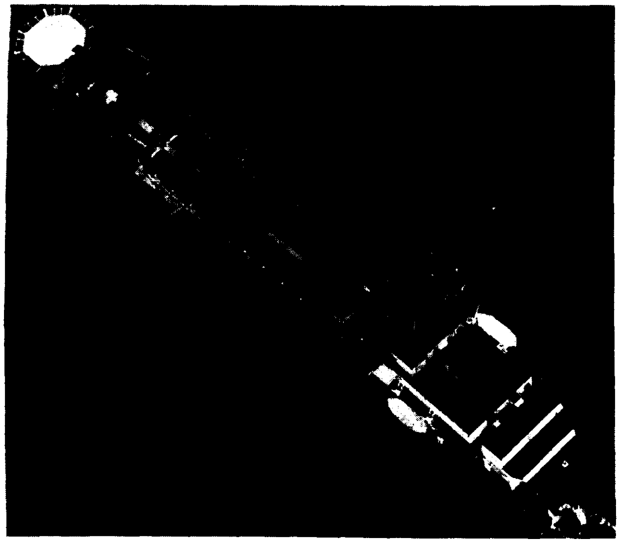
Vessel-of-opportunity skimming systems (VOSS) are systems designed to be deployed *from* **any** suitable vessel that maybe available in the area. They incorporate portable skimmers that are not integrated into a dedicated vessel. The skimmer system is freed to the side of the vessel, and recovers oil while the vessel progresses through the slick (figure 3-2). While these systems have the advantage of greater mobility, they are limited to the suitability of vessels in the area.

Figure 3-2-Vessel-of-Opportunity Skimming System



SOURCE: Engineering Computer Optecnomics, Inc (ECO)

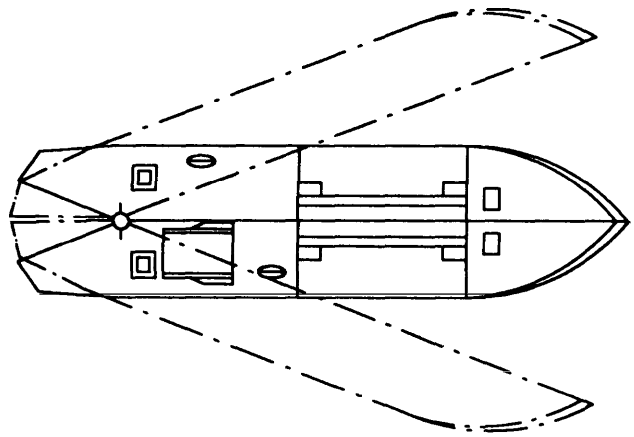
Specially designed oil spill response vessels capable of operating in the open ocean have been developed by European firms, mainly Dutch and German. These are large vessels, unlike some of the smaller skimmers described previously. One of the more innovative is a tank vessel hinged at the stern that operates in a "V" configuration, using its split hulls to form a boom-like collecting system (figure 3-3). Two of these vessels are in use and a third has been ordered by Mexico. These systems have the advantage of being complete systems with significant onboard oil/water separation capability and storage capacity. Disadvantages include their high cost and, since they are not air transportable, their more limited range of use.



Pho credit: IHC Ho nd

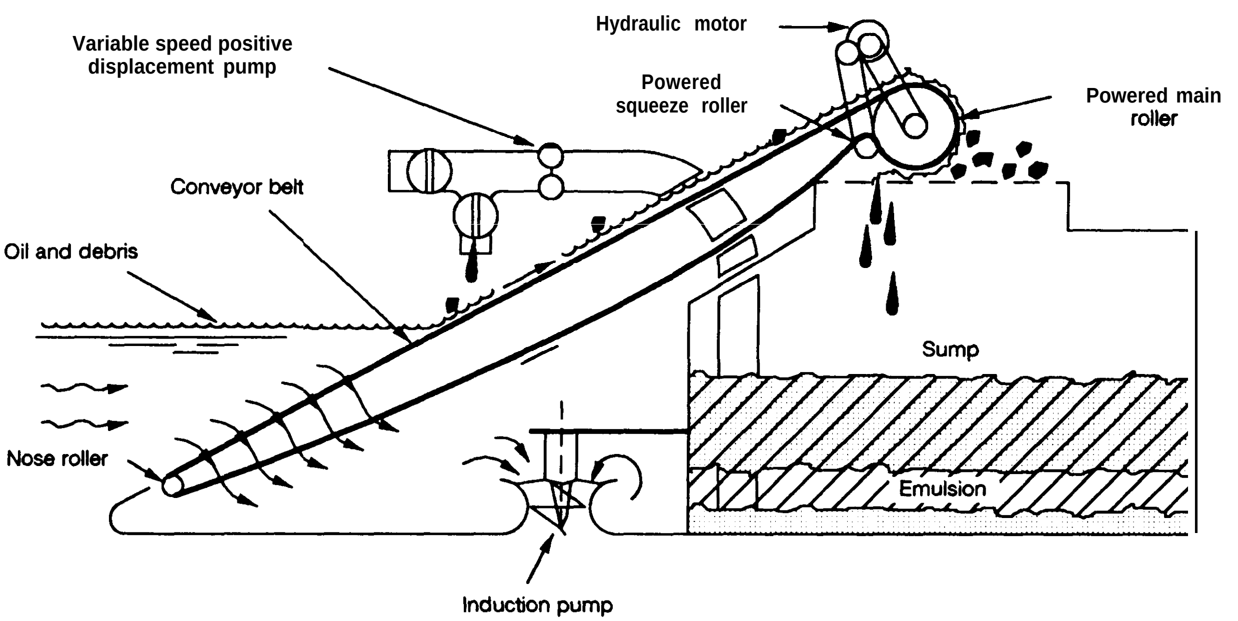
The *Co mo* d p rpose sse b lt both dredg g nd recoveri g The mm ng rm d p ed th p to

Figure 3-3-Schematic Drawing of West German Split Vessel *THOR*



SOURCE: IHC Dredge Technology Corp

Figure 34-Schematic Drawing of the Navy's Class V Oil Skimmer



SOURCE: U S Navy

Multiple-purpose vessels are an economical approach to large-scale, oil spill response systems. The publicity surrounding the use of the Soviet dredge in the Exxon *Valdez* spill has focused attention on the use of dredges and other vessels as platforms for oil spill response systems. The Soviet dredge was designed from the beginning as a trailing hopper dredge with oil recovery capability. The first report of building a dredge with the dual role of oil spill response was in 1977 with the design of the Cosmos, a Dutch ship. The great capacity of these vessels for storage of viscous materials and their pumping systems (including suction hoses up to 24 inches in diameter) make them ideal for recovering very viscous weathered oil. U.S. Army Corps of Engineers dredges were also used in the Alaskan oil spill, but without specific modification. Initial design modifications would include spark suppressing electrical systems, oil/water separation equipment, and ventilation systems for dealing with flammable volatiles. Unmodified dredges would be limited to recovering weathered oil that presents no fire hazard. The advantages of dual-purpose dredge vessels are their usefulness as a dredge during most of their lifetimes and their large capacity in the event of a major spill. Both the U.S. Coast Guard and the Army Corps of Engineers are studying the use of multi-purpose vessels. The Coast Guard is studying the feasibility of giving buoy tender vessels oil spill cleanup capabilities, and may add this capability to new buoy tenders as they are built.

Recovery and containment systems cannot be deployed at the site without the provision of significant support resources. These support resources include material handling equipment such as forklifts and cranes, boom and skimmer handling vessels, storage vessels, surveillance airplanes, and trained personnel. Table 3-1 shows the minimum equipment required to *deploy* various response components.

DISPERSANTS

Perhaps the most controversial issue in the field of oil spill response is the use of chemicals to disperse the oil. In general a dispersant is sprayed onto a slick to reduce the cohesiveness of the slick so that the oil can be broken into small droplets by wind, wave, and current action. The oil droplets disperse into the water column where they become diluted to low concentrations and are subjected to natural processes such as biodegradation.

Much of the controversy that has surrounded the use of dispersants has arisen from their impact on the environment. While early dispersants were toxic, modern dispersants are less toxic than the oil itself.[8] Even so, the use of dispersants involves making an environmental trade-off. In essence, this involves trading the potential short-term environmental effects of a treated slick against the possible long-term shoreline impacts and other effects of an untreated one. The primary impact of a dispersed slick comes from the oil dispersing into the upper water column. While it will rapidly become diluted, the initial concentrations may exceed the acute toxicity threshold of organisms in the upper few meters of the water column. In certain seasons or sensitive areas, this maybe a trade-off that authorities are unwilling to make.

In an untreated spill, evaporation may be responsible for the loss of one-third or more of the oil in a period of a few hours or a day. While hydrocarbons dissolved in water also evaporate, many of the hydrocarbons that dissolve (mainly aromatics) appear to produce the most immediate biological toxicity.[9]

[8]National Research Council, Marine *Boat-d, Using Oil Spill Dispersants on the Sea* (Washington, DC: National Academy Press, 1989).

[9]Ibid., p. 240.

Table 3-1--Equipment Required To Deploy Response Elements

System	Staging area	To site	Onsite	Personnel (per system)
CONTAINMENT	Space Forklift-4 ton Crane-4 ton Maintenance facilities Spares	Vessel with minimum of 8' x 20' clear deck space for each 2000' of boom	A-frame/davit/handling equipment with minimum one ton capacity Boats capable of tending boom – one if boom anchor used – two if no boom anchor used	2 2 per boat
RECOVERY				
Skimming barrier	space Forklift- l O ton Crane-10 ton Maintenance facilities Spares	Vessel with minimum of 8' x 35' clear deck space per system	A-frame/davit/handling equipment with minimum one ton capacity Two boats for maintaining barrier opening and shape and capable of operating at low speed-1 to 2 knots Barge for receipt of recovered oil Tug to tend barge or to shuttle barge to onshore storage location Platform for prime power (may be barge)	4 to 6
Self-propelled skimmer	Sp ce Forklift-10 ton Crane-10 ton Maintenance facilities Spares	Vessel with minimum of 12' x 35' clear deck space per system	A-frame/davit/handling equipment with minimum one ton capacity Two boats for maintaining barrier opening and shape Barge for receipt of recovered oil Tug to tend barge or to shuttle barge to onshore storage location Boat with 10-ton crane at 35' reach deploy and recover	7 to 8
Vessel-of-opportunity skimmer	Space Forklift-10 ton Crane-10 ton Maintenance facilities Spares	Vessel with minimum of 8' x 24' clear deck space per system	A-frame/davit handling equipment minimum one ton capability for deployment and recovery Barge for receipt of recovered oil Tug to tend barge or to shuttle barge to onshore storage location	3 to deploy 2 to operate
DISPERSANT APPLICATION				
Air deliverable	Pumps to transfer from barrels to tank truck Tank truck Ground personnel	See onsite requirements	Surveillance aircraft for spotting Aircraft equipped to spray dispersant	2
vessel deliverable	Space Forklift-8 ton Crane-8 ton Maintenance facilities Spares	Vessel with 8' x 24' clear deck space	Surveillance aircraft for spotting Vessel capable of accepting vessel system	2 to 3 to deploy 2 to operate
TRANSFER PUMPS	Space Forklift-2 ton Maintenance facilities Spares	Vessel with approximate 8' x 24' clear deck space Helicopter with l-ton lift capacity	Barge for receipt of off-loaded oil Tug to tend barge or to shuttle barge to onshore storage location Hoses and couplings Fenders	

SOURCE: Engineering Computer Optecnomics, Inc (ECO), "Analysis of Oil Spill Response Technologies," contractor report prepared for the Office of Technology Assessment, July 19SS

The immediate ecological impacts of dispersed oil vary. In open waters, organisms on the surface will be less affected by dispersed oil than by an oil slick, but organisms in the water column will receive greater exposure from dispersed oil. In shallow areas, less water is available to dilute the dispersed oil to less than lethal concentrations, so organisms will be more severely impacted by dispersed oil. Consequently, dispersant use is generally limited to deeper water. Although some immediate biological effects of dispersed oil may be greater than for untreated oil, long-term effects on most habitats, such as salt marshes, sea grasses, and mangroves, are less, and these habitats recover faster if oil is dispersed before it reaches these areas.[10] Thus, the primary biological benefits of dispersant use are to reduce the hazard to birds (unless the dispersant is sprayed directly on them) and to prevent oil from stranding on shorelines. Sometimes, it may be more the aesthetic value that is protected, particularly if stranded oil is removed from beaches and rocky shorelines by high-pressure hot water at the sacrifice of the local biological communities.

Further advantages of using dispersants in combating a large oil spill are that they can be rapidly deployed (by aircraft) over a large area, may be used when sea conditions preclude mechanical response, and, if successful, can be a very cost-effective oil spill countermeasure. Dispersants can be applied by either fixed wing aircraft, helicopters, or systems installed on a vessel. The most efficient system for large spills is the Airborne Dispersant Delivery System, a portable unit developed for use on any available C-130. Dispersants are most effective when they are applied early, because the oil becomes less dispersible as its viscosity increases. However, dispersants that are effective on higher viscosity oils are being developed. The major consideration in applying the dispersant is to achieve a relatively uniform application on the oil without undue wind drift loss. Most dispersants require an application of dispersant to oil in a ratio of about 1:10 to 1:20. As with mechanical equipment, prepositioning of dispersants is necessary to achieve an early and effective response.

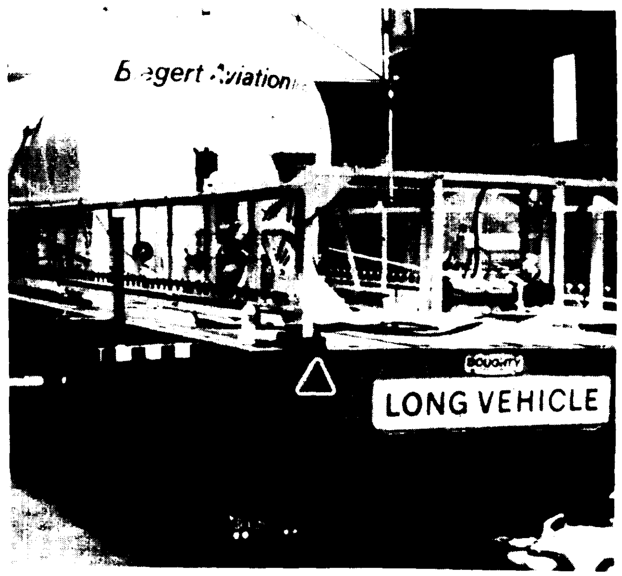


Photo credit: Jim Mm/kc

Airborne Dispersant Delivery System, or ADDS pack, seen mounted on a flatbed for easy transport to a C-130 airplane.

In a major study published in 1989, the National Research Council generally approved the use of dispersants and recommended that they be considered as a potential first response option along With mechanical cleanup.[11] Mechanical cleanup has the advantage of removing oil from the marine environment (although, thereby, creating a waste disposal problem onshore) but is generally limited by inability to cover a large slick area in a reasonable period of time. Dispersants are one of the few countermeasures that can be applied to a large area in a timely manner. One other question surrounding dispersants, however, is the

[10] Ibid., p. 4.

[11] Ibid.

lack of hard data about their effectiveness in actual spill conditions. The National Research Council recommended further research in this area. One difficulty, in particular, is in establishing a methodology for determining dispersant effectiveness at sea.

How well dispersants work depends on sea conditions and application techniques as well as on the chemical nature of both the dispersants and the oil. A certain amount of wave energy is desirable to achieve mixing, whereas a calm sea reduces the immediate effectiveness of dispersants. Improvements have been made in application techniques, but they still appear short of being routinely optimal. Further gains could be made from research in this area.

BURNING, BIOREMEDIATION, AND OTHER TECHNIQUES

In Situ Burning

In situ burning is the process of burning an oil spill in place either with or without the use of fire containment boom. In order to ignite oil on water, the oil must be relatively fresh, and the slick must be at least 3 millimeters thick. To ensure thickness and to isolate oil from contact with a stricken vessel or other object, fireproof booms may be used. Since the more volatile components of spilled oil immediately begin to evaporate, there is less potential for successful in situ burning as the slick ages. Some oil residue (about a 1 millimeter thick layer) will remain in the water after burning oil because the flame is always quenched by heat losses to the water surface when the oil layer gets thin. Such residue is itself a problem to clean up, but burn efficiencies of over 90 percent can be obtained, particularly if the oil is confined with booms or other means to keep the oil layer as thick as possible. Since less evaporation takes place in cold regions, in situ burning maybe more successful in these areas.

Several techniques have been devised for igniting oil spills. Devices used include floating igniters that can be deployed by air and the helitorch igniter, which is a tank system containing gelled gasoline suspended on cables below a helicopter. One device under design is a laser ignition system using two coupled lasers from a helicopter to heat and ignite oil spills.

Burning has been used in response to accidental oil spills with varying success. The use of burning to remove oil from the water produces a trade-off that must be evaluated by local authorities. The trade-off is between removing oil from the water and releasing the products of combustion into the atmosphere. Measurements thus far indicate that combustion products released into the atmosphere are no more hazardous than those released by evaporating oil, and that the total environmental loading of toxic components remains the same or is reduced by the combustion of crude oil spills on water.[12] Burning produces black sooty smoke that is a highly visible pollutant and may raise concerns about human health effects, whereas oil on the surface of the water, while also polluting in terms of volatiles entering the atmosphere, is usually perceived by the public to be less threatening to human health.

The aesthetic trade-off is not only one of ocean v. atmosphere, but also one of time frame, the short-term impact of smoke and combustion products versus the longer-term impact of an oiled shoreline. The major incentive to burn the oil is not only to remove it

[12] David D. Evans, "In-Situ Burning of Oil Spills," Alaska Arctic Offshore Oil Spill Response Technology Workshop Proceedings, U.S. Department of Commerce, National Institute of Standards and Technology, NIST Special Publication 762, April 1989, p. 53.

from the water but to reduce the probability of its becoming stranded on shore.

In some circumstances (e.g., if oil is not isolated from the vessel that spilled it) burning could put a stricken vessel, its remaining cargo, and any personnel still on board at risk. The intentional sacrifice of a vessel and its cargo *may* ultimately cost less than the total cost of a spill that could not be controlled, but this is rarely obvious at the time a response decision must be made. The decision to deliberately set fire to a vessel is one that most people would be very reluctant to make, especially if considerable oil remains on board and if there appear to be other response options. In the case of the Exxon *Valdez,* much more oil remained on the ship than was spilled. Most of this oil was successfully offloaded, thereby averting the greater tragedy that would have occurred if this oil also had spilled. Even so, Exxon's total costs to fight this spill greatly exceeded the value of the ship and its cargo.

