OIL POLLUTION RESEARCH
AND
TECHNOLOGY PLAN

INTERAGENCY COORDINATING COMMITEE

ON OIL POLLUTION RESEARCH

APRIL 1997

Table of Contents

List of Figures

List of Tables

Executive Summary

Background

Title VII of the Oil Pollution Act of 1990 (OPA 90) established the thirteen member Interagency Coordinating Committee on Oil Pollution Research (Committee). The Committee is charged with coordinating a comprehensive program of research, technology development, and demonstration among federal agencies in cooperation with industry, universities, research institutions, state governments and other countries. This responsibility includes preparation of an Oil Pollution Research and Technology Plan, which the Committee prepared and submitted to Congress in April 1992. At the same time, the Committee also provided a copy of the plan to the Marine Board of the National Research Council (Marine Board) for review and comment as required by the OPA 90. Upon review, the Marine Board recommended the plan be revised using a framework that addresses spill prevention, human factors, and the field testing/demonstration of developed response technologies. This updated version of the plan incorporates these Marine Board recommendations.

Plan s Framework and Content

An analysis of the oil production and transportation system serves as the underlying framework for the plan which describes the system and identifies the strengths, weaknesses, and problems associated with the production and transportation of oil and its products. The plan then assesses current oil spill prevention, preparedness, and response technologies and identifies program areas where research and development (R&D) are needed to fulfill the intent of OPA 90. These needs are based on an analysis of activities that result in spills, the sources of spills, and the volumes of oil released at various points in the oil production and transportation system.

Research and Technology Priorities

The plan's analysis of the oil production and transportation system indicates clearly that the threat of oil spills remains real and substantial. By both source and volume, the waterborne transportation system poses the greatest risk of spills, with roughly half of the oil spilled in offshore and coastal U.S. waters coming from tankships and barges. However, inland production, transportation, and distribution also account for a substantial volume of spilled oil, with onshore pipelines becoming an ever increasing source of large oil spills. The positive side of the situation is that over 60 percent of all oil spills are preventable, since they result from equipment failure, operator errors, and deliberate dumping.

Much remains to be done in the broad categories of spill prevention; spill response planning, training, and management; spill countermeasures and cleanup; and fate (what happens to oil when it enters the environment), transport (how oil moves through the environment) and effects, monitoring and restoration. While R&D efforts should continue in each of these categories, spill prevention holds the most significant potential benefits and should be emphasized. However, since spill prevention will never eliminate all oil spills, spill response technology development and evaluation should continue at present levels.

Reduction of the risk of oil spills and their associated environmental and social costs requires that an active, coordinated, and well-funded R&D program be maintained. In pursuit of this goal, the Committee developed this plan to make the case for a continuing federal oil spill R&D program for the next 5-10 year period, and specifically designated the following technology areas as oil spill R&D priorities (Level 1 being highest).

Interagency Oil Pollution Research and Technology Plan

Level 1 Priority

- Prevention through understanding Human Factors related to spill accidents;
- Offshore Facility and Pipeline Design, Inspection, Monitoring, and Spill Prevention;
- Onshore Facility and Pipeline Design, Inspection, Monitoring, and Spill Prevention;
- Decision Support Systems for Contingency Planning and Response;
- Spill Trajectory and Behavior Prediction.
- Offshore countermeasures: Dispersants and *In situ* Burning;
- Improved technologies for Oil Spill Surveillance;
- Effects and effectiveness of Shoreline Countermeasures and Cleanup;
- Environmental Restoration Methods and Technologies; and
- Understanding Spill Impacts and Ecosystem Recovery.

Level 2 Priority

- Improved Navigation and Waterways Management;
- Advanced Vessel Design;
- Training and Readiness Evaluation simulators;
- Improving options for Oily/Oiled Waste Disposal;
- On-Water Containment and Recovery equipment; and
- Basic Fate and Transport of oil.

Level 3 Priority

- Response Personnel Health and Safety protocols;
- Alternative On-Water Countermeasures;
- At Source Containment and Countermeasures; and
- Vessel Damage Assessment and Salvage methods.

(Note: Underlined segment is the title of the technology area as it appears in Table 11 and Appendix A.)

While pursuing R & D in these specific technology areas, there is a need to address several general issues, which will aid in achieving the desired advances in oil spill research and acting on the recommendations of the National Research Council's Marine Board. To carry out the program of field testing that the Marine Board determined to be a vital component of the federal plan, work must continue to develop streamlined permitting procedures and protocols for carrying out experimental oil spills in the environment and capitalizing on spills of opportunity. To bridge the gap from laboratory testing to full-scale field testing and use, mesoscale testing of spill response equipment is critical. The National Oil Spill Response Test Facility provides the research and response communities with unique capabilities in this regard and the Committee supports the facility's continued operation and maintenance by the Minerals Management Service (MMS).

Another recommendation of the Marine Board dealt with public perception of and participation in the decision-making process. One method of addressing this is to recognize the importance of universities and non-profit institutions in finding solutions to oil spill problems, and to encourage the creation of regional centers of expertise. Federal cooperation with various stakeholders should continue with the aim of leveraging both knowledge and resources.

Finally, a great deal of work remains to analyze and model the oil spill system. Success in this area would result in an improved understanding of events leading to oil spills and what actions can be taken to minimize their occurrence. Improving the quality of oil spill data available for building this model, conducting risk analyses, and developing pollution prevention policies, remain topics for continued interagency action.