Bioremediation

Bioremediation is the in situ use of microbes to biodegrade and oxidize hydrocarbon molecules. Biodegradants can be marine bacteria naturally occurring in the spill area, nonindigenous naturally occurring bacteria, genetically engineered microbes, and nutrients that can be added to enhance biological oxidation. Tests of this technique on water have shown little or no enhancement over the naturally occurring biodegradation.[13] Use of bioremediation on impacted shorelines, however, has apparently been successful in some cases. Exxon, in conjunction with the Environmental Protection Agency (EPA), recently conducted a large-scale test of this technique in cleaning up beaches soiled by the *Exxon Valdez* spill. About 70 miles of shoreline were coated with two kinds of nitrogen- and phosphorus-bearing fertilizers to boost indigenous bacterial populations.[14] Initial results are inconclusive, but the data are still being evaluated. One difficulty is measuring the effectiveness of the technique.

Proponents of bioremediation say it is potentially the least damaging and least costly of cleanup techniques, particularly for soiled beaches. Its use on water, however, would appear to be limited except perhaps as a follow up to other actions. The major disadvantage of bioremediation is the long time frame involved. On beaches where it could take 5 to 7 years for oil to breakdown under natural conditions, bioremediation with fertilizer could reduce that to 2 to 5 years.[15] Research needs to be conducted on the effect on local habitat from increased microbial populations and nutrient levels. Efforts to engineer new microorganisms or to identify and cultivate more efficient ones may be promising.

Miscellaneous Chemical Agents

Gelling Agents

Gelling agents change liquid oil into a solid to aid in recovery or are directed toward tanker accidents where pollution might be avoided or diminished by gelling the oil remaining in the tanks. Gelling agents require mixing with oil and allowing adequate time for the gel to set. Some gels set in a matter of minutes, whereas others, depending on environmental conditions, require about 8 hours to form modest strength and several days to form substantial strength. Field tests have shown that large amounts of gelling agent

[13] Fingas, op. cit., footnote 7, p. 30.

[14] Mark Crawford, "Exxon Bets on Bugs in Alaska Cleanup," *Science*, vol. 245, Aug. 18, 1989, p. 704.

[15] Ibid.

may be required, up to 40 per cent of the volume of the oil itself.[16] For these reasons gelling agents are not generally stocked for use by spill responders.

Herding Agents

Herding agents are designed to contract a spill and keep it from spreading. Herding agents are limited in effectiveness and are more successful in controlling small, thin slicks. Tests and actual use of these products showed that utility was limited to very calm waters. Due to their limited application and operating spectrum, there is little remaining use of herding agents at this time.

Sinking Agents

Sinking agents, such as hydrophobic chalk, have been used to prevent oil from reaching shore. The French used about 3,000 tons of powdered chalk to sink an estimated 20,000 tons of oil following the 1967 Torrey Canyon spill. Very little sunken oil came ashore. However, Canadian tests of several sinking agents have shown that none were effective in holding oil after the initial sinking and that it slowly leached back to the surface over a few days.[17] Because the sinking mass causes suffocation of bottom life and also exposes many bottom-dwelling organisms to oil, sinking agents are generally forbidden by environmental regulatory agencies.

Combustion Promoters

Burning agents have been developed to assist in the combustion of oil, but these generally have not functioned well in actual practice. Burning agents are of two generic types, sorbents and pyrotechnical compositions. Sorbents function by collecting oil in thicker masses to assist in burning, and pyrotechnical compositions keep the slick burning. Burning agents are of limited use because of the large amount of material needed for a beneficial effect and by the fact that in situ burning can be accomplished without them.

QUANTITY AND DISTRIBUTION OF RESPONSE EQUIPMENT

Although oil spill response equipment is widely distributed around the United States, the availability of equipment for responding to major spills is limited. Principal stocks are held by the U.S. Navy, the U.S. Coast Guard, and industry cooperatives.

The Navy has two major equipment depots, one in Williamsburg, Virginia the other in Stockton, California. A small amount of equipment is located in Pearl Harbor, Hawaii. The primary mission of Navy resources is to fight spills from Navy ships and facilities; however, its equipment is considered a national resource, and, as in the case of the *Exxon Valdez* spill (in which equipment from both major Navy depots was used), may be called on in emergencies. The Navy has invested a total of approximately $30 million for its equipment. Since much of this equipment was purchased in the mid-1970s, its replacement value would be much greater than this (rough estimates are over $100 million). Navy equipment currently constitutes the largest equipment stock available in the United States applicable for fighting large, offshore spills. The principal Navy countermeasures equipment are 24 Navy-modified belt skimmers, each with a capacity of about 250 gallons per minute. These skimmers were used in the *Exxon Valdez* spill, but were no match for the huge volume of oil to be recovered. They

[16] Fingas, op. cit., footnote 7, p. 29.

[17] Ibid., p. 31.

Photo credit: U.S. Coast Guard

U.S. Navy Marco Class V skimmer deployed in Prince William Sound.

are also not capable of effective recovery in rough seas (above sea state 3). The Navy has no dispersant capability. A potential constraint to efficient operations is that the Navy must depend on outside contractors for off-loading recovered oil, as it has no tank barges of its own. Appendix B contains an inventory of the Navy's principal resources.

The U.S. Coast Guard also maintains two important equipment stocks, one at its Atlantic Strike Team base in Mobile, Alabama, the second at its Pacific Strike Team base at Hamilton Air Force Base, California. Three Strike Teams were maintained until 1987, when the Atlantic and Gulf Strike Teams were consolidated due to budget constraints. Coast Guard stocks include a number of Open Water Oil Containment and Recovery Systems, the principal elements of which are skimming barriers, pumps, and storage bladders (dracones). This equipment is not sufficient to combat a major spill. The Coast Guard relies on private contractors for additional mechanical cleanup equipment. A significant amount of equipment at the two Coast Guard Strike Team bases is devoted to the important mission of off-loading (lightering) stricken vessels to minimize the loss of oil. The Coast Guard has about 20 Air Deliverable Anti-Pollution Transfer Systems for this purpose. Appendix B contains a summary of Coast Guard stock.

Photo credit: US. Coast Guard

Dracone fuel bladder used for temporary storage of recovered oil.

Much of the rest of the available oil spill response equipment in the United States is maintained by industry oil spill cooperatives. There are approximately 93 of these cooperatives in the United States (see app. B), but virtually all are designed for fighting spills in protected harbors, sheltered waters, and inland areas.[18] According to the American Petroleum Institute's recent Task Force Report on Oil Spills, "no U.S. cooperative has been designed to deal with a catastrophic spill."[19] Moreover, little of the available industry equipment would be applicable for more rigorous offshore conditions. Cooperative and other equipment that could be suitable offshore is listed in appendix B, as is a listing of the Alyeska Cooperative's recent acquisitions.

The largest oil spill cooperative in the world is the Oil Spill Response Ltd. (OSR) base in Southampton, England. The base is equipped

[18] American Petroleum Institute, "Task Force Report on Oil Spills," June 14, 1989, p. 10.

[19] Ibid.

with the capability to respond to large offshore spills. (Because Exxon is a full member of this cooperative, it was able to use 50 percent of the equipment on hand at the time to fight the Exxon *Valdez* spill. OSR base equipment was among the first out of state equipment to arrive in Prince William Sound.) The base has been stocked with the intent to be able to respond simultaneously to two 10,000-ton spills (two 3-million gallon spills).[20] Whether this capability could be met in practice is difficult to determine. *In general,* such estimates of response capacity typically depend on the manufacturer's estimates, and such information may be overstated and applicable primarily to ideal conditions. OTA estimates that the capability of the Southampton cooperative is roughly equivalent to that of one of the U.S. Navy depots. OSR base equipment is also listed in appendix B.

The industry has proposed to remedy the lack of equipment for fighting major spills by establishing five regional oil spill response centers and equipping each with the capability to respond to a 30,000-ton spill. Each Petroleum Industry Response Organization (PIRO) center would contain lightering equipment, booms, skimmers, dispersant equipment, and other ancillary equipment, and would be manned by oil spill professionals. The estimated capital cost for each center would be roughly $24 million in 1990 dollars. Although PIRO claims that this amount will enable its response centers to cope with 30,000-ton *(9.2* million-gallon) spills, these claims have yet to be evaluated by an independent organization. It is thus not certain whether response funding will be adequate. The Navy, for instance, estimates that each of its 2 major depots have equipment whose replacement value is about $50 million, and this equipment provided only a limited capability to respond to the *Exxon Valdez* spill. Nevertheless, it is difficult to evaluate response center capabilities by comparing equipment costs alone. Variables such as equipment maintenance, training, and logistics plans are also very important. Proposed regional center capital equipment is presented in appendix B.

In sum, the only significant stock of oil spill response equipment that is readily available, tested, and maintained for fighting a large offshore spill in the United States is that of the U.S. Navy. In Europe, the large industry cooperative at Southampton has a significant capability roughly equivalent to one of the two Navy depots. Other industry capabilities in the United States are either insignificant or not readily available for offshore spills. The API/PIRO proposal for establishing new equipment depots in the United States at strategic locations will significantly improve industry capabilities. However, it is still uncertain whether PIRO would be capable of recovering significant portions of a large offshore spill. It also appears that the funds proposed to be allocated by PIRO may be inadequate for the goal.

[20] A proposal has been made t. expand the OSR base so that it will be capable of handling two 30,000-ton spills. M.D. Long, Assistant Manager, Oil Spill Service Centre, personal communication, Jan. 22, 1990.

Chapter 4
U.S. Oil Spill Response Policy Issues

INTRODUCTION

Prior to the *Exxon Valdez* spill, few saw U.S. oil spill policy as wanting. A seemingly sophisticated response system had been in place for almost 20 years. Even though there had not been a spill in U.S. waters that aroused similar national attention since the 1969 Santa Barbara well blowout, the system seemed to work well. On previous pages we have addressed some of the technology issues associated with responding to spills. However, use of better technology alone will not solve U.S. response problems. On the following pages we consider several aspects of U.S. oil spill response policy, identify some of the problem areas, and suggest some potential solutions. The section after this investigates how several European countries are organized to fight major spills.

TECHNOLOGY: WHICH CLEANUP METHOD?

Currently, the most likely oil spill countermeasures approach to be used in the United States for spills at sea is to rely on mechanical containment and cleanup methods, i.e., booms and skimmers. Even though available booms and skimmers are limited in capacity and capability, they can be deployed in almost any region without concern about additional environmental damage. Such is not the case for dispersants, however, where some limits on their use are usually considered. Modern dispersants are considered safe for many offshore regions, but up to now they have been seldom used. Questions about dispersant toxicity largely have been laid to rest by new formulations, but they do not remove the oil itself and thus many oppose their use. In addition, important questions about the effectiveness of dispersants have not been settled. Burning as a countermeasures approach has been the subject of experiments, and some believe it holds promise under certain favorable conditions.

There is no single or perfect solution to the general problem of dealing with oil on the water. As noted elsewhere in our report, each of several available methods has strengths and weaknesses. Each oil spill is unique, and the approach that works well or at least reasonably well in one situation may work poorly in another. Participants in OTA's oil spill workshop generally agreed that for the most effective response, all approaches must be available to those fighting the spill. This provides the ability to use whatever technique(s) are most appropriate in each case. In particular, better understanding of the conditions and locations under which dispersant use and burning would be appropriate and/or preferable to mechanical equipment is needed.

Related to this, a systematic approach is essential. It makes little sense to have skimmers and booms available but inadequate space for temporary storage of recovered oil or no plan for permanently disposing the oil. Hence, barges or other storage vessels, for example, are as important to the recovery system as skimmers. Similarly, it makes no sense to stock dispersants without an immediately available delivery system. One cannot neglect any element of a comprehensive plan and expect to mount effective oil spill countermeasures. Undoubtedly, the performance of an individual piece of equipment is less important than the overall performance of the system. Moreover, since all spills are different and since resources are usually limited, an integrated system that works reasonably well for several different types of spills (e.g., for viscous oil and for low viscosity oil) and as the physical properties of the spill change with time is preferable to one that works well in one situation but poorly in another.

DECISIONMAKING: DEMOCRATIC AND AUTHORITARIAN APPROACHES

The current U.S. approach to fighting major oil spills, unlike the approach of some European countries, is more democratic than authoritarian. Democratic decisionmaking, however, may not be as appropriate for making decisions in emergency situations where speed is essential.

Currently, the U.S. Coast Guard provides an on-scene coordinator (OSC) for most major spill responses in coastal waters and along adjacent shorelines. The OSC's initial responsibility is to determine whether the polluter can cope with the spill. If not, the OSC is empowered to take control of the spill response. In practice, however, his decisions are subject to the oversight of numerous interested parties. For example, a Regional Response Team, consisting of regional representatives of various Federal agencies, has considerable sway over the OSC's decisions. The OSC must also be mindful of legitimate State and local concerns. The interests of these groups maybe in conflict. It is thus difficult, if not impossible, for the OSC to act quickly. Unfortunately, large spills not rapidly contained will soon be out of control.

It maybe possible to devise a spill response policy that would enable decisions to be made quickly and effectively. It would have to minimize unnecessary and counterproductive interference by others, but at the same time take account of the legitimate concerns of those affected. In many European countries, it appears that the on-scene coordinator is in effect an on-scene commander, that is, someone who has the unquestioned authority to act quickly. Greater authority for U.S. on-scene coordinators could be coupled with a greater effort by all involved to determine, before a spill, what decisions will be made if a particular event occurs–what type response is acceptable, what is not, and when and where a particular response is acceptable. Agreement should be reached before the event, for example, about the circumstances under which dispersants may be used. Once the spill occurs, some decisions could be almost automatic. Planning of this nature should be addressed before spills in Regional Contingency Plans and in Federal Local Contingency Plans.

RESPONSIBILITY: THE POLLUTER OR THE GOVERNMENT?

The current practice in the United States is that the polluter is responsible unless he cannot cope with the situation, at which point the Federal Government – the Coast Guard in the case of offshore spills– will take charge.[1] Although a rather detailed organization – including a National Response Team, Regional Response Teams, on-scene coordinators, and a National Strike Force– has been established to support the Coast Guard, there are several problems with this approach, as illustrated by the Exxon *Valdez* spill. First, given the necessity of acting quickly, by the time the Coast Guard determines that the polluter is incapable of dealing with a spill, it may well be too late for anyone to mount a successful countermeasures effort. Second, the Coast Guard does not now have the resources to mount an effective response to a catastrophic spill, especially one that has not been quickly contained.

[1] The National Response Team, "A Report on the National Oil and Hazardous Substances Response System," Annual *Report,* March 19s9, pp. 6-7.

Several critics of current U.S. response policy[2] have pointed out that although the polluter is initially *responsible* for the cleanup, he lacks the *authority* to respond as he thinks appropriate. The oil industry, and inparticular, the new Petroleum Industry Response Organization (PIRO), although willing to provide equipment and personnel to respond to a spill, argue that large spills should automatically be managed by the Federal Government.[3] Such an action would place both responsibility and authority for cleaning up a spill in the same hands and, theoretically, enable a clear and unambiguous command structure. Small spills which do not create special cleanup problems could still be handled with local spill resources.

As noted elsewhere in our report, virtually all European governments have assumed responsibility for responding to major vessel spills. Although operators of fixed installations, such as offshore platforms, are generally still responsible for oil spill cleanup, governments have generally concluded that it is unreasonable to expect the same degree of preparedness for a vessel spill that might occur anywhere at sea. The polluter, however, is still liable to pay all reasonable costs of the spill.

In the United States, the Federal Government could adopt a similar approach of assuming responsibility for large spills regardless of the polluter's capability. That approach would include a full evaluation of current Federal capabilities and abilities to marshal public and private resources quickly. The Coast Guard, or whatever agency is assigned responsibility for combating major spills, would have to be given the appropriate resources to do the job.

LOGISTICS: ESSENTIAL TO QUICK RESPONSE

A rapid response is essential for effective spill cleanup, so one must either have response equipment near a spill site or have the capability to get to a spill quickly. In a country the size of the United States, it is impractical to station equipment for fighting catastrophic spills every few miles along the coast. Clearly, it is also the case that the risk of oil spills is much greater in some areas than others—areas such as busy tanker lanes and ports.

An oil industry proposal indicates that it will establish, through its new Petroleum Industry Response Organization, five major regional oil spill response depots and a number of small "presaging" bases. The regional centers would be located in the Northeast, mid-SouthAtlantic, Gulf Coast, Pacific Southwest, and Pacific Northwest.[4] This is a more decentralized approach than the Navy's strategy. The U.S. Navy, a large amount of whose equipment was used to fight the *Exxon Valdez* spill, relies mainly on two equipment depots, one on the East Coast and one on the West. All Navy equipment is designed (or modified) and packaged so that it is capable of being trucked or airlifted anywhere in the United States. The U.S. Coast Guard currently has two Strike Teams, one in Mobile, Alabama and one at Hamilton Air Force Base in California. At the present time, the Coast Guard is better prepared to off-load stricken tankers than to fight major spills. It relies heavily on commercial contractors for spill responses.

Both centralized and decentralized logistics strategies may be effective. However, in either

[2] For example, the International Tankers Owners Pollution Federation.

[3] The American Petroleum Institute, "Task Force Report on Oil Spills," June 14, 1989. p. iv.

[4] Steering Committee Report and Recommendations on the Implementation of PIRO. Jan. 5, 1990, p. 54

case it is still necessary to have the capability to get to the spill site quickly, and not just with the appropriate skimmers and booms or dispersants, as the case may be, but also, as necessary, with barges to hold recovered oil, and with the other necessary equipment that would constitute a complete response system. The whole system will be ineffective as long as any element is missing. For instance, while dispersants and dispersant application systems are available, the timely availability of aircraft to apply dispersants has been a problem. This problem has been addressed in several European countries by having contract aircraft on call for emergencies (the U.S. oil industry would like to be able to use government-owned C-130s, e.g., National Guard aircraft, in the future.) Some European countries also have initiated "sleeping contracts" with local vessel owners to ensure that barges, towboats, and other ancillary equipment are available in emergencies.

Much improvement is obviously needed in the national capability to deliver response equipment to the scene of a spill quickly. Some combination of government and private resources will probably always be needed, and thus clear lines of authority and carefully coordinated plans for deploying these resources are essential.

Photo credit U.S. Coast Guard

Using hot water to "clean" the beaches of Prince William Sound

BEACH CLEANUP: HOW MUCH EMPHASIS?

In many cases, no matter how successful the response to a catastrophic oil spill at sea, a significant fraction of the spilled oil is likely to reach shore. The public was appropriately outraged when efforts to control the *Exxon Valdez* spill failed and a significant amount of oil from the spill contaminated hundreds of miles of Alaska's coastline. Although hundreds of millions of dollars were spent "cleaning" the shoreline, many scientists and oil spill professionals have concluded that, except for the benefit gained by appearing to be doing something useful, the money spent was largely wasted.