Introduction

Public outcry over the rash of oils spills in 1989 and 1990, including the now notorious accidental grounding of the EXXON VALDEZ, culminated in the enactment of the Oil Pollution Act of 1990 (OPA 90). Title VII of OPA 90 established the Interagency Coordinating Committee on Oil Pollution Research and specified the membership, which consists of representatives from the Department of Commerce (including the National Oceanic and Atmospheric Administration (NOAA) and the National Institute of Standards and Technology (NIST)), the Department of Energy (DOE), the Department of the Interior (including the Minerals Management Service (MMS) and the U.S. Fish and Wildlife Service (since renamed the National Biological Service (NBS)), the Department of Transportation (including the U.S. Coast Guard (USCG), the Maritime Administration (MARAD), and the Research and Special Programs Administration (RSPA)), the Department of Defense (including the U.S. Army Corps of Engineers (USACE) and the U.S. Navy (USN)), the Environmental Protection Agency (EPA), the National Aeronautics and Space Administration (NASA), and the U.S. Fire Administration (USFA) in the Federal Emergency Management Agency (FEMA). The Act mandated that the Committee, chaired by the Department of Transportation, coordinate a comprehensive program of oil pollution research, technology development, and demonstration among the Federal agencies, in cooperation with industry, universities, research institutions, state governments, and other nations, as appropriate, and foster cost-effective research mechanisms, including the joint funding of research. It also required the preparation of an Oil Pollution Research and Technology Plan that would serve to coordinate all federal oil pollution research activities.

The first Oil Pollution Research and Technology Plan was submitted to the Congress on April 24, 1992. The original plan defined the role of each Federal agency involved in oil spill R&D and outlined the overall Federal approach to this R&D. It listed projects based on three possible levels of effort: (1) current (FY 1992) funding levels; (2) funding based on Congressional appropriation of the $27 million of R&D funds authorized by OPA 90 for each of the next five years; and (3) the funding required to fill all identified information and technology gaps. As required by OPA 90, the Committee contracted with the National Research Council (NRC) of the National Academy of Sciences for an assessment of the plan's adequacy. This review was conducted by the NRC's Committee on Oil Spill Research and Development under the auspices of the Marine Board, and was submitted to Congress in May 1993.

The NRC was appreciative of the efforts that went into developing the plan, specifically its inclusion of many important R&D topics and its formalizing of the communication network for addressing oil spill issues. However, it candidly found that "these features ... do not constitute a comprehensive structure for addressing the oil spill problem in a systematic manner," and noted that the document lacked the elements of a coherent and comprehensive plan. Their overarching recommendation called for an analysis of the oil spill system to identify its underlying problems and suggest solutions. This analysis would then lead to the development of an R&D strategy to achieve these solutions. While budget limitations restricted its efforts to develop a model of the oil spill system, the Committee used the recommended systems analysis approach to revise the plan.

For the federal agencies tasked with oil spill prevention and response, the historically cyclical nature of public attention and funding has recurred in the wake of the EXXON VALDEZ. When the first plan was submitted, it was presumed that the additional resources authorized by OPA 90 would be appropriated. As this did not occur, the plan was not implemented to a level much beyond existing agency programs. Consequently, most of the information and technology gaps of 1990 remain.

A similar loss of priority is evident in the private sector. The Marine Spill Response Corporation (MSRC), the oil industry supported oil spill response organization formed after the string of oil spills that resulted in the passage of OPA 90, funded approximately $30 million dollars of oil spill R&D through 1995. It terminated this program as of January 1, 1996. Meanwhile individual oil companies are funding only minimal oil spill R&D, with much of the work again being conducted through the American Petroleum Institute's (API) ongoing programs.

The Committee has enjoyed modest success through its efforts to improve communications among active members of the federal, state, and industry spill research and response community, and to leverage resources whenever possible. For instance, it is monitoring the activities of several states, including Alaska, California, Louisiana, Texas, and Washington as they conduct R&D activities of particular importance to their community needs. These activities are evaluated with an eye towards establishing partnerships, when feasible, and are likely to provide results with national, if not worldwide applications.

The Committee coordinates the R&D activities of member agencies, including the adaptation of Department of Defense technologies for use in the civilian sector. It oversaw the reopening of the Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) at the National Oil Spill Response Test Facility in Leonardo, New Jersey, which is now under the management of MMS, and through aggressive marketing, is being used by national and international customers. In addition the Committee cosponsored two International R&D forums, bringing together researchers from around the world, and was instrumental in establishing a database of ongoing oil pollution R&D, which is available free of charge and maintained by the International Maritime Organization.

The Committee submits an updated plan structured on the recommendations of the NRC. This plan provides a general assessment of the status of information and technology on oil spill prevention, response, and cleanup, while identifying and prioritizing those areas requiring additional R&D to fill the gaps. It is hoped that by publicizing the federal priorities and actions, non-federal entities will see opportunities to work in partnership with the federal agencies and reduce the risk of oil pollution.

1. The Context of Oil Spill Research and Technology Programs

A. The Oil Production and Transportation System

In keeping with the "systems" approach, Figure 1 is provided to illustrate the major subsystems which make up the United States oil production and transportation system. It ranges from the time crude oil is taken from the ground or transported into United States waters until the finished product is delivered to bulk storage terminals.

As shown in Figure 1, for the purpose of planning R&D activities, the oil production and transportation system is defined in terms of five subsystems:

- **Origination of crude oil in the United States -** This includes onshore and offshore production facilities and crude oil tankers traveling in U.S. waters with crude oil from foreign sources.

- **Movement of crude oil to refineries -** This includes pipelines extending from onshore and offshore production facilities to refineries or intermediate transfer facilities, as well as the loading and unloading of crude oil carrying tank ships, barges, and tank trucks at refineries or intermediate transfer facilities.

- **Refining of crude oil into products -** This includes the storage of crude oil, actual refining operations, the storage of refined products, and the loading of refined products to vessels, barges, tank cars, or trucks.

- **Transport of refined products -** This includes the transportation of the refined products to the bulk distribution point by any mode of transportation. A growing amount of imported refined products enter the system at this point.

- **Storage of refined products -** This includes offloading operations at the bulk terminal, storage of the product, and loading of the product to the tank truck, barge, or other mode of transportation for shipment to the consumer. Retail operations such as local gasoline or home fuel oil sales are excluded.

It is important to recognize that potentially damaging discharges of crude oil or petroleum products can and do occur at every point in this system (the frequency and quantity of oil spills at each point in the system are presented later), and that the factors which can influence the occurrence of these accidental discharges includes: the design, construction, maintenance, and operation of vessels and facilities; personnel training; and human engineering concerns.

The design of an R&D program based on the probability of a spill occurring at any given location in the system would be enhanced by a mathematical model of the movement of oil in the United States and by better spill data. As this model remains in the early stages of development, it is necessary to base risk estimates on expert opinion and anecdotal information. These estimates, along with information on potential spill damage under various geographical and environmental conditions, form the basis for the R&D needs presented in this plan.

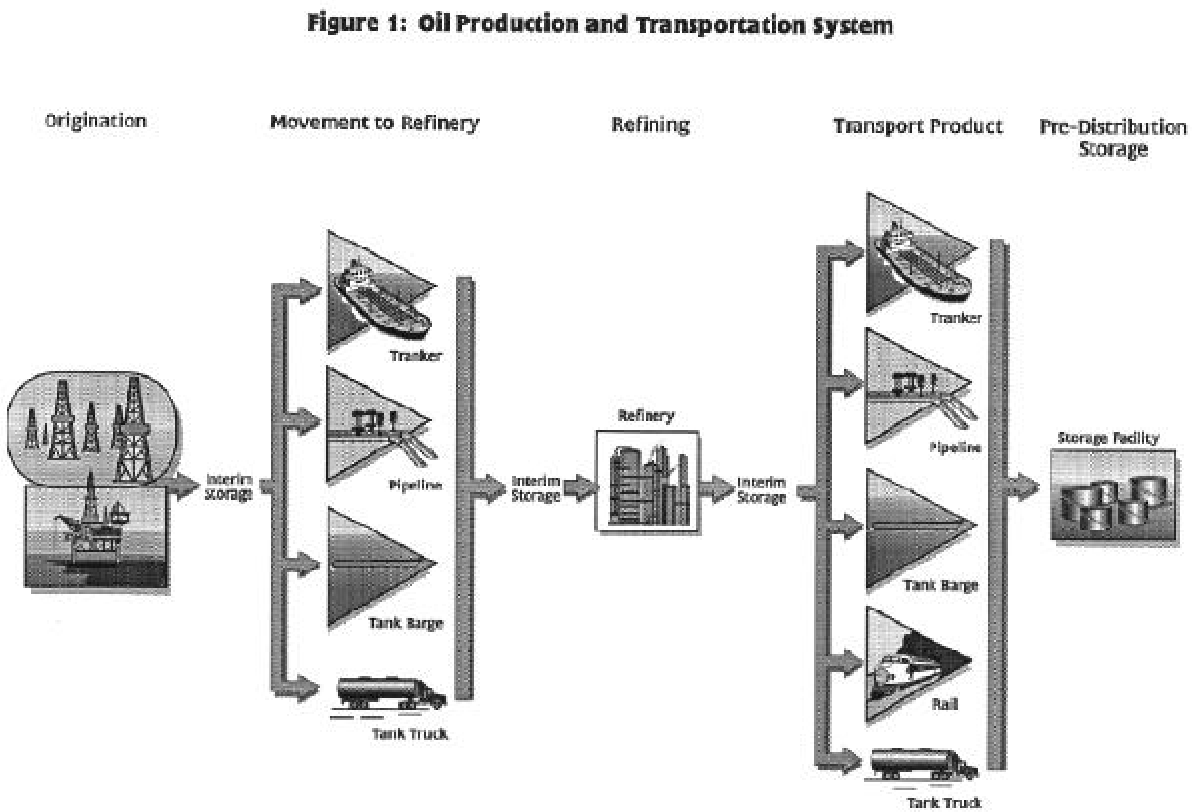

Figure 1 Oil Production and Transportation

B. Qualitative Assessment of Oil Production and Transportation System Spill Risks

If we view each mode of transport and facility type in the simplified schematic of the oil production and transportation system (Figure 1) as a possible oil spill source, we can find data to support claims that improved safety and operating procedures put in place over the last 10 years have generally reduced the risk of a spill at any point in the system. However, because accidental oil spills cannot be eliminated, efforts to improve pollution prevention and response must be continued. In this section, four high risk spill sources are examined to highlight existing weaknesses and concerns, and the efforts being made to address them.

Tank Ships and Tank Barges

The reduction of operational and accidental oil spillage in the U.S. over the past five years can be attributed partially to the stiff economic consequences facing spillers as a result of the liability provisions of OPA 90. The public's intolerance of oil spills has also led to the adoption of national regulations, most of which were mandated by OPA 90. These domestic regulations include requiring (1) new tankers to be equipped with double hulls to reduce accidental discharges of oil in the event of grounding or collision; (2) tankers to be escorted by tugs in environmentally sensitive ports; (3) tankers to carry spill cleanup equipment; (4) better training of vessel crews; (5) emergency oil transfer equipment for tankers; and (6) vessel emergency pollution response plans.

Led by the United States' position on oil pollution prevention and response, the international community, through the United Nations-sponsored International Maritime Organization (IMO), has supported meaningful changes of several international standards. These include Annex I of the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 (MARPOL 73/78), the International Convention for the Safety of Life at Sea (SOLAS), and the Standards for Training, Certification and Watchstanding (STCW). The amendments to SOLAS and STCW are noteworthy in that they look beyond the traditional equipment or engineering fixes to oil pollution by recognizing and addressing the significant role that the human element plays in marine casualties and oil spills. Changes include the creation of the International Safety Management Code in SOLAS, Chapter 9, which requires independent audits of the managerial practices of vessel operating companies. Enforcement of this code should help ensure that vessels engaged in oil transport are receiving the home office support necessary to complete a casualty free voyage. STCW changes are aimed at increasing the levels of training received by officers and crew, and providing more rest for watchstanders.

While these regulatory changes are significant and helped move the shipping community in the direction of prevention, the threat of a catastrophic oil spill in United States waters remains high and is arguably growing. The key risk factor associated with this claim is the ever-increasing volume of imported oil and refined product entering the country. This results in increased tank ship movements, the use of larger tank ships, and more inherently risky offshore lightering operations. The trends towards reduced crew complements and increased use of multinational crews, which often have language barriers and lack adequate training, also pose significant risks and must be addressed.

Offshore Exploration and Production Facilities

The relatively excellent spill record for domestic offshore drilling and production over the past 20 years suggests that technology and procedures for preventing oil spills are being employed effectively. In order to sustain this record, the offshore industry must continue R&D activities to meet the new challenges associated with deep water development, reduced staffing, and increased participation by smaller, and often less experienced operators.