While considerable public pressure exists to take immediate action to restore polluted shorelines to prespill conditions, this inherently costly, labor intensive undertaking has seldom had more than modest success, particularly on rocky shorelines. Moreover, in some instances, shoreline cleanup has resulted in more damage than good. Marshes and other wetlands are particularly vulnerable to mechanical cleanup methods, but cleanup of sandy and rocky beaches can also cause additional damage. In some instances, the best course of action, although not a satisfying one, is to do nothing and let the beach slowly recover naturally.

It maybe possible to give greater attention to beach protection and beach cleanup, but the inherent limitations of the available equipment and methods should be made clear to all involved to eliminate false expectations. As noted elsewhere in our report, beach cleaning activities in Europe are usually the responsibility of local authorities. Local authorities in France, for example, have strategically placed stocks of everything from rakes and shovels and hot water pumps to booms. The

Norwegians have gone so far as to require a local response capability in each of the 52 areas that comprise the coastal zone. Where not already done, more attention to defensive booming may require that local and State authorities devise detailed plans and purchase equipment to protect the most sensitive and vulnerable areas.

Bioremediation--the application of nutrients to speed the degradation of oil – is emerging as one promising technique for future beach cleaning. Experiments are now being conducted in Alaska, and the results of these tests will be carefully evaluated over the next year. Nevertheless, effective application of this technique may also be quite limited. Research is being conducted on other chemical treatments as well.

FEDERAL REGULATIONS AND EMERGENCY SITUATIONS

There may exist some situations where what may be appropriate laws or regulations for normal situations unnecessarily hinder effective cleanup operations during emergency situations. Some OTA workshop participants noted, for instance, that the Federal Clean Water Act, in prohibiting oily discharges from tankers[5], makes no exception for the decanting of water collected with oil during skimming operations. Since a considerable amount of water may be collected with oil, the capacity of whatever storage vessel is used may be rapidly reached, unless water that has been or could be separated from the oil can be discharged. This may be accomplished with very little oil reentering the sea. If not done, once storage capacity is reached, skimming operations must cease until oil and water can be offloaded. This may result in far less oil being recovered, for example, as the skimmer sits idle and as the oil spreads further, weathers, and in general becomes more difficult to skim. Ordinary discharge permits may be granted, but may take up to 18 months to obtain. Thus, a general permit preapproving discharge of oily water during oil spill emergencies may be useful to consider.

Second, several foreign vessels were used in recovery operations during the Exxon *Valdez* spill. Such vessels may either be on the scene and therefore handy for mounting portable skimmers or in themselves specialized oil spill vessels. However, under U.S. law, foreign vessels cannot automatically be used in emergency situations as "vessels of opportunity. " The Jones Act prohibits foreign vessels from engaging in coastwise trade, and this act has been interpreted to apply to vessels that transport recovered oil from an offshore site to an off-loading terminal on shore[6]. Waivers to this regulation may be obtained only if a *national security concern can be demonstrated.* The *Exxon Valdez* spill was considered to fall into this category, and waivers were granted by the U.S. Customs Service without undue delay for about a dozen vessels to help in cleanup operations. National security concerns may sometimes be difficult to justify, however, so a general waiver of Jones Act restrictions may be appropriate for oil spill emergencies.

Third, U.S. customs regulations require that foreign equipment formally pass through customs and that duty be paid. Since customs delays are possible, some have suggested that these regulations could be a potential stumbling block to efficient cleanup operations. This concern appears to have little merit, as the Secretary of the Treasury has the authority to waive the regulation in connection with

[5] The "sheen rule" prohibits discharges that "cause a film or sheen upon or discoloration of the surface of the water or adjoining shorelines... " 40 Code of Federal Regulations, Sees. 110.2, 110.3, and 110.4.

[6] Paul Hegland, U.S. Customs Service, personal communication, Nov. 15, 1989.

emergency situations.[7] Waivers are usually obtained without undue delay.

Finally, the ultimate disposal of recovered oil and oiled articles from the *Exxon Valdez* spill proved contentious. The industry wanted to incinerate, and, in some instances, openly burn recovered material. It complained because it could not get permits to do so quickly enough. The State of Alaska hesitated in issuing permits because it wanted to be certain that this method of disposal would not cause an air quality problem. Permits took 2 to 3 months to obtain. Decisionmaking about final disposal of recovered material may not be as urgent as many other decisions that must be made, but when large amounts of oil and oily debris are being recovered by numerous recovery assets, temporary storage capacity may be quickly overwhelmed. In the future it would seem appropriate that contingency plans include plans for waste disposal, specifying for instance, what kind of incinerators are to be used and where they are located.

EQUIPMENT TESTING: HOW REALISTIC? HOW EFFECTIVE?

Equipment testing is an important element of any research and development program. Equipment testing in large tanks, such as in the now closed Oil and Hazardous Materials Simulated Environmental Test Tank (the OHMSETT facility), provides useful information – especially because variable factors such as wave height can be controlled-but is no substitute for testing at sea under realistic conditions. Currently, very little performance data exists on the open ocean, and few laboratory effectiveness tests have been correlated with real field conditions. In particular, no testing with oil has been conducted in recent years in U.S. waters.

There are, necessarily, safety limits to how realistic tests can be. Where safety is not a factor, however, oil spill researchers would like to be able to conduct occasional controlled offshore oil spills for scientific and equipment testing purposes. Such test spills have been conducted in Canada, Norway, the United Kingdom, and France, for instance, and have provided valuable data. While not strictly prohibited in U.S. waters, the "red tape" associated with obtaining permission from the Environmental Protection Agency has effectively blocked intentional spills, according to some OTA workshop participants. One participant noted that a minimum of 20,000 gallons (65 tons) would be needed for a realistic test. Testing at sea, while clearly useful, is also expensive, perhaps costing up to $1 million every time a test is conducted.

As an alternative or supplement to testing equipment offshore with intentionally spilled oil, some have suggested that U.S. Government personnel take advantage of so-called "spills of opportunity" for testing equipment and/or for providing occasions for response personnel to refine skills. The U.S. Government does have a formal program in place to take advantage of spills of opportunity to evaluate equipment, but spills of opportunity do not usually represent ideal test situations. For one, the control over environmental variables that is needed for scientific purposes is not possible during these spills. In addition, researchers may be perceived as being in the way of the cleanup operation.

A related testing issue is the measurement of effectiveness. For some types of equipment, e.g., containment booms, a standard test protocol has been developed to measure effectiveness.[8] It is still very difficult, however, to

[7] 19 CFR 10.107.

[8] Ed Tennyson, Minerals Management Service, OTA Workshop, Aug. 15, 1989.

measure quantitatively the effectiveness of skimmers and dispersants.[9] Lack of an adequate measure of effectiveness has much to do with the controversy over how effective dispersants are (and in what situations).

PERSONNEL, TRAINING, AND DRILLS

The availability of skilled personnel for fighting oil spills is possibly more important than having the ideal type of equipment for a particular spill. The objective of maintaining a work force of oil spill response experts has been frustrated on several counts, however, not least of which is because major oil spills have been rare events in the United States. In all, there exist too little knowledge and experience among those who may have some responsibility for fighting major spills.

The U.S. Coast Guard, which provides on-scene coordinators for spills and, if necessary, a strike team, does not have a career track for oil spill experts. Both the Captain of the Port, who would be designated on-scene coordinator in a spill, and strike team commanders rotate to other positions after 2 to 4 year assignments. Although they receive simulation and classroom training, few are able to acquire experience fighting major spills.[10] The U.S. Navy has contract personnel dedicated to oil spill response. The Navy may be called to provide equipment and help fight major U.S. oil spills (as in the case of the *Exxon Valdez* spill]; however, the primary responsibility of its oil spill unit is to support Navy operations worldwide. Would-be contractors find it difficult to stay in business given the rarity of major spills. Those that do exist largely to support industry cooperatives, and neither the cooperatives nor the contractors have much experience dealing with catastrophic spills.[11]

To remedy this situation, several OTA workshop participants suggested that the United States create a professional cadre, perhaps within the Coast Guard and/or within the private sector, whose entire career is dedicated to dealing with spills around the country. Such a group could be available to respond to all major U.S. spills as well as to provide advice and assistance for smaller spills. Rather than losing experience through rotation and reassignment, a group of oil spill professionals would retain and build experience. The skills and experience of such a group might be enhanced further by giving it the capability to advise or participate in responses to major spills elsewhere in the world, as needed. Moreover, it may be prudent (although more expensive at the time) to over-respond to certain types of spills. If a spill turns out to be less severe than initially thought, advantage may still be taken by using the response as a training exercise. (Funds spent when an overresponse proves not to be justified may be more than offset on those occasions when the initial response *is* justified). Oil spill experts must maintain skills that may not be required for long intervals. Notably, the petroleum industry, through its proposed Petroleum Industry Response Organization, has proposed to man each of its regional response centers with "dedicated, trained personnel" and to stress training and drilling of its personnel.[12]

Personnel training must include instruction about the capabilities and limitations of a range of countermeasures techniques and equipment. Most of the equipment on the

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[9] Merv Fingas, OTA Workshop, Aug. 15, 1989.

[10] Mr. Jim O'Brien, OOPS, Inc., OTA workshop, Aug. 15, 1989.

[11] The American Petroleum Institute, "Task Force Report on Oil Spills," June 14, 1989. p. 10.

[12] Ibid. p. iv.

market is operator sensitive; hence, the performance of a given piece of equipment is directly related to the operator's knowledge of it. Also, contingency plans need occasional testing, preferably full scale testing of the complete containment, cleanup, and disposal system. With few major spills, complacency may easily become a problem unless steps are taken to counteract it. Contingency plan testing should involve State and local authorities who will have some responsibility in the event of a spill, as well as oil spill professionals.

The National Forest Service has developed one system for responding to natural disasters that may be worth emulating. Its Incident Command System for forest fire fighting is based on a complete training program for individuals within various separate organizations who can be called on in the event of a large fire. This system creates a management structure for responding to these rare events. This same approach could be applied to large oil spills.

RESEARCH AND DEVELOPMENT

Organizations and Programs

Several agencies within the Federal Government are engaged in oil spill countermeasures research and development. The three most important are the Department of the Interior (DOI), the Department of Transportation (DOT), and the Environmental protection Agency (EPA).

Within the DOI, oil spill research is conducted by the Technology, Assessment, and Research Branch of the Minerals Management Service (MMS). Among other things, MMS has plans to:

- finalize offshore equipment test procedures,
- continue field verification of in situ burning,
- continue refining airborne oil thickness sensors,
- conduct final testing of the high-speed water jet barrier boom,
- develop beach line cleanup techniques that are environmentally acceptable,
- continue to conduct research to improve the effectiveness of chemical treatment agents,
- continue developing a remote sensor for detecting oil in broken ice and darkness,
- finalize standard equipment and technique test procedures, and
- continue assessing the behavior of heavy oils.[13]

MMS would also like to reopen the Oil and Hazardous Materials Simulated Environmental Test Tank– the OHMSETT facility, located in New Jersey. OHMSETT was formerly operated as a cooperative interagency program to evaluate oil spill response equipment and procedures, but closed when funding dried up.

The Department of the Interior has increased funding for oil spill research in response to the Exxon *Valdez* spill. Notably, it has entered into an agreement with the American Petroleum Institute to jointly fund some research and development. Each will contribute $1 million per year for the next 3 years. The projects listed above are among

[13] Interagency Planning Workshop on Oil Spill Research and Development, Sep. 26-2'7, 1989, Groten, CT. Workshop report prepared by Decisions and Designs, Inc., Arlington, VA.

those being considered for funding. Some of the research may be done in cooperation with other agencies and with parallel Canadian efforts.

Oil spill research and development in the Department of Transportation is carried out by the U.S. Coast Guard. The Coast Guard proposes to spend about $4.1 million in fiscal year 1990 on oil spill response projects and about $1.8 million on prevention projects. It is considering allocation of funds for the following oil spill response projects:

- spill response information system development,
- spill response training aids development,
- surveillance systems development,
- satellite imagery for spill tracking,
- rapid deployment technology assessment,
- tanker salvage and countermeasures development,
- mechanical recovery systems development,
- OHMSETT support,
- Coast Guard countermeasures/equipment development,
- chemical countermeasures technology assessment,
- in-situ burning development,
- short term test and evaluation in Alaska, and
- spill response personnel health and safety.[14]

In the aftermath of the *Exxon Valdez* spill, the Coast Guard R&D center in Groten, Connecticut acted as a clearinghouse for proposals and suggestions concerning cleanup. As table 4-1 indicates, 139 of these proposals were considered to have immediate applicability for combating the *Exxon Valdez* spill. Although a significant number of proposals were rejected as not feasible, a still sizable number merit future investigation by government and industry researchers.

EPA plans to spend $1 million during 1990 for oil spill research. This funding will be largely devoted to the continuation of the shoreline bioremediation program started last year in Alaska. EPA and Exxon have signed a cooperative agreement to carry out the research. Exxon has provided a total of $3 million to date for this program. EPA is currently developing a 5-year research plan, which will be implemented if Congress passes the implementing legislation.

Several other agencies are also conducting important oil spill response research and development. The Army Corps of Engineers used two dredges to *recover* some of the oil spilled by the *Exxon Valdez,* and is now investigating how to use its dredges more effectively. The National Institute of Standards and Technology, in conjunction with MMS and the American Petroleum Institute, is conducting in situ burning research. And the National Oceanic and Atmospheric Administration is developing electronic communications for response situations and studying the fate and behavior of oil.

The Exxon *Valdez* spill also galvanized oil industry support for spill research and development. In April of 1989 the American Petroleum Institute created an oil spill Task Force to review industry operations in the areas of

[14] U.S. Coast Guard preliminary marine environmental protection research and development plan, fiscal year 1990. Nov. 18, 1989. (Draft).

Table 4-1 -Suggestions Received by the Coast Guard

Category		Number
Proposals for future government investigation:		
Bioremediation		34
Chemical (dispersant, degreaser)		14
Physical (solidification, absorbent, etc.)		19
Collection - vessel		17
Collection - mechanical		17
Skimmer - booms		30
Hull patching		4
Oil movement		3
Wild-life cleanup		5
Incineration		4
Miscellaneous		13
25% of database	Total	160
Proposals forwarded to Exxon:		
Bioremediation		2
Chemical (dispersant, degreaser)		24
Physical (solidification, absorbent, etc.)		36
Collection - vessel		14
Collection - mechanical		19
Skimmer - booms		–
Hull patching		
Oil movement		–
Wild-life cleanup		–
Incineration		5
Miscellaneous		39
22% of database	Total	139
Other responses:		
● Previous research/application indicates method not feasible		
● Letters of general concern		
53% of database		

SOURCE: United States Coast Guard, 1990

oil spill prevention and response. As a result of the Task Force's deliberations, the industry created the Petroleum Industry Response Organization (PIRO). In addition to establishing the operational capability to respond to catastrophic oil spills, PIRO will design and manage a research and development program. The oil industry has pledged $30 million to $35 million to PIRO during its first five years for this purpose and expects to contribute $1 million to $4 million per year thereafter. Six major subject areas have been identified:

1. preventing loss of oil from or away from the ship,
2. on-water oil recovery and treatment,
3. preventing and mitigating shoreline impact,
4. fate and effects of oil in the environment,
5. wildlife preservation, and
6. health and safety.[15]

Among those projects on which PIRO would expend the most funds during the initial 5 year period are bioremediation of shorelines, development of chemical dispersants and skimmers for on-water recovery and treatment, and development of absorbents and absorbents for shoreline use.[16] In all, some 38 projects have been considered for funding. PIRO recognizes a need to coordinate with government agencies to avoid duplication of research.

Both Senate and House oil spill bills (S 686 and HR 1465, respectively) pending as of this writing provide for the establishment and funding of oil spill research and development programs. Among the priority research identified in the Senate bill are on-water oil recovery and treatment, prevention of loss away from vessels, and prevention and mitigation of shoreline impacts. The House bill specifies – among other things– research, development, and demonstration of new or improved systems of mechanical, chemical, biological,

[15] PIRO Implementation, Inc., draft statement of PIRO's proposed R&D program, Oct. 10, 1989.

[16] Ibid.

and other methods (including the use of dispersants, solvents, and bioremediation) for the recovery, removal, and disposal of oil. Both bills establish coordinating committees to oversee oil pollution research. The House bill would establish a minimum of six regional research centers at universities or other research institutions to address one or more of the research needs identified in the bill. The Senate bill would establish a Prince William Sound Oil Spill Recovery Institute to identify and develop the best technology for dealing with spills in arctic and subarctic marine environments.

Discussion

OTA's investigation of oil spill response technologies indicates that the country's ability to recover oil from large spills is inadequate. It can be improved, but a large technology research and development effort does not offer the promise of major breakthroughs. Although most of the R&D projects proposed by government and industry appear to be worthwhile, OTA's analysis shows that only *modest and gradual improvements* can be expected from most mechanical response technology R&D. And it is important to remember that technology is only one of many variables that can affect the recovery of oil from a spill. The benefits likely to result from improvements in technology alone may not be noticed in the ultimate amount of oil recovered from any major spill. An R&D program can be justified, however, on the basis of the need to maintain the best capability possible and to understand the most appropriate uses, capabilities, and limitations of all the systems that may be available in the future.

Creation of a program to test oil spill equipment under realistic, at-sea conditions — occasionally using real oil —is particularly desirable. OTA's analysis indicates that much equipment has mechanical deficiencies because it has never been field-tested. Testing has been conducted in the past at the now closed OHMSETT facility. Additional work at a reopened OHMSETT may be useful, but a bigger payoff would result by testing response technologies at sea. Although controlled spills have been allowed in many European countries (sometimes with U.S. observers present), it has been more than 10 years since an experimental offshore oil spill has been allowed in the United States. In light of recent events, it would be useful to allow occasional experimental spills to test equipment. Whatever U.S. testing is undertaken should be coordinated with similar efforts in other countries.

OTA's investigations also show that coordination of R&D efforts within the government, between the government and the private sector, and among the many other interests worldwide is essential to reaching desired goals with minimum waste of resources. The several Federal agencies with R&D programs have different purposes and perspectives, but there is considerable overlap as well. MMS, the Coast Guard, and EPA are all concerned with acceptable standards and evaluation of performance of cleanup systems. They must work together to agree on final results, but one agency could take the lead in major program funding for best efficiency.