For example, innovative subsea, floating, and tension leg facilities are being employed as production in deep water areas of the Gulf of Mexico increases. However, modifications in production safety systems are required to work in these areas and the effectiveness of deep water design and safety management practices remains to be demonstrated.

Also, many new operators are assuming responsibility for production from aging facilities in the shallower waters of the Gulf of Mexico, while major producers are operating facilities with fewer personnel and an increased reliance on contractors. These changes pose both management and operational challenges.

MMS is working with the offshore industry to evaluate these concerns. Current efforts involve joint deep-water work groups to evaluate development options and associated safety and environmental risks, industry-prepared operating plans addressing the application of new technology and procedures, and third-party review of facility design and installation proposals.

Additionally, many operators are developing Safety and Environmental Management Programs (SEMPs) which address the human and organizational factors critical to accident and spill prevention. MMS and the Department of Energy are assisting the smaller companies in developing these plans. The MMS Technology Assessment and Research Program is cooperating with industry on a series of workshops and studies to assist operators in assessing and mitigating operational risks.

Pipelines

While they typically do not receive the media attention given to major marine casualties, pipelines have historically been a primary source of oil spills both offshore and onshore. MMS records for 1984-1993 show that 98% of spills associated with Outer Continental Shelf (OCS) operations, which were greater than 50 barrels or 2100 gallons, resulted from pipeline operations. While the aging of the offshore pipeline network is of concern, corrosion and other age-related factors have not been a major cause of offshore spillage. In fact, virtually all of the major OCS pipeline spills have been caused by external damage from anchors and other vessel-related activities. Consequently, reducing OCS spills depends on a reduction in pipeline incidents.

Recent efforts to locate and accurately mark all OCS pipelines appear to be having their desired effect, as incidents involving external damage have declined in recent years. MMS is digitizing this location data for all OCS pipeline segments in order to provide readily available information on pipelines that could be affected by proposed offshore construction activities, and to assist in determining the source of any leaks. A similar program for pipelines in state waters could provide similar benefits.

As a result of OPA 90, the onshore oil pipeline system has received increased scrutiny. In contrast to the record of offshore pipelines, the cause of onshore pipeline accidents is split almost evenly between external damage and age-related factors. The Research and Special Program's Administration's Office of Pipeline Safety is engaged in collaborative R&D with industry which focuses research in those areas likely to reduce significantly the risk of pipeline accidents. These R&D programs include a national locating and mapping program similar to the MMS offshore effort; improving and integrating information systems to facilitate response and risk management activities; expanding the technology of non-destructive evaluation through research into automated inspection probes ("smart pigs"); and ongoing refinements in risk analysis and assessment to improve the agencies regulatory program.

Refining and Storage Facilities

Despite a decrease in the number of domestic refineries from well over 200 in the early 1980s to less than 180 today, their throughput has been essentially constant at about 15 million barrels per day. This is the case because remaining refineries operate at increased capacities to compensate for the lack of production at decommissioned older refineries. However, refinery profit margins have decreased due to ever-increasing competition, and the number of refinery personnel has fallen significantly as operators seek to maximize output with minimum operating costs.

Thousands of above ground crude oil and refined product storage tanks are in service at refineries and other oil/product handling facilities. American Petroleum Institute (API) Standard 653 governs tank inspections and requires that tanks be taken out of service periodically and visually inspected for leaks. While used as a guide by nearly all facilities, this standard is often ignored since inspection can cost an estimated $100,000 per tank.

Buried pipelines within refinery boundaries represent another source of leaks, and according to the API, have led to more ground water contamination than the more visible storage tanks. API Standard 2610 provides procedures for operators to verify piping integrity - with most refinery operators relying on subsurface monitoring to detect leakage. As a result, the enhanced practices of recent years have significantly reduced releases from tanks and piping. Due to the decrease in federal oversight resources, however, inspections are not always carried out with the recommended frequency. These irregular inspection intervals, combined with the aging domestic refinery infrastructure, increase the risk of spillage and dictate that better procedures be developed to detect potential problems.

Another possible source of leakage is the refinery process line. Current refinery practices involve company-specific in-service inspection procedures based on API Standard 510, which requires a refinery to shut down so that inspections can be performed under ambient conditions. These inspections are typically manual and cost several million dollars a year for a typical refinery.

A long-term objective of refinery operators and government is the development of better survey methodologies for their physical plant. As a result, automated in-service petroleum tank and piping inspection devices are being developed. Though not in commercial service, these devices promise better inspections at lower costs. This will conceivably lead to more frequent inspections and a higher degree of confidence in the overall structural integrity of the facility. Additional developments being encouraged by the refiners are in-service inspection systems that can survey pressure boundary structures. These systems also hold promises for longer-term improvements in inspections at significantly reduced costs.

C. Quantification and Trends of Oil Spills

Data Availability and Uses

Why do spills occur and where can the greatest improvements be made? While the answers to these questions require an understanding of the oil transportation and production system, they also require an understanding of spill causes and effects. The more we know about the incidents - where, when, and how they have occurred - the better we will be able to determine how to prevent them. Therefore, to plan and prioritize future oil spill R&D activities, it is necessary to analyze some of the available oil spill statistics to determine the primary source, cause, location, size, and oil type of these spills.

Information relevant to answering the above questions and reducing the risk of oil spills is found in a number of federal databases which compile data produced under a variety of statutes and regulations mandating facilities and/or carriers to report pollution events. (The scope, data elements, and a general cross comparison of seven major federal databases containing spill data used in preparing this plan is included as Appendix B.) The databases are used for a variety of purposes in oil pollution prevention and response. These include:

- Supporting emergency planning activities;
- Identifying weaknesses in the oil transportation system;
- Performing risk analyses;
- Determining inspection priorities;
- Gauging results of technology changes and developing new technologies;
- Assessing results of regulatory programs and developing new spill prevention programs;
- Facilitating impact analyses on lives, property, and the environment;
- Guiding agencies' allocation of resources; and
- Supporting agency compliance and enforcement programs.

It is important to note, however, that differences exist among statutes with regard to whom reports must be made, threshold reporting requirements, when a report must be made, and what information must be included in the report. Coupled with these reporting incongruities is a lack of quality data regarding the causal chain of events that led to the spill. As a result there are significant data gaps and analysis limitations with regards to spill causes, spilled oil's fate and effect, and shipment information. Unfortunately, the data that do exist are not subjected to rigorous quality control, particularly for consistency of terms and definitions. Furthermore, these databases are not linked, making it very difficult for researchers to search in and compare multiple databases. Until a long-term solution is reached, no clear understanding of reality can be obtained. Ongoing efforts to make existing data more usable, available, and comparable need to continue.

The Coast Guard's Marine Safety Information System (MSIS) data represents spills reported to the Coast Guard by responsible parties, other private parties, government agencies, and Coast Guard personnel. All reported discharges into U.S. navigable waters, including territorial waters, tributaries, the contiguous zone, onto shorelines, or into other waters that threaten the aquatic environment of the United States are included. Since this database appears to give the best overall summary of trends in oil spill occurrences in navigable waters, it was used in conjunction with MMS data on OCS operations and Environmental Protection Agency (EPA) data on inland spills as the basis for establishing the plan's research and technology priorities. Available oil spill data were analyzed to determine trends in primary spill source, cause, size, location, and type of oil spilled.

Oil Spill Trends

Figure 2 shows clearly the downward trend in oil spilled as a function of domestic oil demand. Whether this is attributable to the heightened environmental awareness of the past 25 years or an increasingly effective campaign by political, economic, and regulatory agencies to protect our natural resources, it indicates that we are on the right track. However, we must still expect and plan for the periodic "disasters" that cause the peaks in the graph.

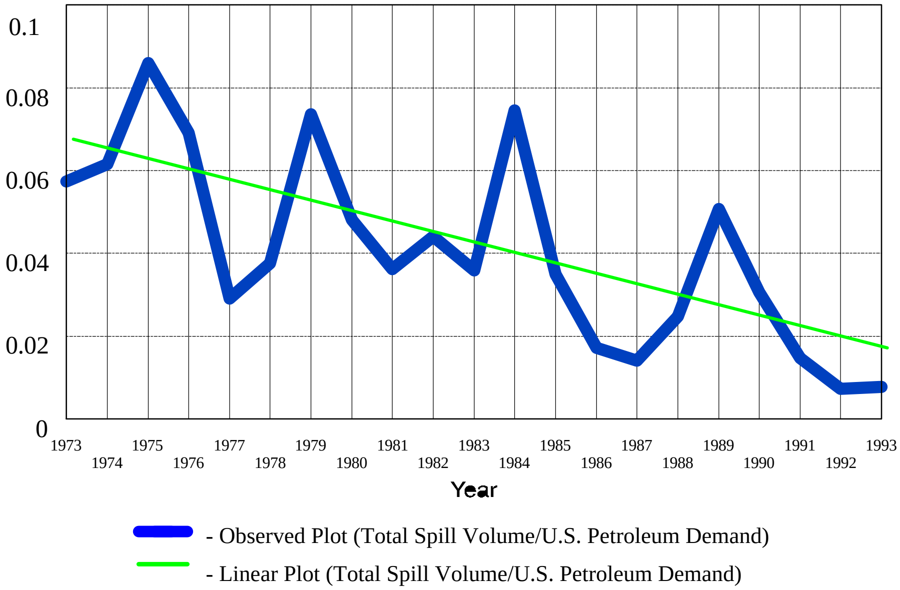

Figure 2 Oil Spillage as Percent of Domestic Oil Demand

MSIS oil spill data for each of the years 1973 through 1993 were analyzed by the U.S. Coast Guard[1] and led to several telling conclusions, the most important of which are listed below and/or presented in several of the plan's tables.

- The number of reported spills averaged approximately 8100 / year;
- Of these reported spills, 5% accounted for 95% of the spilled oil volume;
- Less than 0.2% of reported spills exceeded 100,000 gallons ("major spills");
- Tank ships, tank barges, and other vessels were the source of approximately 52% of the spilled oil volume; and
- Pipelines, facilities, and non-waterborne transport sources accounted for 48% of the spilled oil volume;
- 85% of the oil spilled into water occurred in the coastal and internal waters.

Tables 1 through 6 provide information regarding the sources, relative volumes, location, and contributing cause of oil spills in the waterborne transportation, Outer Continental Shelf, and inland regimes. It is important to bear in mind that the "cause" attributed to any of these spills is the final action or event that resulted in a pollution incident. Numerous reports over the past two decades estimate that from 60-80% of marine casualties result from "human errors" that occur somewhere in the event chain.

---

[1] United States, Dept. of Transportation, U. S. Coast Guard, Pollution Incidents in and around U.S. Waters: A 25 Year Compendium 1969-1993 (Washington, DC. 1995).

One positive result of this high percentage, which is often yet viewed as conservative, is the generally accepted notion that most oil spills are preventable. Table 3 summarizes the causes of 88 tanker spills of 10,000 gallons or more in U.S. waters over a 15 year period. While fortunately a relatively small sample size, it reinforces the position that reducing human error (i.e. in ship handling and cargo operations) will prevent a significant amount of oil pollution. It is in this area that researchers and regulatory bodies are increasingly looking for advancements.

Table 1. Oil Spilled in U.S. Waters by Source (1973 - 1993)

Source: U.S. Coast Guard, 1995

Source	Number of Spills	Volume Spilled (millions of gallons)	Percent of Total Volume Spilled
Tank Ship	8,034	66	30
Tank Barge	12,765	38	17
All Other Vessels	38,778	12	5
Facility	48,295	40	18
Pipeline	7,813	39	18
All Other Non-Vessels	7,900	7	3
Unknown	46,755	19	9
Total	170,340	221	100

Table 2. Oil Spilled in U.S. Waters by Operation (1973-1993)

Source: U.S. Coast Guard, 1995

Operation	Volume Spilled (millions of gallons)	Percent of Total Volume Spilled
Underway/Transporting	65.5	29
Cargo Transfer	50.7	23
Movement in Congested Waterway	13.6	6
Tanker/Facility Operations	4.2	2
Lightering	4.2	2
Bunkering	1.7	1
Pipeline	1.4	1
Pumping Bilges	0.2	< 1*
Other Known Operation	50.6	23
Unknown Operation	28.9	13
Total	221	100