It is also vital that the Federal Government coordinate its efforts with those of private industry, especially if a substantial R&D program by PIRO gets underway as planned. This is important for several reasons. First, the industry work may be directed at its own priorities; government priorities could be different and require additional work in areas not covered by industry. Second, the government must be completely knowledgeable about new technologies and techniques if it is to fulfill its role as principal coordinator and/or manager of future response efforts. Third, if the industry supports good, credible programs in certain areas, it would be wasteful for the government to duplicate the effort.

An area in which greater collaboration between the United States and other countries on oil spill issues could lead to a sizable payoff is research and development. The United States and Canada have long cooperated on oil spill R&D, and this relationship appears to have been profitable for both countries. However, aside from the biennial Oil Spill Conference meetings, at which research findings are often presented by foreigners, no formal forum exists for the exchange of information between the United States and other countries. OTA has observed that there appears to be a significant amount of overlap in the research of organizations like the French Center for Documentation, Research, and Experimentation on accidental pollution (CEDRE), the British Warren Springs Laboratory, and the Dutch State Waterways Board with oil spill researchers in the U.S. government. Greater coordination and/or collaboration could lead to less duplication, faster dissemination of research results, faster progress on problems of mutual concern, and a better use of limited R&D funds.

Table 4-2 displays a summary of R&D plans for the organizations that OTA has contacted and that have current plans for oil spill R&D expenditures over the next few years. The planned programs of PIRO, the Coast Guard, MMS (in cooperation with API), and the EPA are displayed and broken down into several research areas with notations of high, medium, low, or no priority under each. The total planned expenditures are about $10 million to $15 million per year in the near term. About two-thirds will be from industry and one-third from government. It can be seen that there are many areas of multiple interest that could lead to waste if not carefully coordinated. It can also be seen that some areas that seem to offer promise of future improvement may be neglected. For example, it appears that the engineering of complete systems for rapid deployment, recovery, handling, storage, and support for large operations— perhaps including vessels of opportunity– is one area where additional progress is needed. No group appears to be focusing on deployment systems as a whole (although PIRO has plans to do so). Another potential oversight is the needed development of more reliable and rugged components in mechanical recovery equipment to handle viscous oils, water emulsions, debris, etc.

In general, however, R&D attention by the several groups that have planned programs appears to be focused on important problems. If these plans are carried out, if they are well-coordinated, and if developments become the basis of a major expansion of equipment resources strategically deployed in high readiness condition — this would offer needed improvements in national response capability.

Table 4-2-Selection of Planned R&D Efforts by Federal Agencies and Industry

Research area	PIRO	Coast Guard	MMS (with API)	EPA
Surveillance/ data	-	H	H	M
Deployment systems	–	M	L	-
Source containment	L	H	–	–
Mechanical recovery	L	H	L	
Dispersants	H	L	M	M
Bioremediation	H	–	–	H
Burning	M	H	H	--
Other/ shoreline remediation	M	–	H	M
Fate and effects	H		–	H
Health and safety	L	M		–
Disposal	M	–	–	–
Training/ testing	–	H	M	Bio Test with Exxon ($3 million)
Proposed Budgets $ million/yr	$7	$3-$4	$2	$1

NOTE: Hi = High, M = Medium, L = Low
PIRO = Petroleum Industry Response Organization
MMS = Minerals Management Service
API = American Petroleum Institute
EPA = Environmental Protection Agency

SOURCE: Office of Technology Assessment, 1990

Chapter 5

Selected European Oil Spill Policies

INTRODUCTION

In order to investigate oil spill technologies in use abroad and to learn how the United States might benefit from the oil spill experiences and policies of some other countries, OTA staff visited four countries bordering the North Sea in September, 1989: France, the Netherlands, the United Kingdom, and Norway. OTA's trip was coordinated by the International Petroleum Industry Environmental Conservation Association and included visits to a number of government and industry organizations in these countries. The four countries selected represent a wide range of technologies and countermeasures policies. Below are some of the highlights of our findings.

FRENCH OIL SPILL POLICY

The French seriously began to consider a comprehensive approach to fighting oil spills in the aftermath of the *Torrey Canyon* grounding off England in 1967, but French policy evolved significantly as a consequence of France's unfortunate experience with the *Amoco Cadiz* spill in 1978. This accident, in which approximately 223,000 tons (68 million gallons) of oil were spilled along the Brittany coast, was about 6.5 times as large as the *Exxon Valdez* spill, making it the fourth largest in history (table 5-l).

Notably, the French have assigned responsibility for fighting oil spills at sea to the French Navy, whose responsibilities are generally the equivalent of those of both the U.S. Navy and U.S. Coast Guard. Although emphasis is placed on spill prevention, once a spill has occurred the French Navy has the authority to use whatever means are deemed most appropriate to fight the spill. Oil that has reached the shoreline is the responsibility of local authorities.

For fighting oil spills at sea, the offshore area surrounding France has been divided into three maritime regions. Oil spill responses within each region are directed by the responsible Maritime Prefect, a senior Navy officer who is also responsible for the defense of the area.[1] The Maritime Prefect's first priority is to prevent maritime accidents by enforcing navigation regulations. Traffic separation lanes have been established in some areas, and large, ocean-going tugs are used as both "watch dogs" and rescue ships. In the event of a spill, the Maritime Prefect functions as onscene commander rather than onscene coordinator, and hence has considerably more authority than his U.S. Coast Guard counterpart. (If a similar arrangement were in effect in the United States, *at least* **4** "maritime prefects, " possibly U.S. Coast Guard officers, would be required, one each for the East, Gulf, West, and Alaskan coasts). Relatively minor spills are handled with local equipment. If a spill occurs that is larger than local resources can handle, an offshore marine pollution plan, POLMAR MER, is invoked, and the Maritime Prefect can then draw on the equipment and expertise of other regions, and, if necessary, of private stocks.

Local civil authorities are responsible for containment and cleanup when an oil spill reaches or threatens to reach land. Each of France's 26 coastal departments (states) prepares its own POLMAR TERRE response plan, which the prefect (governor) of each department can invoke in the event of a major threat. The plans identify priority areas to be

[1] G. Marchand, G. Bergot, M. Melguen, and G. Peigne, "French Know-How in the Prevention and Fight Against Accidental Oil Spills, " 1987 *Oil Spill Conference Proceedings,* Apr. 6-9, 1987, Baltimore, MD, pp. 15-22.

protected and specify how booms will be installed in these areas, what public and private equipment is available, and where storage sites and treatment centers for recovered products are located.[2] Small spills are handled by commune officials (mainly by fire departments) with local equipment stocks. The Army may be called for major spills and used to clean beaches with material and equipment from the POLMAR stocks. Having experienced major beach pollution and having recognized that a significant proportion of any major spill may reach the coastline no matter what measures are taken, the French have put much effort into research and development of beach cleaning equipment and into planning and training for beach cleanup. OTA found French beach cleaning technology and organization to be an impressive element of its oil spill cleanup plans. There is no comparable emphasis on defensive beach protection measures in the United States.

Stocks of equipment for fighting offshore spills are maintained at POLMAR centers in Brest, Cherbourg, and Toulon, the headquarters of each of the three maritime regions, and also in Le Havre, Lorient, Port de Bouc, and Ajaccio. Purchase and maintenance of this equipment is the responsibility of the French Ministry of Defense. Booms for the protection of sensitive nearshore and onshore areas are located in eight POLMAR centers around the country, so that no part of the coastline is further than 250 kilometers from a boom storage center. Equipment for land cleaning opera-

Photo credit: Jim Mielke

French sand washing machine.

[2] Ibid.

tions (e.g., sand washing equipment and hot water pumps) is stationed at two of these eight centers.[3] The Secretary of State for the Sea is responsible for the purchase of equipment for onshore activities.

Unlike the three other countries OTA visited, the French do not rely primarily on one countermeasure technique. Both mechanical equipment and dispersants are at their disposal, and the technique or techniques best suited to the circumstances will be employed. While recovery at sea is preferable, the Navy may use dispersants without conferring with others if the spill is seaward of environmentally sensitive areas (as a rule of thumb, where the water depth is greater than 30 meters).

French mechanical cleanup equipment is not radically different from that available in the United States. Some French technology, including the Egmolap skimmers successfully used in nearshore operations in Prince William Sound, is available in the United States. Beach cleaning technology (e.g., sand washers) is innovative and deserves some attention for use in the United States. Also, the French have been experimenting with biodegradation accelerating agents. They supplied one of the products (Inipol eap 22) for bioremediation experiments in Prince William Sound.

In the wake of the *Amoco Cadiz* oil spill the French government established CEDRE, the Center for Documentation, Research, and Experimentation on accidental pollution. Among other things CEDRE advises authorities responsible for pollution control about state-of-the-art techniques, assists and advises authorities during crises, trains personnel, conducts research to improve existing methods, and tests equipment (including occasional testing in small, deliberate oil spills at sea). The organization has a permanent staff of 26 and a budget of 10 million francs per year. There is no equivalent U.S. organization, although counterparts of many of CEDRE's missions are spread around various U.S. Executive Branch agencies. CEDRE is a key element in the French oil spill countermeasures approach. Its existence ensures that at least some attention is devoted to oil spill issues in the sometimes long periods between major spills.

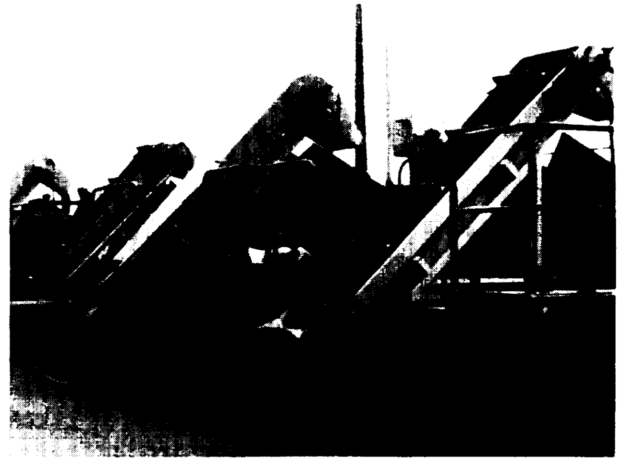


Photo credit Jim Mielke

French Egmolap skimmers stockpiled at the POLMAR center in Brest. Egmolap skimmers were used to recover oil in nearshore areas of Prince William Sound.

DUTCH OIL SPILL POLICY

The Dutch rely entirely on mechanical recovery for fighting spills as they have no confidence in the effectiveness of chemical dispersants. The most notable aspect of Dutch reliance on mechanical means is their use of large dual purpose vessels. Large skimming vessels have advantages over small skimmers because they can simultaneously skim and store much more oil than a small vessel and because they can operate in heavier seas. Nevertheless, large, dedicated spill vessels are expensive to maintain and operate and slow to respond to distant spill sites. The Dutch argue that a large vessel built purely for pollution control purposes would be idle for the greater

[3] Centre POLMAR de Brest, "The Fight Against Oil Pollution on the Coastline: Missions and Methods of the POLMAR Centers," May 1987.

part of its life and is therefore economically difficult to justify.[4] However, vessels that can be put to use in periods between oil spills are much more attractive. Hopper dredges are especially suitable for dual use purposes in the Netherlands: the country is small, has a sandy coastline, and has significant dredging needs in important ports and waterways. These dredges can be equipped with recovery equipment and can hold sizable amounts of recovered oil. Dredges normally operate in areas where the risk of oil spills is high– the approach channels to ports. Moreover, it takes only a few minutes for a hopper dredge to discharge its cargo and to be available for spill cleanup duties.

The Rijkswaterstaat, or State Waterways Board, is responsible for vessel pollution countermeasures at sea, along the coast, and in the main navigable waterways in ports.[5] It also conducts oil spill research. As in France, although the government takes charge in the event of vessel spills, the polluter is liable for all cleanup costs. Oil companies are expected to fight platform spills. In the event of a large tanker spill, one or more dredges may be called into cleanup action. Notably, dredges are under contract to the government rather than owned by it. Where the flash point of the spilled oil is high enough, any dredge under contract may be used. If the flash point is below 140°F, which is occasionally the case, a dredge designed to tanker specifications (e.g., the *Cosmos)* is used. When called, a dredge drops its spoil, proceeds to its base, is fitted with sweeping arms for oil containment and recovery, and sails to the spill site to begin recovery. The whole process generally takes about four hours, although Dutch dredges are seldom further than 20 kilometers from their bases.

The Dutch system is intended (perhaps optimistically) to be able to cope with a 30,000 cubic meter spill (about the size of the *Exxon Valdez* spill) in 3 days. Assuming that about 50 percent of a spill evaporates, mechanical equipment must be able to recover 15,000 cubic meters. In all, 7 units, each unit containing 200 meters of boom, 2 sweeping arms, a recovery vessel, and an assistant vessel, are available to meet this goal.

Dual use dredges could prove useful in the United States. Although no single approach is likely to be the magic solution for all situations, major port areas where dredges are operating would be primary candidates for such systems. As with other approaches, supporting equipment and facilities must also be available. The usefulness of oil skimming dredges in areas far from ports, for which significant time would be required to reach, is less obvious, although in some cases dredges may be able to steam to a spill site in time to make a difference in the cleanup effort. The Dutch State Waterways Board suggested to OTA that 10 to 20 sets of sweeping arms, located at key ports around the United States, might be adequate coverage. Existing dredges either owned or chartered by the Army Corps of Engineers could be converted to accept the sweeping arms. IHC estimates that costs to reconfigure dredges to accept sweeping arms would be about $400,000 per vessel, and that the equipment itself– which could be shared among several vessels–would cost about $600,000 per set. At present, the Army Corps of Engineers has no responsibilities for oil spills, so a change in the basic U.S. approach would be required.

[4] IHC Dredge Technology Corp., "The IHC Slicktrail and Its Possible Application in the U. S.A.," Prepared for U.S. Army Corps of Engineers, Trailing Suction Hopper Workgroup Session, Atlantic City, NJ, June 14-15, 1989.

[5] "Comparative Study of Pollution Control Policy and Contingency Plans in France and in the Bonn Agreement Member Countries," paper presented at the Nineteenth Meeting of the Bonn Agreement Working Group on Operational, Technical, and Scientific Questions Concerning Counter Pollution Activities, Renesse: May 3-6, 1989, p. 22.

UNITED KINGDOM OIL SPILL POLICY

Responsibility for responding to offshore tanker spills in the United Kingdom is accepted by the central government. The government provides the response equipment, directs the response operation, maintains and updates the national contingency plan, and reviews developments in pollution control equipments This authority has been delegated to the Marine Pollution Control Unit (MPCU) of the Department of Transport. The MPCU is assisted by the Coastguard, whose primary role with respect to marine pollution is to detect and report pollution incidents. Response to platform spills in the North Sea is the responsibility of the operator. Response policy for these spills is set by the Department of Energy, but the MPCU provides advice and may help with the cleanup operations if the operator's resources prove inadequate. Pollution that reaches shore is primarily the responsibility of local authorities, but the MPCU advises and assists as required. In a major coastal pollution incident (one beyond the resources of a local authority) the MPCU would set up a Joint Response Center and would then coordinate and lead the onshore response to ensure a fully integrated at-sea and on-shore cleanup operation.[7] Stocks of specialized beach cleaning equipment are held by the MPCU to supplement local resources. Cleanup costs are initially borne by the MPCU, but where the polluter can be identified, he will be required to refund the costs of the measures.

It is the policy of the British government to rely on dispersants as a first line of defense for oil spills; mechanical recovery plays a secondary role. This policy is based on the government's lack of faith in the effectiveness of mechanical equipment in weather conditions and sea states typical of the North Sea and other waters surrounding the United Kingdom and on the view that recent advances in dispersants have improved their effectiveness and made them much less toxic. According to the MPCU General Information Notes, "The only operationally proven technique for combating oil at sea in the conditions prevalent around the coastline is spraying with dispersants."[8] Only dispersants which have passed appropriate tests may be used. Immediately after a spill occurs, a determination is made as to whether dispersant use would be safe and effective. The MPCU consults with the Fisheries Department and the Nature Conservancy Council on the appropriateness of dispersant use in sensitive areas and in water less than 1 mile from shore or less than 20 meters in depth.

The MPCU currently has seven airplanes under contract for applying dispersants. Two remote sensing aircraft are available to direct the response effort. Aircraft and dispersants are strategically positioned at airports around the country. During daylight, aircraft must be ready to fly within 30 minutes of notification; at night they must be ready within 2 hours. Hence, the MPCU is able to start spraying dispersants very soon after a spill occurs, an important advantage since effectiveness depends on early application, and in most cases oil can no longer be dispersed after about 48 hours. The Unit also has dispersant spraying equipment fitted to a number of commercial tugs located at strategic positions around the U.K. coast; a small amount of mechanical recovery equipment to deploy in chartered vessels; a stock of cargo transfer equipment for lighter-

[6] W.H.H. McLeod, "Control of Oil Pollution Response Activities," *The Remote Sensing of Oil Slicks,* A.E. Lodge (cd.) (London: John Wiley & Sons, Ltd., 1989), p. 115.

[7] Department of Transport, "MPCU General Information Notes. "

[8] Ibid. p. 10.

ing operations; and stockpiles of beach cleaning equipment.

During OTA's visit, two tankers collided off the Humber Estuary, resulting in an oil spill of 800 tons. The MPCU determined that the oil could be dispersed, and had the spraying operation under way within 3.5 hours. In the United States, both the decision to use dispersants and the mobilization of airplanes and ships may take much longer.

With available dispersant equipment, the MPCU maintains it can treat 5,000 tons of oil at sea in a 48-hour period. Planned upgrades in the aircraft fleet will increase this capability to 14,000 tons. The MPCU assumes that in most coastal spills the greater part of the oil will come ashore and estimates that with the assistance of MPCU beach cleaning equipment a local authority can clean up some 6,000 tons of oiled material from beaches every 7 to 10 days.

In the event of a very large spill, the MPCU may ask for assistance from neighboring countries. The United Kingdom and seven other countries bordering the North Sea have entered the Agreement for Co-operation in Dealing with Pollution of the North Sea by Oil, commonly called the Bonn Agreement, to facilitate the sharing of equipment and the exchange of information about oil spill countermeasures. The United Kingdom also has bilateral oil spill agreements with France (the Manche Plan) and Norway (the Norbrit Plan). Although no formal agreement exists between industry and the government, the MPCU may also ask for assistance from the oil industry's oil spill response base, located in Southampton, England. The Southampton base currently maintains one of the largest stocks of oil spill equipment in the world, valued at about 4 million pounds. Exxon is a paying member of this cooperative, and was therefore able to use about half of the Southampton stock in the *Exxon Valdez* spill. The Southampton Base is a joint venture company. The full participants are Esso, British Petroleum, Shell, Texaco, and Mobil. These full participants can call on a maximum of 50 percent of the available equipment to respond to spill emergencies worldwide. Petro Canada is a lesser participant and, as such, may only use equipment in proportion to its contribution.