* Spill amount is 0.1% of total

Table 3. Causes of Tanker Spills in U.S. Waters of 10,000 Gallons or More (1978-1992)

Source: Golob, 1992

Cause	Number of Spills	Percent of Total Spills
Grounding	23	26
Collision	12	14
Cargo Transfer	12	14
Ramming	9	10
Structural Failure	8	9
Equipment Failure	8	9
Explosion/Fire	6	7
Other	10	11
Total	88	100

Table 4. Oil Spilled in U.S. Waters by Location (1973-1993)

Source: U.S. Coast Guard, 1995

Source	Volume Spilled (millions of gallons)	Percent of Total Volume Spilled
Internal/Headwaters	109	49
Coastal (0 - 3 mi.)	80	36
Contiguous Zone (3 -12 mi.)	3	1
Coastal Ocean (12 - 200 mi.)	21	10
General Ocean	2	1
Other	6	3
Total	221	100

Table 5. Sources of Oil Spills from Inland Transportation and Distribution System (1987-1995)
Source: EPA ERNS Database

Inland Source	Number of Spills	Volume Spilled (millions of gallons)	Percent of Total Volume Spilled
Fixed Facility	43,188	79.5	62
Pipeline	13,771	33.7	26
Highway Transport	13,280	6.2	5
Rail Transport	2483	3.7	3
Above Ground Storage Tank	921	4.4	3
Underground Storage Tank	795	0.5	<1
Total	74,438	128	100

Table 6. Causes of Oil Spills from Inland Transportation and Distribution System (1987-1995)
Source: EPA ERNS Database, (Stalcup, 1995)

Cause	Number of Spills	Volume Spilled (millions of gallons)	Percent of Total Volume Spilled
Equipment Failure	11,476	22.8	50
Operator Error	4,235	4.3	9
Transportation Accident	3,187	3.0	7
Natural Causes	583	1.7	4
Dumping	2,250	1.0	2
Other	2,584	2.3	5
Unknown	934	10.4	23
Total	25,249	45.5	100

D. Oil Spill Costs

Over the years, awareness of oil's detrimental environmental effects has increased and actions have been taken to reduce the volume of oil entering the environment accidentally. Yet despite improvements in spill prevention technology, accidents continue, sometimes with staggering environmental and economic consequences. To complicate matters, the cleanup technologies employed following a spill may also have negative environmental impacts. As a result, information that aids in a rapid assessment of the potential environmental impact from the spill and the proposed cleanup operations is essential to mitigating the damages. The following sections present some of the factors that need to be considered in developing an effective oil pollution research program.

Response, Property, and Environmental Costs

The costs resulting from a spill are numerous and include economic, social, recreational, and ecological losses. While spill response and property damage costs are relatively easy to identify, two of the biggest unknowns after any spill are the costs involved in restoring the environment to its pre-spill condition or compensating those who have been harmed by the spill. Claims are frequently made for losses to commercial enterprises such as fisheries, waterfront facilities, and tourist industries.

The expanded range of damages permitted by OPA 90 has resulted in an escalation of spill costs. The following illustrate some of the costs associated with oil spill response and restoration:

- The cost of recovering or eliminating oil offshore is typically 10 to 100 times less than removing the same oil from shorelines.[2]

- Cleanup costs for on-water physical containment and removal of oil with no significant shoreline average $4.03 per gallon. Shoreline cleanup, wildlife rescue and rehabilitation, and other labor intensive operations can drive the cost up to as much as $263 per gallon as was the case in the EXXON VALDEZ spill.[3]

- Federal agency costs for the EXXON VALDEZ 1989 cleanup season alone were $110 million. EXXON's response costs exceeded $2 billion.

- In response to the tank barge BERMAN spill off Puerto Rico in 1993, government response costs were over $80 million with natural resource damage (NRD) costs still pending. In the case of the tank ship NAUTILUS off Staten Island in 1990, the potential responsible party's response costs were $20 million with NRD costs of $4 million.

- Union Oil of California spent $13 million to clean up the oil and settle claims resulting from a 6300 gallon oil spill from a near shore pipeline in south-central California in 1992.

While it is generally accepted that the unit cost (i.e. $/gallon) of an oil spill typically decreases with increasing volume, thus resulting in smaller spills having dramatically higher unit costs than larger spills, cleanup and restoration cost data on spills in the United States is scarce and non-centralized. In fact, actual response costs often only scratch the surface of a spill's overall net cost to the nation in lost productivity and opportunity.

---

[2] Allen, A.A. and R.J. Ferek., Advantages and Disadvantages of Burning Spilled Oil, (Washington: API, 1993)

[3] Etkin, D.S., The Financial Costs of Oil Spills, (Arlington, MA: Cutter Information Corp., 1994)

Factors Exacerbating Physical and Biological Impacts to the Environment

The adverse environmental impacts and costs from an oil spill vary depending on a multitude of factors, each of which has the potential to exacerbate the impact of the spill on the surrounding community. This complexity makes it difficult to predict the severity of impact and to develop effective response and restoration techniques. The following sections discuss some of these factors.

Oil Type and Behavior - The different physical and chemical properties of crude and refined oils influence the physical and biological effects of an oil spill. For example, lighter, highly toxic, refined products, i.e. jet fuels, which can cause immediate impact to organisms, often evaporate rapidly. Heavier oils, i.e. crude oils and heavy fuel oils, often form a thick oil and water mixture (emulsification) which clings to rocks, sand, and organisms, and can persist in the sediments for many years. Regardless of the type of oil, damage to the environment is increased if the volume of the spill is large or if the spill occurs in confined areas.

Another important factor in determining the potential harm to the environment is the degree to which the oil has been "weathered." Weathering is a series of chemical and physical changes that cause spilled oil to be altered through the natural processes of dissolution, evaporation, emulsification, and oxidation. For instance, when an oil spill occurs close to shore, it has an increased potential to cause harm because the oil does not weather significantly before it reaches shore, and as a result, still contains many toxic compounds. Weathering is also critical in determining the type of response method that will be effective. For example, emulsification retards the loss of toxic compounds through evaporation, and limits or prevents the use of dispersants or *in situ* burning. In addition, emulsification of a spill significantly increases the volume of oily liquid to be recovered, which exacerbates the problem of oil and debris disposal.

Environmental Sensitivity - The environment's sensitivity to oil varies depending on many factors including the composition of the oil, its concentration, the type of shoreline, and the amount of energy in the environment. These factors, in turn, impact the biological consequences. For instance, the environmental impact of a spill at sea is primarily on the surface layer and on those animals and plants that utilize that part of the water; research has shown that only under specific conditions is the oil likely to impact organisms living in the water column or on the ocean floor.

Organism Vulnerability - The amount and condition of the oil in the environment, and the organism's exposure, strongly influence the potential impact of a spill on organisms living in close proximity to the spill. For instance, oil spills have the potential to affect every level of the marine food chain, from the organisms that live in the sediments to those that float on the surface of the water. Various factors will determine what organisms are effected, the degree to which they are injured, and the rate at which they can recover. Included in these factors are season of the year, life stage of the organism, type of oil spilled, and duration of exposure.

Cleanup and Restoration - In addition to the incident characteristics affecting the severity of environmental impact, the actions taken to clean up the oil and to mitigate its effects are also crucial to determining the rapidity of environmental recovery and the injury remaining. For instance, some mechanical cleanup techniques can increase the severity of impact in certain environments, while some non-mechanical cleanup measures, if applied to the wrong environments, can similarly exacerbate environmental impact and slow recovery. Conversely, properly applied removal actions can facilitate recovery over no action. Understanding the balance between cleanup and cessation of cleanup, the match between removal activity and environment type, and the indicators of successful actions are basic to developing a truly effective oil spill response capability.

Recovery - Although biological recovery is generally possible after an oil spill, recovery times vary widely, from a few days to more than ten years, and the reestablished community may not have the same composition or age structure as the preceding community. An environment's ability to recover depends on many factors such as, exposure level, habitat, and ability to re-colonize. Organisms that can rapidly colonize are often the first to recover, whereas organisms that experience sub-lethal effects may take over ten years to recover.

E. Regional Interests

Whether it is providing economic benefits through job growth or causing environmental harm as the result of a spill, oil production and transportation affects most every region of the country. The waterborne petroleum transportation system of the United States alone has been defined as serving 48 ports and port groups and in 1993 handled 817 million tons of oil. The ten largest volume ports were responsible for 80 percent of the total tons of all crude and petroleum products shipped by tank ship and barge.[4]

Table 7. Petroleum Products Shipped Through U.S. Ports (1993)

Source: RSPA 1995

Port	Percentage of Tons Shipped
Mississippi River	18
Houston/Galveston, TX	12
Alaska	11
Delaware Bay	9
Port of New York/New Jersey	7
San Francisco, CA	5.5
Los Angeles/Long Beach, CA	5
Port Arthur, TX	4.5
Strait of Juan de Fuca, WA	4
Corpus Christi, TX	4
Total	80

Note: Total United States shipments in 1993 = 817 million tons

[4] John A. Volpe National Transportation Center, Petroleum Transportation Systems Assessment & Modeling, (Cambridge, MA, 1995)

.

The following summarizes briefly a few of the issues of regional interest. To address some of these concerns, Alaska, California, Louisiana, and Texas have developed active oil pollution research programs, as shown in the following table.

Table 8. State R&D Activities

State Program	Research Focus
Alaska, Prince William Sound Oil Spill Recovery Institute (OSRI).	Implemented an aggressive R&D program covering numerous technologies for prevention and response. Focus is on Arctic and Sub-Arctic environments. The Institute interacts with federal agencies through the OSRI Scientific and Technical Committee.
California Department of Fish and Game	Dispersant testing with Marine Response Spill Corporation (MSRC) including: toxicity of dispersed oil; effectiveness of dispersants on California oils; and kinetics of organism uptake of mechanically and chemically-dispersed oils). Effects of oil exposure on marine mammals and birds. Developing monitoring and treatment techniques for marine birds. Developing marine mammal & bird population assessment techniques and baseline data for California.
Louisiana, Applied Oil Spill Research and Development Program	A range of projects tailored to the Gulf Coast environment including: trajectory modeling; risk assessment; oil-water separation; *in situ* burning; bioremediation,; fate and effects; and restoration.
Texas General Land Office R&D Program	A range of projects including trajectory modeling, dispersant application, bioremediation, and shoreline cleanup. Primary sponsor for the Coastal Oil Spill Simulation System at Texas A&M University. Projects have been undertaken jointly with MSRC and federal agencies.

Gulf of Mexico

Proven oil reserves, an established production infrastructure, and a well-developed onshore refining and transportation system make the Gulf of Mexico a center for producing, refining, and transporting oil from a variety of sources. The importance of the oil and gas industry to the states of Louisiana and Texas cannot be overstated; the dramatic changes in the level of oil and gas activity over the past 20 years within the region, as well as that occurring elsewhere but supported by the region, caused large fluctuations in population, labor, and employment. As a result of the economic importance of the energy and marine industries to Gulf states, the area is very receptive to oil-related activity and development. (The area is also vital to national interests as it contains a high percentage of chemical production, the Strategic Petroleum Reserve, and the Louisiana Offshore Oil Port (LOOP), the only deep water oil terminal in the nation.)

Transportation of oil and gas from offshore facilities in the Gulf of Mexico has traditionally relied on an ever-expanding pipeline network. While industry has discussed the use of shuttle tankers to transport oil from deep water leases to shore, such a plan has not been implemented to date. Consequently most of the oil and gas produced in the region will continue to be transported to the shore by pipeline for the foreseeable future. This fact raises the concern about the structural integrity of the pipelines and the adequacy of leak monitoring methods. Of considerable environmental concern is the possible impact on the numerous marshes and swamps in the region. Since there is little natural flushing in the marshes, a large spill could be catastrophic. Both Louisiana and Texas have been active in pre-approving alternative spill response cleanup measures.