The MPCU also funds a research program to develop improved techniques for predicting the behavior of spilled oil, dealing with it at sea, and predicting its environmental impact. This program also covers hazardous chemicals.

NORWEGIAN OIL SPILL POLICY

Oil pollution control policy in Norway is the responsibility of the State Pollution Control Authority (SPCA) within the Ministry of the Environment. For major pollution, the SPCA presides over the Government Action Control Group, which also includes representatives from other government ministries, the oil industry, and the scientific community. Responsibilities for actual cleanup are divided among the SPCA, local authorities, and the offshore oil companies. In general, the polluter is responsible for cleaning up oil spills, but if the polluter is incapable of handling a spill or if extra help is required, the SPCA may, at its discretion, take over the operation.[9] In this sense, Norwegian oil spill policy is similar to that of the United States. In practice, the oil and gas industry has prepared specifically to respond to offshore platform spills, while the SPCA generally expects to respond to spills from ships– an important difference between U.S. and Norwegian approaches.

The SPCA has decreed that oil pollution will be fought by mechanical means to the extent possible. Dispersants are used only if mechanical cleanup has proved ineffective and

[9] The Norwegian State Pollution Control Authority, "Oil Pollution Control: Emergency Services in Norway," February 1983.

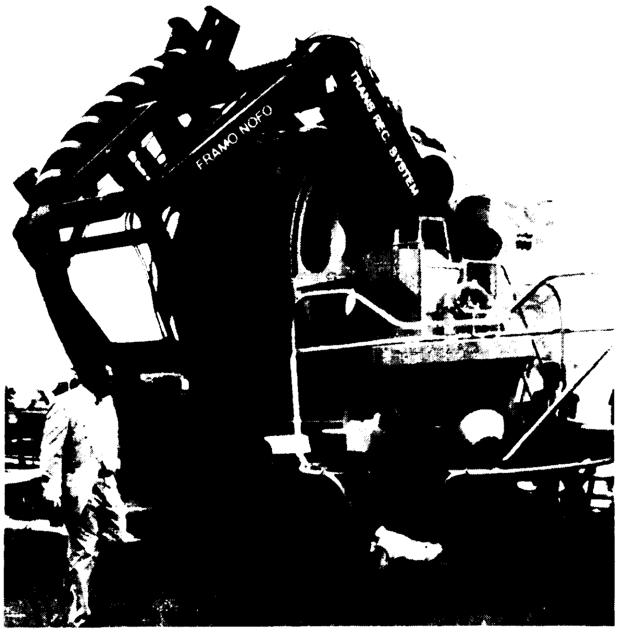


Photo credit: Jim Mielke

Norwegian Transrec weir skimming system.

only with approval from the SPCA. The SPCA requires that the offshore oil and gas industry be able to recover 8,000 tons of oil per day, that the equipment for doing so be able to operate in significant wave heights of up to 2 meters and in currents of up to 1.5 knots, and that this equipment beat the spill site within 48 hours of a spill. The SPCA has also imposed requirements on refineries and large terminals. These are required to be able to cope with 5,000-ton spills.

To meet offshore requirements, the eleven oil and gas companies that operate on the Norwegian continental shelf have organized the Norwegian Clean Seas Association for Operating Companies (NOFO). NOFO maintains a total of 14 oil recovery and transfer (Transrec) systems and 8,750 meters of heavy duty boom at 5 strategic locations along the Norwegian coast. The Transrec systems have been designed for operation in rough North Sea conditions and are among the largest skimming and transfer systems available anywhere. These systems have been designed to be mounted on the large industry work boats that make regular shuttles between shore bases and offshore platforms, and, hence, are never far from an equipment depot. These boats have a storage capacity of about 1,000 tons.

Local authorities are responsible for fighting spills on and within 3 miles of the coast. Fifty-two municipal and intermunicipal contingency areas have been designated, and within each area an Oil Pollution Control Committee, with direct responsibility for the cleanup effort, has been established. Local resources are used for small spills. The costs of municipal oil spill equipment are shared equally between the central and local governments.

Spills that are larger than can be handled locally and/or beyond the capacity of the polluter to handle are in part or totally taken over by the SPCA. The SPCA has established 12 equipment depots at strategic locations along the coast. Each depot is stocked with about $1 million (U. S.) worth of equipment, including heavy, medium-heavy, and light booms, one large and two smaller skimmers, and a supply of beach cleaning equipment. In addition, the SPCA has contracted with a number of coastal tankers, tugs, and purse seine fishing vessels. These vessels are on call and maybe used in a large spill. The purse seiners can be equipped with skimmers and operate as both oil recovery vessels and oil storage vessels. In all, municipal, state, and private organizations have established a total of 17 oil spill depots along the coast containing about 60 miles of light and heavy booms and 300 skimmers. Numerous storage and boom towing vessels are on call.

Norway has made a strong commitment to oil spill response training. The SPCA's Oil Spill Control Center in Horten offers a series of courses and exercises in oil spill control. A most impressive aspect of this program is the wide range of personnel that participate: virtually all municipal, state, and private employees involved in decisionmaking and/or cleanup operations in Norway receive train-

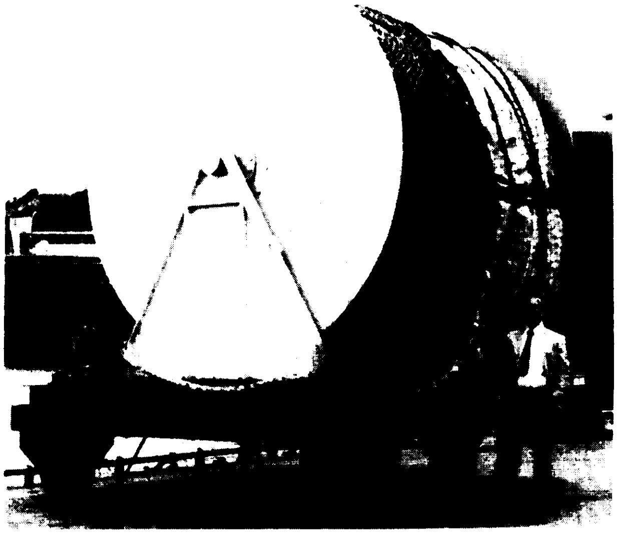


Photo credit: Bill Westermeyer

Large offshore boom on reel, used by the Norwegian Clean Seas Association for Operating Companies (NOFO).

ing. The goals of this program are to train personnel to know their responsibilities in an emergency spill situation and to give them the knowledge and experience needed to meet these responsibilities. As one notable training device, the Center has developed an elaborate "tactical exercise." In this exercise accident situations are simulated and trainees play the roles they would play in a real emergency situation. Such roles may range from state or municipal decisionmaker to master of a vessel to a fisherman complaining of damaged gear. In addition to simulations, major seagoing exercises (which can include experimental, controlled oil spills) are conducted yearly. A consequence of the emphasis on training in Norway is that those with oil spill cleanup responsibilities at all levels of government and industry– an estimated 3,000 people—are well informed about the decisionmaking process and about the types of things that can go wrong. Uncertainty about how to respond appears to have been reduced to a minimum.

GENERAL COMMENTS

There exist almost as many approaches to fighting oil spills in Europe as there are European countries (table 5-l). The degree of reliance on mechanical cleanup methods is one area, for example, where the full range of possible approaches are exhibited: some countries rely exclusively on mechanical cleanup methods, others on both mechanical methods and dispersants, and still others almost solely on dispersants. No European country, however, relies on burning as an important part of its spill response arsenal. Some other variables include the type of mechanical equipment preferred, the government agency assigned primary authority for oil spill response, the division of authority between local and statewide officials, the amount of oil for which countermeasures must be prepared to deal, the role of private industry in cleanup efforts, and the preferred approach to training, drills, and equipment testing.

These differences are based, in part, on circumstances peculiar to each country, e.g., the use of dual purpose dredges seems to make particularly good sense in the Netherlands, given the amount of local dredging activity, as does the use of large work boats for countermeasures platforms in Norway, given their utility in rough seas and the fact that these vessels regularly shuttle between the offshore platforms and shore bases. No doubt different approaches are also based on the different experiences of each country. In European countries, as in the United States, progress is made, much of the time, by the pressure of events, and revisions in contingency plans have been made in several countries in the aftermath of major pollution incidents.[10] Importantly, some differences among countries seem to be based on different perceptions about the effectiveness of a technique, about risk, and/or about costs v. benefits, i.e., on

[10] Op. cit., footnote 5, page 39.

Table 5-1 -Summary of Oil Spill Response Arrangements

Country	Central government departments primarily involved	Responsibility for clean-up: At sea	Responsibility for clean-up: On-shore	Policy for clean-up at sea	Clean-up resources
Belgium	Ministry of Defense Ministry of Interior	Navy	Coastal munici-palities; Civil Defense Corps	Dispersants applied from vessels	Limited mainly to dispersants and spraying equipment.
Denmark	Ministry of Environment	National Agency for Environmental Protection	National Agency for Environmental Protection; coastal local authorities; Civil Defense Corps	Containment and recovery almost exclusively although provision for limited use of dispersants	Specialized vessels equipped with booms and skimmers. Also equipment and materials for shore clean-up in district stockpiles.
France	Secretary of State for the Sea Ministry of Defense Ministry of Interior	Maritime Prefect (Navy)	Coastal communes: Commissioner of the Department	Containment and recovery preferred but dispersants used in designated areas	Extensive stocks of specialized equip ment and materials in regional stockpiles. Also strike teams and aircraft for dispersant spraying.
Federal Republic of Germany	Ministry of Transport	Federal Board of Waterways and Navigation; coastal states	Coastal states	Containment and recovery preferred but dispersants also used in North Sea	Specialized vessels, booms, skimmers, spraying equipment and dispersants.
Netherlands	Ministry of Transport and Public Works	North Sea Directorate of State Waterways Board	Coastal provincial and municipal states	Containment and recovery exclusively	Specialized vessels, including combined dredgers/oil combating ships equipped with oil recovery equipment. Other vessels for deploying booms. Other equipment held by salvage and private contractors.
Norway	Ministry of Environment	State Pollution Control Authority/Maritime Directorate	Coastal community and intercommunity areas	Containment and recovery almost exclusively, but will consider dispersants if mechanical means are ineffective	Extensive stocks of specialized equip-ment and trained response teams at 12 regional centers.
Sweden	Ministry of Defense	Coast Guard Service	Municipal fire brigades; provincial authorities	Containment and recovery preferred although dispersant application permissible under certain conditions	Large fleet of vessels equipped for anti-pollution work, Extensive stocks of clean-up equipment in some 30 coastal sites.
United Kingdom	Department of Transport	Marine Pollution Control Unit of Maritime Directorate	Marine Pollution Control Unit of Maritime Directorate; coastal local authorities	Aerial application of dispersants; containment and recovery where applicable	7 dedicated spraying aircraft, vessel-mounted spray gear and extensive stocks of dispersant. Also containment and recovery equipment and equipment for shore clean-up in 3 regional stockpiles.

SOURCE: J N Archer and C White, "Organisation to Combat 011 Spills: The Case for Coordination of Government Practice, " International Tanker Owners Pollution Federation, p 5 many of the issues currently being debated in the United States.

It is clear that no single countermeasures practice will be applicable in all locales and for all types of oil spills. This is especially true in the United States, a large country with thousands of miles of coastline. Yet some approaches adopted in Europe deserve serious consideration for applicable parts of the United States. Among these:

- equip existing dredges with oil recovery capabilities (as in the Netherlands) in the U.S. port areas where dredges routinely operate,
- expand the use of supply vessels as platforms for heavy duty skimmers (as in Norway) in such oil production areas as the Gulf of Mexico and Southern California,
- preapprove dispersants for use in nonsensitive areas using on-call airplanes for delivery systems (as in the U.K.),
- expand training and contingency planning exercises (as in Norway).

Despite differences, several generalizations about European oil spill response policies may be made. With respect to terminals, refineries, offshore platforms, and other fixed facilities, the general rule is that the party causing the pollution should clean it up. Operators of these facilities are expected to have contingency plans and to provide equipment and materials in the event of a spill.11 Direct government involvement in the response generally only takes place if the polluter is unable to cope with the spill. Virtually without exception, however, the central government–whether represented by the ministry of defense, environment, transportation, etc. in any given country– is assigned responsibility for vessel spills.

> Most countries accept that it would be unrealistic to expect the same level and promptness of response if the polluting source was a vessel at sea, especially if the owner or operator had no presence in the country whose shores were threatened. For this reason, in northwest Europe the responsibility for combating oil pollution from tankers and other vessels is normally accepted by governments on the understanding that the costs of any reasonable measures taken will be recoverable from the owner and his insurer.[12]

For these types of spills, unlike the current situation in the United States, both *the responsibility and the authority* for cleanup are in the hands of the central government.

Also, there is a distinction in most European countries between those responsible for combating oil at sea and those responsible for dealing with it on the coast.[13] On shore, responsibility for implementing initial cleanup measures usually lies with local authorities, with the central government often providing advice and coordination. As the actual or potential impact of a spill increases, central governments assume more responsibility, and are able to provide equipment, logistic support, and technical and financial assistance. Coordination between local onshore responsibilities and central government offshore responsibilities is usually the charge of a single government department or committee. Several European countries (e.g., France and Norway) appear to be far better equipped and/or organized than the United States to respond to spills that reach or threaten the coast.

[11] J.N. Archer and I.C. White, "Organization to Combat Oil spills: The Case for Coordination of Government practice, " The International Tanker Owners Pollution Federation Ltd.

[12] Ibid. p. 3.

[13] Ibid. p. 4.

A wide variety of mechanical cleanup technology is used in Europe. Some types of booms and skimmers in use or under development may offer some marginal advantages to equipment manufactured in the United States; however, OTA found no evidence that European technology was dramatically better than that available in the United States. Much of this technology is, in fact, marketed in the United States, and those responsible for purchasing equipment are (or are becoming) familiar with it. Some European equipment was used in the *Exxon Valdez* oil spill. French Egmolap skimmers used in beach cleaning were reportedly particularly successful.

OTA was impressed with the total amount of equipment available in Europe. In the event of a major spill, countries have not only their own local, regional, and national equipment stocks on which to draw, but could also have access to equipment from other nearby countries and from the private sector. Several cooperative agreements exist. In addition to the Bonn Agreement, already discussed, the Commission of European Communities (CEC) in Brussels has a task force that can provide expertise to member countries that need advice. The CEC maintains a list of equipment throughout Europe that potentially could be used in the event of a large spill. Also, a number of bilateral agreements exist to facilitate cooperation regarding oil spills occurring on or near the offshore boundaries. (While helpful, these bilateral agreements do not always work to each country's satisfaction, e.g., when one country's policy is to use dispersants and the other's is to rely on mechanical equipment).

All European countries OTA visited assured us that they were prepared for major oil spills. We suspect that had we toured U.S. facilities before the *Exxon Valdez* accident, we would have received similar assurances, so European confidence is at least somewhat questionable. On the whole, however, European countries are better organized than the United States, have more resources on which to draw, and conduct more frequent training exercises. In part this is due to activity undertaken in response to unfortunate experiences with their own major oil spills. As some Europeans readily admitted, no country, no matter how well organized and equipped, would have been able to cope satisfactorily with a spill the size of the *Exxon Valdez* spill — particularly in such a remote location.

Appendix A
Mechanical Containment and Cleanup Technologies

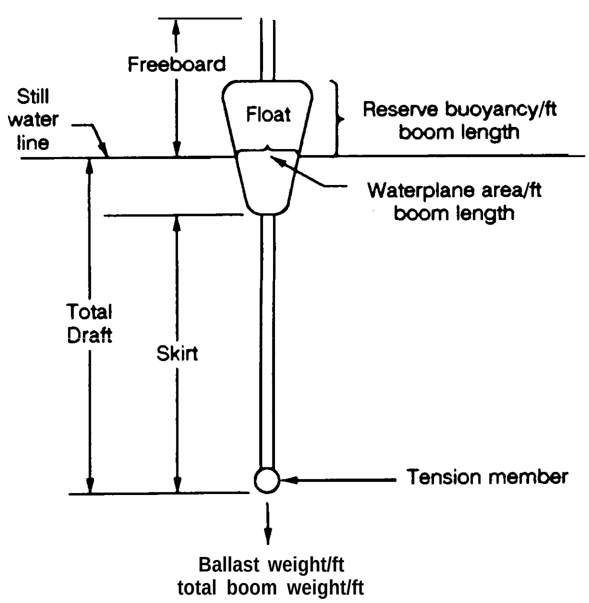
Containment Booms

Oil spill containment barriers or booms are floating devices generally resembling short curtains that restrict an oil slick from spreading beyond the barrier. Several designs have been produced for conditions ranging from protected waters to open ocean. Some barriers are designed to be towed, while others remain stationary. Barriers designed for protected waters would be less effective in strong currents or heavy waves but generally are more easily deployed than offshore booms. Oil spill containment booms generally have five operating components as shown in figure A-1.

Float

The float is the buoyancy member that keeps the boom riding on the surface of the water. Heavier booms or booms used in rough seas need more buoyancy and therefore have a larger volume of float materials. Floats may be rigid or flexible and should be relatively smooth so that they don't trap debris or produce vortices that may cause the loss of oil under the boom.

Figure A-1 -Components of a Boom



SOURCE: World Catalog of 011 Spill Response Products

Freeboard

The freeboard is the vertical height of the boom above the water. The freeboard prevents oil from washing over the top of the boom, but if it is too high, the boom may be pushed over in high winds. The boom must be flexible enough to rise and fall with the waves so that the freeboard is not lost with each passing wave.

skirt

The skirt is the continuous portion of the boom below the floats. The skirt helps to contain the oil. While a deeper skirt is more effective in containing oil, increasing skirt depth increases the current load on the tension members of the boom.

Tension Member

Tension members consist of any elements such as cables, chains, lines, or boom fabric that carry the horizontal tension loads on the boom.

Ballast

Weight is applied to the bottom of the skirt to improve boom performance. Ballast is generally a chain (which also serves as a tension member) or a series of weights along the entire length of the boom.

There are two basic types of booms in general use today: **fence booms** and **curtain booms.** Fence booms have a rigid or semirigid material as a containment screen for oil floating on the water. Curtain booms have a flexible skirt held down by ballast weights or a tension chain or cable. Their major difference is the way in which they respond to waves, current, and wind. If current and wind roll a fence boom away from the vertical, there is a loss of freeboard and draft. A curtain boom has a flexible skirt that is free to move independently of the freeboard and flotation, thus movement of the skirt away from vertical does not necessarily mean loss of freeboard. Other booms, not necessarily of different types, are designed for special purposes. These include fireproof booms, ice booms designed for spills in ice-filled water, and sorbant booms used to contain and absorb small amounts of oil in relatively calm waters.

Booms are classified according to their physical characteristics, which include freeboard, draft, reserve buoyancy to weight ratio, total tensile strength, skirt fabric tensile strength, and skirt fabric tear strength. Although all of these characteristics are important, only the freeboard and draft will be mentioned hereto convey an idea of the overall size of booms that are used for various applications (table A-l).

In the above classification, based on that used in the World Catalog of Oil Spill Response Products, calm water is defined to have a significant wave height of less than 1 foot, harbors less than 3 feet, and offshore less than 6 feet. The significant wave height is the maximum wave height for which booms in that category are likely to be effective. The table shows that booms recommended for harbors and offshore are quite large. A boom recommended for harbors would have a vertical dimension (freeboard plus draft) of 22 to 42 inches and a boom recommended for offshore use would have a vertical dimension of more than 42 inches.

These classifications should be used with some flexibility. For example, offshore booms typically have long skirts. However, in offshore areas of fast currents a shorter skirt may be more effective. In this case, a boom classified as a harbor boom maybe more suitable than an offshore boom.

Table A-1 - Boom Classification According to Freeboard and Draft

Service	Freeboard (inches)	Draft (inches)
Calm water	4-1o	6-12
Harbor	10-18	12-24
Offshore	>18	>24

SOURCE: Office of Technology Assessment, 1990

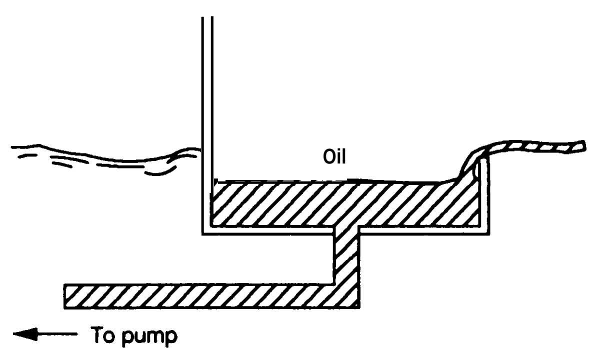
Mechanical Recovery Devices

Several devices have been developed to collect oil from surface waters. Since the efficiency of an oil recovery device is improved by increasing the thickness or depth of an oil slick, these devices are frequently used in combination with containment barriers. Oil spill recovery skimmers are generally separated into categories according to the way in which they pick up oil. Fourteen categories and subcategories can be identified. These are defined as follows:

Weir – A skimmer that has an interior basin with a slightly submerged lip over which the oil floats and is collected by gravity (figure A-2). The weir is generally a floating skimming head used with a pump to continuously empty the collecting basin. These skimmers work best if the edge of the weir is right at the oil/water interface, but in practice, this adjustment is difficult to achieve and maintain. Weir skimmers have the advantages of being simple, reliable, and commonly available. In thick layers of oil (25 mm or more), weir skimmers have high recovery rates with a recovery efficiency of around 50 per cent. In thinner slicks (1 to 8 mm), the recovery efficiency drops to 10 per cent. Conventional floating weir skimmers have problems in becoming clogged with debris and do not work well in waves. Archimedes screw devices have been incorporated in some weir skimmers to grind up debris.

suction – A suction skimmer is a simple suction head acting somewhat like a weir used on a floating hose from a vacuum truck or portable suction pump (figure A-3). Pump suction draws the oil to the

Figure A-2 - Weir Skimmer



SOURCE: World Catalog of Oil Spill Response Products.

skimmer head. This also is the same principle used when a suction hopper dredge is converted to oil spill recovery. The advantages of suction skimmers are that they are simple to operate, shallow draft, and can be used nearly everywhere, even under piers. They are likely to have a fairly high pumping rate but with a low recovery efficiency, particularly in a thin slick. They are not effective, however, if there is any appreciable water movement such as choppy waves.

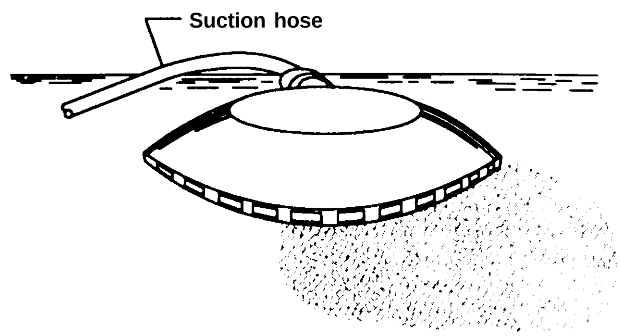
Boom Skimmer – A boom skimmer is a recovery system with one or more skimmers mounted in the face of a spill containment boom, regardless of the skimmer type, although the recovery device is generally a weir (figure A-4). Weirs installed on booms that can follow the wave surface reasonably well are kept near the surface of the water and therefore able to maintain a high rate of recovery. In general, boom skimmers have a high rate of recovery and are designed for dealing with large spills at sea. Since the weir is employed in the collection pocket of the boom, recovery efficiency is increased. Boom skimmers are large pieces of equipment with many working parts needing maintenance. They are adversely affected by the same debris problems as other weirs.

Vortex – A vortex skimmer draws oil and water into a collection chamber and separates it by centrifugal force (figure A-5). This centrifugal action discharges the water out of the bottom and concentrates the oil so that it can be pumped off through a hose to storage. This principle is sometimes combined with a weir serving as the collection chamber. Vortex skimmers can achieve a reasonable recovery rate in medium to heavy oils, but generally have a fairly low efficiency.

Moving Surface – Moving surface skimmers utilize a moving material that absorbs or causes oil to adhere to it in preference to water. The oilcoated material then passes over a scraper, squeezer, or other device to remove and recover the oil in a sump. There are several varieties of moving surface skimmers including, disk/drum, brush, rope mop, and belt types as follows:

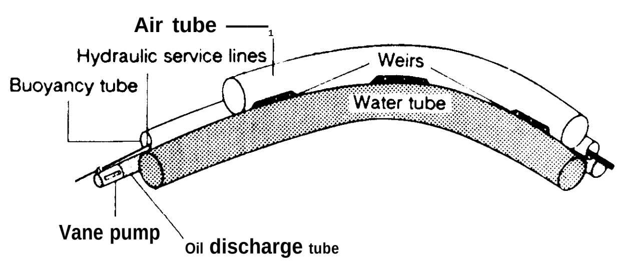
Disk/Drum– Any disk or drum devices that rely ***on*** the adhesion of oil to a solid surface (figure A-6). Disk type devices have a series of vertical disks that are rotated through the oil surface. Drum skimmers have a horizontal drum that rotates through the slick. Many small disk skimmers have the disadvantages of being expensive, complicated, more likely to break down, and vulnerable to becoming clogged

Figure A-3– Floating Suction Skimmer



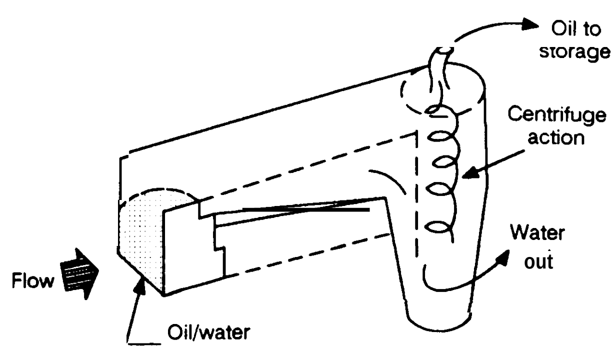
SOURCE: World Catalog of 011 Spill Response Products

Figure A-4-Schematic Drawing of a Weir Skimmer



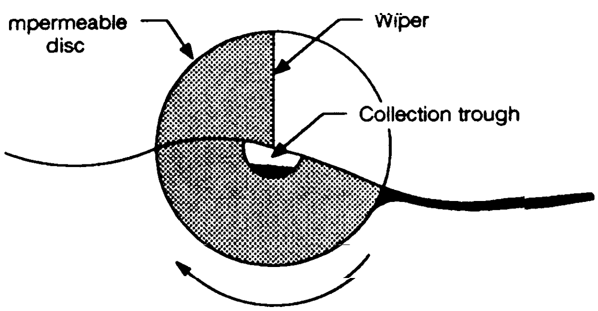
SOURCE: Vikoma International

Figure A-5-Vortex Skimmer



SOURCE: World Catalog of 011 Spill Response Products

Figure A-6- Disc Skimmer



SOURCE: World Catalog of Oil Spill Response Products

with debris. On the other hand, they have high recovery efficiency which can be a considerable advantage if storage volume is limited. Large disk skimmers are likely to be more durable and some disk skimmers have vanes or screens to keep out debris. Because of the vertical dimensions of the disk, disk skimmers are effective in waves. Some large floating disk skimmers are effective in fairly high sea states.

Brush – Skimmer with a horizontal brush that rotates through the oil and past a scraper which removes the oil into a sump. This skimmer is designed for recovering highly viscous oil and oil on ice.

Rope Mop – Rope mop skimmers employ along, continuous loop of absorbent oleophilic (oil loving) material that floats on the surface of the water and is then led through a combination scraper-wringer that removes the oil along with some water (figure A-7). Rope mops can be deployed from shore and the rope guided around a pulley that has been secured offshore or can be operated from boats. Rope mop skimmers generally have a high recovery efficiency and are most effective in medium viscosity oils. Rope mops can operate in shallow water, water filled with debris, water mixed with ice, and under ice. They are relatively easy to maintain.

Belt – Belt skimmers are identical in that they all employ a moving belt which mayor may not be of absorbent material. Six types of belt skimmers can be identified.

1. Paddle Belts – Paddles are attached to the belt to lift oil out of the water (figure A-8). A typical paddle belt skimmer pulls oil up a ramp using four or more paddles. Paddle belt skimmers have a high recovery rate and operate best in medium to high viscosity oils, but are likely to have problems in short period waves.[1] They also handle debris very well.

2. ***Sorbent Belts –*** A sorbent belt skimmer is one that has a continuous, flat belt that moves horizontally over the water in the well of the collection vessel (figure A-9). High recovery rates can be expected and debris handling is excellent. This skimmer was developed for the U.S. Coast Guard as a zero relative velocity skimmer with the belt moving as fast as the vessel is traveling forward (or current moving aft). Apparently, while technically feasible, it has not been very practical operationally and has never been commercially produced. Perhaps further development could prove useful.

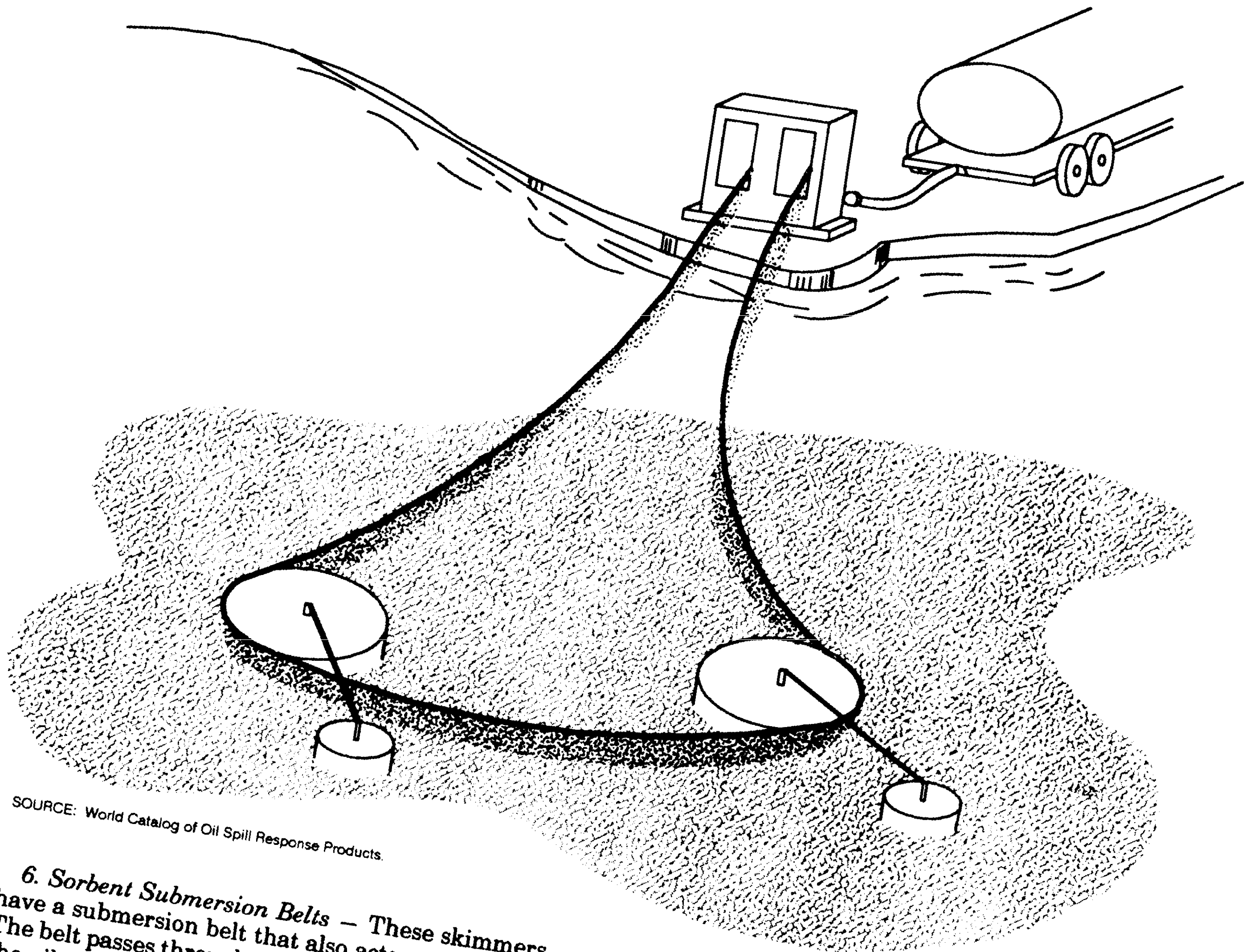
3. *Sorbent Lifting Belts –* A sorbent belt skimmer that has a belt inclined to the water's surface and lifts the oil out of the water (figure A-10). Sorbent lifting belts are made of porous oleophilic material that allows water to pass through. The belt passes through a set of rollers where the oil is scraped and wrung out of the belt. Sorbent lifting belt skimmers are often mounted on fairly large vessels and are intended for use in harbors and offshore. They can be expected to have a high recovery rate and high efficiency.

4. ***Brush Lifting Belts –*** These skimmers have a chain of brushes that lift the oil from the water. Cleaning devices remove oil from the brushes at the top of the ramp. These would be particularly useful in large spills of highly viscous oil.

5. ***Submersion Belts –*** The operating principle of submersion belt skimmers is the opposite of lifting belt skimmers (figure A-n). Instead of carrying the oil up out of the water, the submersion belt moves along a plane forcing the oil under water. The oil then surfaces in a collection sump. Submersion belt skimmers work best in low viscosity oils and thin slicks, in contrast to most other skimmers that require thick accumulations of oil for most effective operation.

[1]World Catalog, p. 226.

Figure A-7—Rope Mop Skimmer

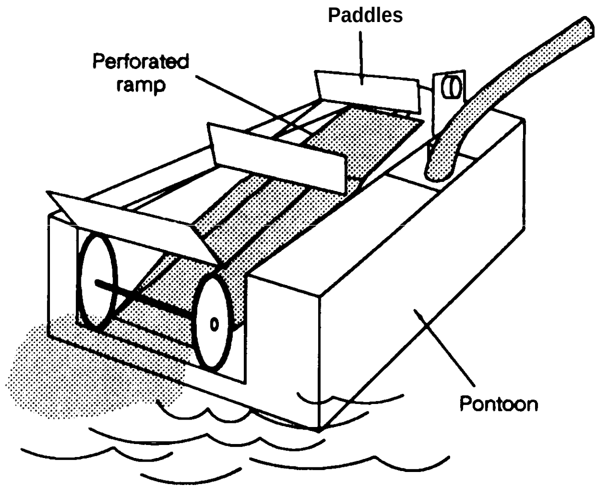


SOURCE: World Catalog of Oil Spill Response Products.

6. Sorbent Submersion Belts – These skimmers have a submersion belt that also acts as a sorbent. The belt passes through a set of rollers that remove the oil. Oil that is not absorbed is carried beneath the belt and rises in a collection chamber located aft of the belt. These skimmers are effective in light to heavy oils in thicknesses of several millimeters and work best in calm seas or moderate seas with a swell up to 3 feet.

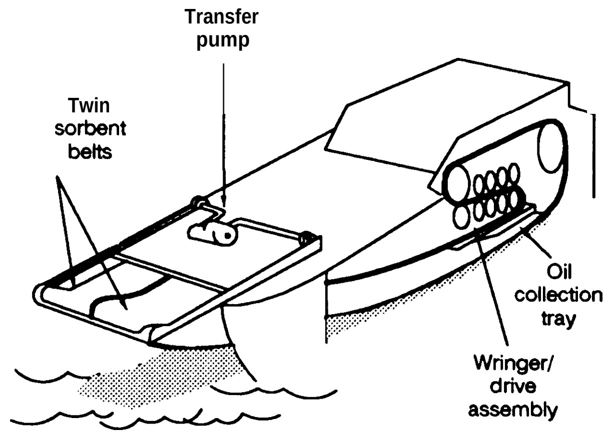
Submersion Plane – The submersion plane skimmer has a fixed plane which is advanced through the oil, submerging it and directing it into a collection area aft. It is similar to the submersion belt skimmer except that it does not have any moving parts. Submersion plane skimmers work best in light to medium viscosity oils.

Figure A-8-Paddle Belt Skimmer



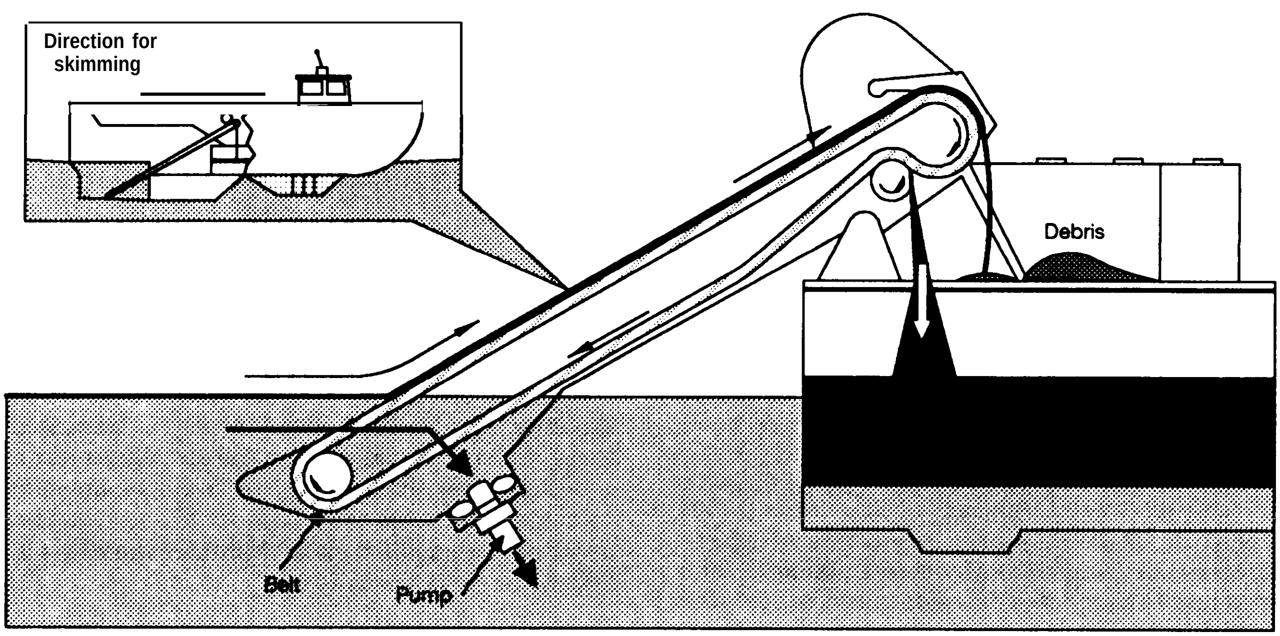
SOURCE: World Catalog of Oil Spill Response Products

Figure A-9- Sorbent Belt Skimmer



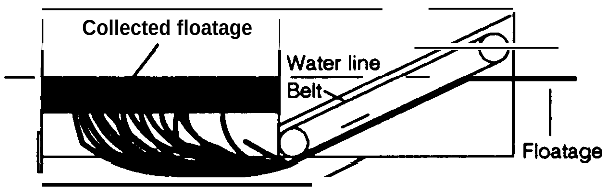
SOURCE: World Catalog of Oil Spill Response Products

Figure A-10--Sorbent Lifting Belt Skimmer



SOURCE: World Catalog of Oil Spill Response Products

Figure A-n –Submersion Belt Skimmer



SOURCE: World Catalog of Oil Spill Response Products

Appendix B
Quantity and Distribution of U.S. Equipment

The following tables provide information on the type, quantity, and location of major oil spill response equipment within the continental United States. The first two tables identify U.S. Navy and U.S. Coast Guard equipment. The following four tables list skimmers, booms, dispersant delivery systems, and off-loading pumps that could be applicable for offshore spills. Except for the Navy equipment maintained at Williamsburg, Virginia and Stockton, California and the Coast Guard equipment in Mobile, Alabama and Hamilton Air Force Base, California, this equipment is held by industry oil spill cooperatives. The 93 cooperatives are listed in the next table, and, following this, the new equipment acquisitions of the Alyeska cooperative following the *Exxon Valdez* spill are identified. Next, we list the equipment based at the Oil Spill Service Centre in Southampton England, about half of which was used in the *Exxon Valdez* spill. Finally, the equipment proposed to be purchased for each regional oil spill response center to be established by the Petroleum Industry Response Organization is presented. A caveat: response capability depends on much more than the type of equipment on hand, including such variables as maintenance, training, and logistics, so conclusions about the capabilities of the organizations presented here based solely on examining equipment are likely to be inaccurate.

Table B-1 -Major Types, Quantities, and Location of U.S. Navy Spill Response Equipment

	Quantities/location		
Equipment description	Williamsburg, Virginia	Stockton, California	Pearl Harbor, Hawaii
Spilled oil recovery equipment:			
Skimmer vessel system (36' aluminum hull)	12	11	1
Skimming system (sorbent belt voss)	1	1	0
Skimming system (screw pump voss)	2	2	0
Skimmer, sorbent rope mop (36")	2	1	0
Boom vans (42" x 1980' boom)	6	7	0
Boom mooring system	37	34	4
Boom handling boat (24' 260 hp)	8	6	2
Boom tending boats (19' x 23' inflatable)	2	2	1
Boom tending boats (18' rigid hull)	4	4	1
136,000 gal oil storage bladder .	6	4	0
26,000 gal oil storage bladder	4	3	1
Pumping equipment:			
Pump, 6" submersible	11	8	2
Floating hose (6" x 100')	65	0	0
Hot tap system . .,	4	3	0
Boarding kit.	1	2	0
Firefighting system ., ., . .	3	2	0
Ancillary equipment:			
Command trailer (40' communications and command center)	1	1	0
Command van (20' communications and command center)	3	2	0
Fender system (8' x 12' foam)	16	4	0
Fender system (14' x 60' Ip air) . .	8	0	0
Fender system (10' x 50' Ip air)	24	0	0
Shop vans	3	2	0
Rigging vans	2	3	0
Personnel bunk van	2 0	0	
Beach transfer system (4-wheel drive veh.) . .	1	0	0
Communication system (SAT phone, land)	1 0	0	
Communication system (SAT phone, ship)	1	0	0
Oil/water separator (parallel plate 100 gal/rein)	2	1	0
Cleaning system van	1	2	0

SOURCE: U S Navy, 1989

Table B-2– Major National Strike Force Equipment of the U.S. Coast Guard

	Atlantic team	Pacific team
Spilled oil recovery equipment:		
Open Water Oil Containment and Recovery Systems:		
Skimming barriers	5	19
Fast surface delivery systems	11	11
Pumping subsystem	7	17
Dracone barges (various sizes)	8	4
Expandi harbor boom (1,600 feet)	1	0
Pumping equipment:		
Air Deliverable Anti-Pollution Transfer Systems (ADAPTS):		
Prime movers . . . ., ...	7	13
Submersible pumps	11	15
Hydraulic hose (5,000 feet)	1	1
Discharge hose (4,000 feet) . . .,	1	1
Fuel bladders	?	8
Viscous oil pumping systems		
Prime movers	2	1
Submersible pumps . . . .,	?	8
Chemical transfer systems	2	7
Nonsubmersible pumps	9	16
Ancillary equipment:		
Command Posts	3	2
Tractors	4	2
Boats (various small boats)	10	6
All purpose vehicles	7	5
Trailers	3	12
Radios . . . .,	42	36
Computers	3	7
Monitoring equipment	?	Y
Testing equipment . . . ., . . .	?	'f

SOURCE: U S Coast Guard, 1989

Table B-3--Major Sources of Skimmers in the United States

Region	Location	service type	No.[a]	Type[a]	Power[b]	Storage capacity (gallons)	Recovery (gal/.min)	Performance[c] sea state 1	2	3	Viscosity	Debris	Expected[d] availability
East cost	Davisville, RI	Weir	2	B	N	1,700	1,000	G	G-F	F	G	F	B
	Williamsburg, VA	Sorbent lifting belt	8	SC	Y	1,700	200	G	F	F-P	F	G	A
	Davisville, RI	Weir	4	VOO	N	0	120	G	F	P	G	F	B/C
	Davisville, RI	Weir	2	VOO	N	0	120	F	F	P	G	F	B/C
Gulf coast	Mobile, AL	Weir	8	B	N	0	1,000	G	G-F	F	G	F	A
	Venice, LA	Weir	1	VOO	N	0	120	G	F	P	G	F	B/C
	Venice, LA	Weir	1	VOO	N	0	120	G	F	P	G	F	B/C
	Venice, LA	Weir	1	VOO	N	0	120	G	F	P	G	F	B/C
	Intercostal, IA	Weir	1	VOO	N	0	120	G	F	P	G	F	B/C
	Cameron, IA	Weir	1	VOO	N	0	120	G	F	P	G	F	B/C
	Cameron, LA	Weir	1	VOO	N	0	120	G	F	P	G	F	B/C
	Houma, IA	Weir	2	VOO	N	0	120	G	F	P	G	F	B/C
	Grand Isle, IA	Weir	1	VOO	N	0	120	G	F	P	G	F	B/C
	Geand isle, LA	Weir	1	SC	Y	j0							C
	Rockport, TX	Weir	1	VOO	N	0	120	G	F	P	G	F	B/C
	Galveston, TX	Weir	1	VOo	N	0	120	G	F	P	G	F	B/C
west coast	Stockton, Ca	Sorbent lifting belt	8	SC	Y	1,700	200	G	F	F-P	F	G	A
	Port San Luis, CA	Weir	1	VOO	N	0	120	G	G	F	F	F	c
	Port San Luis, CA	Weir	2	SC	Y	0	250	G	G-F	F	G	F	c
	Santa Barbara, CA	Weir	2	SC	Y	0	250	G	G-F	F	G	F	c
	Santa Barbara, CA	Weir	1	VOO	N	0	120	G	G	F	F	F	c
	Hdamilton AFB, CA	Weir	19	B	N	0	,000	G	G-F	F	G	F	A
	Concord, CA	Weir	1	VOO	N	0	120	G	P	P	F	F	c
	San Pedro, CA	Weir	1	VOO	N	0	120	G	P	P	F	F	c
	San Pedro, CA	Weir	1	VOO	N	0	120	G	G	F	F	F	c
	San Pedro, CA	Weir	1	VOO	N	0	200	F	P		G	G	c
	Seattle, WA	Submersion belt	1	SC	Y	10,000	500	G	G	F	G	F	c
Alaska	Valdez	Weir	1	SC	Y	1,700	200	G	F	F-P	F	G	c
	Valdez	Weir	1	SC	Y	3,400	400	G	F	F-P	F	G	c
	Dutch Hahrbor	Weir	1	VOO	N	0	300	G	F	P	F	F	B
	Dutch Harbor	Weir	1	VOO	N	0	120	G	G	F	F	F	B
	Deadhorse	Weir	1	SC	Y	0		G	F	F-P	G	G	C
	Dutch Harbor	Weir	2	Voo	N	o	120	G	F	P	G	F	B/C

[a] B = Barrier Skimmer
SC = Self-propelled/self-contained skimmer
VOO = Skimmer system operatad from a "Vessel of Opportunity"

[b] Y = Self-propelled
N = Requires external source of power

[c] Rating indicates estimated performance of the system as a whole, including barriers. support, etc Where posswible, information on the performance characteristics (P = poor, F = fair, and G = good) of the equipment is given in terms of (1) gallons affected, (2) sea state performacne, and (3) composition of the oil encountered In addition, a sense of the ready availability of the resources is provided as not all assets can be Utilized in a direct manner. SOURCE: COMDTINST M1S4662, "Oil Pollution Response Planning Guide for Extreme Weather"

[d] Availablility is indicated as follows:

A = Readily available in moat cases. This equipment is mainly government resources of the U.S Coast Guard and the U S Navy Coaat Guard equiopment is baaed at Mobile, ALand Hamilton Air Force Base, CA Navy equipment is primarily based at Williamsbusrg, VA and Stockton, CA

B = Equipment which may be available depending on specific equipment needs and circustances existing at the time of need These assets are mainly held by cooperatives for the convenience of its membership within a defined area either as a matter of operating or economic necess ity. in the case of the former (such as offshore lease equipments), warvere from governmental entities may have to reobtained, or agreement may be required among the members 10 cease or reduce operations

C = Resources that maybe made available but only within a specified area Equipment that is permanently installed on a vessel would, for instance, only be available within that vessel's areal limitation

SOURCE: Engineering Compuster Optecnomics, inc (ECO), "Analysis of Oil Spill Response Technologies," contractor report prepared for the Office of Technology Assessment, July 19S9

Table 54- Major Sources of Containment Boom in the United States

Region	Location	Total length (feet)	Free board (inches)	Draft (inches)	Unlit weight (per 100')	Tensile strength (lbs)	Sea state performance[a] 1	2	3	Maximum	Expected[c] availability
East coast	Davisville, RI	1,000	24	36	1,280	18,000	G/G	F/G	P/G	4	B
	Davisville, RI	1,476	14	16	880	69,000	G/G	F/G	P/F	5	B/C
	Davisville, RI	2,000	24	36	1,200	120,000	G/G	G/G	F/G	5	B
	Williamsburg, VA	12,000	12	24	1,280	18,000	G/G	F/G	P/G	4	A
Gulf coast	Mobile, AL	2,448	21	27	1,600	50,000	G/F	G/G	F/G	5	A
	Mobile, AL	2,448	21	27	1,600	50,000	G/F	G/G	F/G	5	A
	Grand Isle, LA	1,040	12	24	300	20,000	G/P	G/G	G/F	5	B
	Venice, LA	1,000	12	24	300	20,000	G/P	G/G	G/F	5	B
	Venice, LA	1,000	12	24	475	16,500	G/G	F/G	P/G	4	B
	Intracoastal, TX	1,000	12	24	1,400	40,000	G/G	F/G	P/G	4	B
	Galveston, IX	1,000	12	24	1,400	40,000	G/G	F/G	P/G	4	B
	Rockport, TX	1,000	12	24	1,400	40,000	G/G	F/G	P/G	4	B
West coast	Concord, CA	8,000	17	27	152	55,000	G/G	G/G	G/G	5	C
	Concord, CA	4,000	14[b]	17[b]	156	5,700	G/G	F/G	P/G	3	B/C
	San Pedro, CA	5,000	20	30	1,800	104,000	G/G	F/G	P/G	5	B/C
	San Pedro, CA	5,000	14	16	880	69,000	G/G	F/G	P/F	5	B/C
	San Pedro, CA	4,100	16	23	360	95,000	G/G	G/G	F/G	5	B/C
	San Pedro, CA	3,100	12	24	1,280	18,000	G/G	F/G	P/G	4	B/C
	San Pedro, CA	16,500	14	17	156	5,700	G/G	F/G	P/G	3	B/C
	San Pedro, CA	4,000	20	23	353	16,500	G/G	G/G	F/G	4	B/C
	San Pedro, CA	6,400	17	27	152	55,000	G/G	G/G	G/G	5	C
	Santa Barbara, CA	2,000	20	23	353	16,500	G/G	G/G	F/G	4	B/C
	Santa Barbara, CA	10,900	14	17	156	5,700	G/G	F/G	P/G	3	B/C
	Santa Barbara, CA	3,200	17	27	152	55,000	G/G	G/G	G/G	5	c
	Santa Barbara, CA	2,696	12	24	1,280	18,000	G/G	F/G	P/G	4	B/C
	Santa Barbara, CA	2,035	14	24	1,280	18,000	G/G	F/G	P/G	4	B/C
	Stockton, CA	11,000	12	24	1,280	18,000	G/G	F/G	P/G	4	A
	Hamilton AFB, CA	12,852	21	27	1,600	50,000	G/F	G/G	F/G	5	A
	Seattle, WA	6,000	14	16	880	69,000	G/G	F/G	P/F	5	B/C
	Seattle, WA	14,000	—	—	475	25,000	G/G	G/G	F/G	4	B/C
Alaska	Valdez	11,000	14	16	880	69,000	G/G	F/G	P/F	5	B/C
	Valdez	11,000	12	24	290	30,000	G/G	F/G	P/G	4	C
	Valdez	8,000	17	27	152	55,000	G/G	G/G	G/G	5	C
	Deadhorse	5,400	—	—							B/C
	Deadhorse	4,000	14[b]	16[b]	880	69,000	G/G	F/G	P/F	5	B/C
	Deadhorse	2,035	14[b]	24[b]	1,280	18,000	G/G	F/G	P/G	4	B/C
	Dutch Harbor	4,500	14[b]	17[b]	156	5,700	G/G	F/G	P/G	3	B/C
	Anchorage	4,500	12	24	1,280	18,000	G/G	F/G	P/G	4	A

a Rating indicates estimated performance of the system as a whole, including barriers, support, etc Where possible, information on the performance characteristics (P = poor, F = fair, and G = good) of the equipment is given in terms of (1) gallons affected, (2) sea state performance, and (3) composition of the oil encountered In addition, a sense of the ready availability of the resources is provided as not all assets can be utilized in a direct manner
SOURCE: COMDTINST M164662, "Oil Pollution Resopnse Planning Guide for Extreme Weather"

b Measured in feet

c Availability is indicated as follows:

A = Readily available in most cases This equipment is mainly government resources of the U S Coast Guard and the U S Navy Coast Guard equipment is based at Mobile, AL and Hamilton Air Force Base, CA Navy equipment is primarily based at Williamsburg, VA and Stockton, CA

B = Equipment which may be available depending on specific equipment needs and circumstances existing at the time of need These assets are mainly held by cooperatives for the convenience of its membership within a defined area either as a matter of operating or economic necessity In the case of the former (Such as offshore lease requirements), warvers from governmental entities may have to be obtained, or agreement may be required among the members to cease or reduce operations

C = Resources that maybe made available but onfy within a specified area Equipment that is permanently installed on a vessel would, for instance, only be available within that vessel's areal limitation

SOURCE: Engineering Computer Optecnomics, Inc (ECO), "Analysis of Oil Spill Response Technologies, contractor report prepared for the Office of Technology Assessment, July 19S9

Table B-5-Major Sources of Offloading Pumps in the United States

					Performance characteristics[a]						
					Viscosity		Debris tolerance				
Region	Type	city	Units	capacity (gal/min)	Light	Heavy	Silt	Gravel	Seaweed	Emulsify liquids	Expected availability[b]
East coast	Destroil	Williamsburg, VA	2	310	G	P	G	G	F	G	A
	Thune-Eureka	Williamsburg, VA	10	2000	F	G	G	G	P	P	A
	Viscous Oil	Elizabeth City, NC	1	2000	F	G	G	G	P	P	A
Gulf coast	Adapts	Mobile, AL	12	1000	P	G	G	G	P	P	A
	Viscous Oil	Mobile, AL	1	2000	F	G	G	G	P	P	A
west coast	Adapts	Hamilton AFB, CA	12	1000	P	G	G	G	P	P	A
	Viscous Oil	Hamilton AFB, CA	2	2000	F	G	G	G	P	P	A
	Thune-Eureka	Stockton, CA	11	2000	F	G	G	G	P	P	A
	Destroil	Stockton, CA	2	310	G	P	G	G	F	G	A
	Adapts	Concord, CA	1	1000	P	G	G	G	P	P	B
	Adapts	Concord, CA	1	1000	P	G	G	G	P	P	B
Alaska	Destroil	Anchorage, AK	1	310	G	P	G	G	F	G	B
	stops	Valdez, AK	2	1000	G	G	G	G	P	P	B
Other	Thune-Eureka	Detroit, MI	5	2000	F	G	G	G	P	P	A
	Adapts	Detroit, MI	2	1000	P	G	G	G	P	P	A

[a] P = poor, F = tier, G = good

[b] Availability is indicated as follows:

A = Readily available in moat cases This equipment is mainly government resources of the U S Coast Guard and the U S Navy Coast Guard equipment is baaed at Mobile, AL and Hamilton Air Force Base, CA Navy equipment is primarily based at Williamsburg, VA and Stockton, CA.

B = Equipment which may be available depending on specific equipment needs and circumstances existing at the time of need These assets are mainly held by cooperatives for the convenience of its membership within a defined area either as a matter of operating or economic necessity In the case of the former (Such as offshore lease requirements), waivers from governmental entities may have to be obtained, or agreement may be required among the members to cease or reduce operations

SOURCE: Engineering Computer Optecnomics, Inc (ECO), "Analysis of Oil Spill Response Technologies," contractor report prepared for the Office of Technology Assessment, July 19S9.

Table B-6- Major Sources of Dispersant Delivery Systems in the United States

	Location	Platform	Oil treatment [a] rate comparison (gal/rein)	Storage capacity (gallons)	Expected availability
East Coast	Davisville, RI	Boat	500	500	B
Gulf Coast	Grand Isle, LA	Boat	500	500	B
	Houma, IA	Boat	500	500	B
	Rockport, TX	Boat	500	500	B
	Galveston, TX	Boat	500	500	B
	Chandler, AR	DC-4	Less than 8000	00	B
	Chandler, AR	ADDS/C-130	Less than 8000	2500	A
	Mesa, AR	DC-4	Less than 8000	2500	B
West Coast	San Pedro, CA	Boat	4a	Drums	B
	San Pedro, CA	Boat [c]	4a	Drums	c
	Santa Barbara, CA	Boat [c]	4a	Drums	c
	Santa Barbara, CA	Boat [c]	48	Drums	c
	Santa Barbara, CA	Boat	48	Drums	B
Alaska	Anchorage, AK	Boat	500	Drums	B
	Anchorage, AK	Helicopter	1600	Drums	B

a SOURCE: COMDTINST M16466 2, "Oil Pollution Response Planning Guide for Extreme Weather,"' Rating indicates estimated Performance of the system as a whole, including barriers, support, etc

b Availability is indicated ss follows:

A = Readily available in most cases This equipment is mainly government resources of the U S Coast Guard and the U S Navy Coast Guard equipment is based at Mobile, AL and Hamilton Air Force Base, CA Navy equipment is primarily based at Williamsburg, VA and Stockton, CA

B = Equipment which maybe available depending on specific equipment needs and circumstances existing at the time of need These assets are mainly held by cooperatives for the convenience of its membership within a defined area either as a matter of operating or economic necessity In the case of the former (Such as offshore lease requirements), waivers from governmental entities may have to be obtained, or agreement may be required among the members to cease or reduce operations

C = Resources that may be made available but only within a specified area Equipment that is permanently installed on a vessel would, for Instance, only be available within that vessel's areal limitation

c Installed on response vessel

SOURCE: Engineering Computer Optecnomics, Inc (ECO), "Analysis of Oil Spill Response Technologies," contractor report prepared for the Office of Technology Assessment, July 1989

Table B-7- Alyeska Response Equipment

Since the *Exxon Valdez* spill incident, Alyeska has substantiality increased the amount of spill response equipment that it has on hand to respond to any future spills. The equipment obtained is listed below.

3 ERVs (Ship Escort) — **Escort Response Vessels** – ERVs are 210-foot converted ocean going, ice strengthened tugs. These vessels have twin variable pitch propellers and bow thrusters for increased maneuverability. Each ERV is equipped with:
- 2 Vikoma Seaskimmer 50's (nameplate 385 bbl/hr each)
- 1,600 ft. RoBoom Ocean 2000 on deck reels
- 3,000 ft. Expandi 4300 Boom (self inflating)
- 4,000 bbl recovered oil storage capacity.

1 WRV (Valdez) — **Weir Boom Response Vessel** – equipped with:
- 2 Framo Transec boom/skimmer systems (initially 1 Vikoma weir boom skimming system - nameplate 4200 bbl/hr)
- 20-foot work boat.

1 DDS (Knowles Head) — **Dynamic Skimming System** - A 180,000 bbl integrated tug/barge, permanently named, equipped with:
- 2 Marflex Sweep Arms (nameplate 2100 bbl/hr).

1 (Knowles Head) — **Lightening Vessel** – A 140,000 bbl integrated tug/barge equipped with:
- Fenders
- 3 Framo salvage pumps
- Ancillary salvage equipment (hoses, etc.)
- Moorings.

2 (Valdez) — **Storage Barges** – (73,000 bbl and 63,000 bbl). Each equipped with an assortment of:
- Spill containment booms including Vikoma HI 950 Boom, Scot Boom, Arctic Harbor Boom (total approximately 16,000 ft.)
- Supersucker pump/skimming systems
- Absorbent materials.

2 (Valdez) — **Ship Assist Tugs** – Two tugs available for pollution response duties.

Other Resources Available for Spill Response
- 62,000 gallons of dispersant
- 2 aerial dispersant applicators (ADDS PACKS)
- Dispersant application systems mounted on escort vessels
- Fire boon, igniters, and other burning eq m
- A portable communications module
- Reconnaissance aircraft

SOURCE: Aiyeska 1990

Table B-8-Equipment Based at the Oil Spill Response Center, Southampton, U.K.

Item	Quantity	Item	Quantity
1. Containment booms		2. Skimmers	
BP Weir Boom System	1	Vikoma Seaskimmer 100, disk skimmer	3
Vikoma Oceanpack including 500m boom and recovery module	3	Vikoma Seaskimmer 50, disk skimmer	4
Vikoma Boom Reel including 500m boom on winders	3	Vikoma Komara 12K, disk skimmer	8
Vikoma Seapack including 450m boom	4	BP Fastflow Skimmer, static skimmer	1
Nordan Ocean Boom, 200m inflatable 106cm boom on winders	2	Slurp Skimmer, weir skimmer	2
Roulands Ro-Boom, 200m inflatable 1.95m boom on winders	4	Scavenger Skimmer, weir skimmer	2
Vikoma Coastalpack, 250m boom on winder	1	Vikoma Kebab 600, disk skimmer	3
Hoyle Standard Boom, 1.52m lengths of 30.5cm foam boom	152m	OMI Mark II – 9DP Mop Wringer, rope mop skimmer	2
Skimmex Shoreline Barrier, 12m sections	158m	OMI Mark II – 4D Mop Unit, rope mop	2
Hoyle Shore Guardian Boom, 25m sections	1,750m	OMI Mark I – 4VE Mop Unit	1
Hoyle Sea Sentinal Boom, 10m and 25m lengths	3,300m	Oil Mop 55 Hand Mop	2
		ORI Jaws 552, Mop Unit	1
		Harrier V4 Skimmer, suction skimmer	1
		BP Vacuum Head, suction head skimmer	11
		Molex Vacuum Tanks, skid mounted vacuum tank	2

SOURCE: Oil Spill Response Centre, Southampton, United Kingdom, 1969

Table B-8- Equipment Based at the Oil Spill Response Center, Southampton, U.K. (Continued)

Item	Quantity
2. Skimmers (continued)	
Egmolap, heavy oil belt skimmer	1
Clam Shell Skimmer 3	
Heavy Fuel Oil Skimmers, toothed disk skimmers	2
Heavy Oil Skimmers (medium)	2
Heavy Oil Skimmer (small)	1
Ancillary equipment for skimmers	
HIAB Jib with power pack	4
Vacuum Box for use with BP Vacuum Head	3
3. Temporary oil storage	
Dunlop Dracone 1D5, capacity 100 tons	1
Dunlop Dracone 1E, capacity 30 tons	1
Leigh Flexible Pillow Tanks, capacity 25 tons	10
Leigh Flexible Pillow Tanks, capacity 12 tons	10
Fastank Storage Unit with liners, capacity 7 tons	17
Hoyle P/U Storage Tank, capacity 25 tons	2
Skimmex Storage Tank, capacity 6 to 7 tons	1
Skimmex Storage Tank, capacity 2.5 tons	1
Vikoma Pillow Tank, capacity 30,000 liters	2
Avon Storage Tank, capacity 25,000 liters	1
4. Transfer pumps	
Thune Eureka CCN 100 Pump	2
Spate Pump 3B 5	
Putzmeister Concrete Pump, screw and ram pump	1
Desmi/Destroil Screw Pump	4
Godiva Fire Pump 1	
5. Dispersant equipment	
WSL Offshore Spray Unit	11
Biggs Wall Wide Spray Unit	1
Rototech TC3 Spray Module	2
WSL Inshore Spray Unit	7
Seaguard Pack Super Dispersant Spray Unit	1
Backpack sprayers– Falcon 2 gallons	17
Falcon 3 gallons	5
Gell set unit	1
Beach Pump AR-30 2	
Beach Pump AR-15 2	
Additional hose – 70m on reel	11
50m on reel	6
Pillow Tanks, capacity 300 gallons	3
Aerial Dispersant Delivery System	1
6. Communications equipment	
Sailor VHF Radio Type RT 144,61 channels	3
Motorola VHF Radio Type HT 200, 6 channels	6
Motorola VHF Radio Type MX 300S, 24 channels	6
Stomo VHF Radio Type 500, 3 channels	2
Aquastar Radio Telephone Type WP/1, 24 channels	1
Lafayette VHF Scanning Monitor, 7 channels	3
Telescopic Masts, 9m 3	
7. Miscellaneous items	
Floodlights	2
Zodiac 16 ft. inflatable boat	1
Avon 12 ft. inflatable boat	1
Alvis Stalwart Amphibious Vehicle	1
High pressure hot water cleaners	5
Hipower multipurpose power packs	7
Bauer Compressor Type 1C40	1
Rollalong Mobile Command Center	1
Mini Power Pack, diesel power pack on wheels	5
8. Vessels	
45 ft. work boat 1	
Fast personnel carrier 1	
28m training/operation vessel	1
Air transportable work boat	1
9. Ancillary equipment	
Vikoma Emergency Air Blower for boom inflation	5
Small air blowers 13	
Vulcanisers for on-sits boom repair	5
Boom cleaner, Ro-Clean system	1
Mooring buoys, anchors, chains	
Rotary hand pump for filling knapsack dispersant sprayers 2	
Hand pump for liquid transfer	1
Atlas Copco Air Compressor	1
Welding units	3
Road trailers	3
Fork lift trucks	3
Ford tractor	1
Foam generator 1	
Video camera/recorder	1
Camera and accessories	1
Absorbants, booms, pillows, pads, etc.	

SOURCE: Oil Spill Response Centre, Southampton, United Kingdom, 1989

Table B-9-Petroleum Industry Response Organization: Proposed Capital Equipment for Each of Five Regional Centers

Item	Current number estimated	Current $ estimate
Lightening:		
Pumps	4	$851,524
Fenders	8	$240,000
Dracones	8	$1,000,000
		$1,891,524
Containment boom (ft):		
Offshore	30,000	$3,974,580
Medium	30,000	$1,917,900
Lightweight	10,000	$0
Skimming barrier	4,000	(Included in skimmer cost)
		$5,892,480
Skimmers:		
Skimming barrier	4	$1,870,000
Other skimmers	14	$2,770,382
Power packs	0	(Included in skimmer cost)
		$4,840,382
Dispersant equipment:		
Adds pack	1	$500,000
Helicopter system	4	$121,080
Dispersant chemical	50,000	$800,000
		$1,221,080
	Major equipment subtotal	$13,845,448
Other:		
vessels		$4,000,000
Office equipment & computers		$130,000 [ab]
Bird cleaning		$20,000 [a]
Protective boom (lightweight boom)		$587,300
Temporary oil storage (Dracones)		$1,750,000
Forklifts, compressors, etc.		$500,000 [a]
Trailers/cargo containers		$380,000
Maintenance shop equipment		$25,000 [a]
Vehicles, 4-wheel drive		$120,000 [a]
Tractors for trailers		$540,000
Pre-stages barges		1,750,000
Other equipment		$200,000
Spare parts		$800,000
		$10,582,300
	Other subtotal	$10,582,300
Equipment total for one regional center:		$24,207,746
Equipment total for five regional centers:		$121,038,731
Headquarters office equipment and computers:		$130,000
	Total capital equipment	$121,188,731

[a] Indicates data not available to allow reprojection of costs

[b] PII estimate for non-mainframe computers = $2.0 million/regional center

SOURCE: Petroleum Industry Response Organization (PIRO), 1990.

Table B-10– U.S. Oil Spill Co-Ops

Alaska Clean Seas
Anchorage, AL

Altoona Area Industry Association
Altoona, PA

Arco-Total Cooperative
Traverse City, MI

Atlanta Area Terminals Oil
Doraville, GA

Bi-State Metropolitan Oil
Bettendorf, IA

Boston Harbor Oil Spill Cooperative
East Boston, MA

Bridgeport Harbor Pollution Abatement Committee
Bridgeport, CT

Buffalo River & Harbor Oil Spill Cooperative
Buffalo, NY

Burlington Harbor Pollution Abatement Committee
Montpelier, VT

Central New York Oil Spill Cooperative
Rochester, NY

Central New York Oil Spill Containment
Rochester, NY

Charleston Industry Liquid Spillage Control Committee, Inc
North Charleston, SC

Clean Atlantic Associates
New Orleans, LA

Clean Bay
Concord, CA

Clean Caribbean Cooperative
East Boston, MA

Clean Channel Association
Mont Belvieu, TX

Clean Coastal Waters
Long Beach, CA

Clean Gulf Associates
New Orleans, LA

Clean Harbors Cooperative
Perth Amboy, NJ

Clean Islands Council
Honolulu, HI

Clean Land & Harbor, Inc
Wilmington, NC

Clean Rivers Association
Convent, IA

Clean Rivers Cooperative
Portland, OR

Clean Rivers/Coos Bay cooperative
Coos Bay, OR

Clean Islands Council
Honolulu, HI

Clean Seas
Carpinteria, CA

Clean Sound Cooperative
Seattle, WA

Continental Shelf Associates
Jupiter, FL

Connecticut River Pollution Control Committee
Hartford, CT

Cook Inlet Response Organization
Nikiski, AK

Corpus Christi Area Oil Spill control Association
Corpus Christi, TX

Delaware Bay & River Cooperate
Lewes, DE

Delaware River Co-Operative
Philadelphia PA

Detroit Area Industrial Mutual Aid
Detroit, MI

Evansville Mutual Assistance Association
Evansville, IN

Fairfax City Petroleum Terminals Air & Water Conservation & Safety Organization
Fairfax, VA

Four Corners Area Oil Control Coordination Committee
Cortez, CO

Greater Caribbean Energy and Environmental Foundation
Miami, FL

Greater Cincinnati Hazardous Material Control Committee
Cincinnati, OH

Green Bay Oil Men's Clean Waters Control Board
Green Bay, WI

Humboldt Bay Oil Spill Cooperative
Eureka CA

Jacksonville Spillage Control, Inc
Jacksonville, FL

Marine Industry Group
Gretna LA

Massachusetts Petroleum Council
Boston, MA

Memphis Area Petroleum Assistance Association
Memphis, TN

Metro-Milwaukee Petroleum Operations Group
Milwaukee, WI

Middletown-Portland Cooperative
Portland, CT

Miss-Ota-Croix Oil Control Coordination Committee
St Paul, MN

Montana-Wyoming Oil Control Coordination Committee
Laurel, MT

Muskegon Tri-Cities Mutual Assistance Association
North Muskegon, MI

Mutual Assistance Pact-Wichita
Tulsa, OK

Nashville Mutual Assistance Association
Nashville, TN

National Fire Protection Association
Quincy, MA

Neches River Oil Control committee
Beaumont, TX

New Haven Harbor Petroleum Cooperative
New Haven, CT

Norwalk Abatement Committee
Norwalk, CT

Oil City Petroleum Co-op Committee
Oceanside, NY

Pensacola Spillage Control, Inc
Pensacola, FL

Peoria-Tazewell Conservation Committee
Pekin, IL

Petroleum Committee of Sioux Falls for Environmental Protection
Yankton, SD

Plattsburg-Lake Champlain Oil Spill Control Committee
Plattsburgh, NY

Port of Miami Spillage Cleanup Committee
Miami, FL

Port Manatee Environmental Protection Association
Palmetto, FL

Port of Palm Beach Environmental Protection Committee
Riviera Beach, FL

Port Canaveral/Brevard County Spillage Cleanup Committee, Inc
Cape Canaveral, FL

Port Everglades Spillage Committee
Ft. Lauderdale, FL

Portsmouth Harbor Oil Spill Committee
Concord, NH

Pt. Everglades Spillage Cleanup
Ft Lauderdale, FL

Roanoke Valley Mutual Aid Association
Roanoke, VA

Savannah River Oil Control Coordinating committee
Savannah, GA

Southeast Wyoming Oil Spill Cooperative
Casper, WY

Stamford West Branch Harbor Association
Stamford, CT

Tampa Port Committee for Spillage Control, Inc
Tampa FL

Texas City Harbor Oil Spillage Contingency Program
Texas City, TX

Thames River petroleum Cooperative
Norwich, CT

The Port of Mobile Oil Spill cooperative
Mobile, AL

Toledo Harbor Spill Control Committee
Toledo, OH

Tri-City Industrial Anti-Pollution Committee
Braintree, MA

Tri-State Pollution Prevention and Cleanup Committee
Charleston, WV

Tulsa Area Oil Control Committee
Tulsa OK

Ulster/Greene Counties Harbor Pollution Control Cooperative
Port Ewen, NY

Utica-Rome Oil Pollution Control Committee
Marcy, NY

Vicksburg Association for Clean Port & River
Vicksburg, MS

Will-Grundy Industrial Conservation Committee
Lockport, IL

SOURCE: Robert Schulze, op cit., footnote 5

Appendix C
Acknowledgments

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Appendix D
Acronyms

API	American Petroleum Institute
CEC	Commission of European Communities
CEDRE	Center for Documentation, Research, and Experimentation on Accidental Pollution (France)
DOT	Department of Transportation
DOI	Department of the Interior
EPA	Environmental Protection Agency
MPCU	Marine Pollution Control Unit (United Kingdom)
MMS	Minerals Management Service
NOFO	Norwegian Clean Seas Association for Operating Companies (Norway)
OHMSETT	Oil and Hazardous Materials Simulated Environmental Test Tank
OSR	Oil Spill Response Ltd. (Southampton, U. K.)
OSC	On-Scene Coordinator
PIRO	Petroleum Industry Response Organization
USCG	United States Coast Guard
SPCA	State Pollution Control Authority (Norway)
VOSS	Vessel-of-Opportunity Skimming Systems