Lightering of oil from “supertankers” to shallower draft tank ships capable of entering the coastal and river ports of Texas and Louisiana will continue to grow in frequency as the demand for imported oil climbs. While this activity has generally been a low risk, it should not be ignored.

West Coast

Economic interests similar to those in the Gulf exist in central and southern California where there are numerous onshore oil wells and refineries, but the state’s economy is more diversified and not as dependent on the oil and gas sector. While California has a long history of offshore oil production, environmental concerns since the 1969 Santa Barbara Channel spill have led to strict limits on its growth and virtually stopped new exploration and development. Washington continues to refine a significant amount of oil, particularly Alaskan North Slope crude, much of which supplies regional demand, and shares with California a similar view towards offshore exploration and development. Finally, the States/British Columbia Task Force serves as a forum for the states of Alaska, California, Oregon, and Washington, along with British Columbia, to address common concerns related to spill risks and protection of marine resources.

Alaska

Alaska's economy is directly tied to the vitality of the oil and gas industry due to the large amount of production on the North Slope and in Cook Inlet. Prospects of future production from the Beaufort Sea raise concerns about spill prevention, response, and cleanup in an ice-covered regime with which we have relatively little experience. However, tourism and fishing are also vital to the state’s economy and require a clean environment to be successful. The state is working hard to balance the needs of all sectors and to protect as much of its pristine area as possible.

Much of the oil produced in Alaska is shipped through areas which are environmentally sensitive due to the presence of fish hatcheries and spawning grounds. There is also great concern over the potential effects on the permafrost that could result from pipeline spills. The Prince William Sound Oil Spill Recovery Institute (also authorized by OPA 90) is working to identify and develop the best available technologies to deal with oil spills in the Arctic and Subarctic environments.

East Coast and Great Lakes

In contrast to the other coasts, the Atlantic and Great Lakes areas have no primary offshore production facilities. As a result, these regions of the country are affected primarily by the importation and refinement of crude oil and transportation of its products. Delaware Bay and New York/New Jersey are the main oil port areas on the East Coast. Coastal tank ships and barges and extensive pipeline networks move crude oil and products to their distribution points. Protection of the Atlantic fisheries and beaches, and Florida’s coral reefs are major concerns.

In the Great Lakes region, Joliet, IL; Lamont, IL; Whiting, IN; St. Paul, MN; and Toledo, OH; have the largest refineries, each with the capacity to process over 100,000 barrels of oil per day. This oil arrives in the region largely by pipeline, including significant imports from the Canadian provinces to the west. Product distribution within the region is by pipeline, barge, rail, and truck.

2. Research and Technology Programs - Accomplishments and Potential Benefits

This section describes the progress made in the various technology areas outlined under the original Interagency Oil Spill Research & Technology Plan, including an assessment of current technology based on accomplishments since the passage of OPA 90, and recommends future program directions. Four categories where improvements in technology can lead to the attainment of a significant goal are:

- Spill Prevention - Reduce the number and volume of spills by addressing items in the causal chain of events that result in spills.
- Spill Response Planning, Training, and Management - Improve the effectiveness of response through better coordination and pre-spill planning.
- Spill Countermeasures and Cleanup - Improve the ability of responders to remove oil without causing further environmental injury.
- Fate, Transport and Effects (FTE), Monitoring and Restoration - Improve the ability to predict movement and impacts of oil spills and restore the environment to its pre-spill condition.

The overall objective of oil pollution research and technology is to minimize the likelihood and impacts of accidents. In each of the above areas, the technologies and procedures must be re-examined to ensure that the most current information is used, especially in light of the changes which have occurred since the passage of OPA 90.

The first portion of this section describes the activities and responsibilities of the various agencies on the Interagency R&D Committee, highlighting specific accomplishments in meeting the mandates of OPA 90 and advancing the nation's capability to prevent and respond to spills. Included in this discussion is a brief summary of current research activities and future development opportunities in each of the four technology areas. Detailed descriptions of the state-of-the-technology and future research required for each specific technology are contained in a series of technology assessment and forecast summaries contained in Appendix A.

The second portion of this section looks at the individual technology areas in these four categories, and qualitatively assesses their potential impact for limiting oil pollution and its effects. Although research was initiated to better quantify the risks of oil spills associated with the marine transportation system and the impact of technological advances, the work is incomplete. Consequently, while these assessments fall short of providing the rigorous cost/benefit analysis for each technology area called for by the National Research Council Report (NRC, 1993), they do provide a basis for identifying major shortfalls in the federal oil spill research and technology development program and assigning relative priorities.

A. Overview of Federal Efforts and Accomplishments

Before summarizing the current status and future directions for each technology area, it is helpful to review the research focus areas of the various federal agencies, highlighting specific accomplishments aimed at fulfilling the expectations of OPA 90. Since the passage of OPA 90 and the resultant revitalization of the nation's R&D efforts to control oil pollution, the agencies of the Interagency Coordinating Committee on Oil Pollution Research have pursued R&D programs consistent with their level of appropriated funds. As envisioned in the original R&D Plan, agencies have focused their efforts on areas appropriate to their regulatory and operational responsibilities. These major focus areas are outlined in the following table.

Table 9. Oil Pollution R&D Focus Areas of Committee Member Agencies

Agency	Responsibilities	Research Focus
Dept. of Transportation U. S. Coast Guard	Coastal On-Scene Coordinator. Develop and enforce marine prevention regulations.	Prevention (particularly in advanced navigation, crew training and evaluation, vessel inspection, and human factors). Spill planning and management (all areas). Countermeasures and cleanup (particularly surveillance, at-source countermeasures, *in situ* burning, mechanical recovery). Regional Grants and Port Demonstrations.
Dept. of Defense Army Corps of Engineers	Support OSC by providing technology, systems, and operational assistance.	Countermeasures and cleanup (particularly in satellite and aircraft surveillance, trajectory modeling, and mechanical recovery).
Environmental Protection Agency	Inland On-Scene Coordinator. Prepare National Contingency Plan (NCP). Manage NCP Product Schedule. Develop and enforce inland prevention regulations.	Prevention (for facilities). Planning and management (particularly training/readiness and DSS development). Countermeasures and cleanup (particularly dispersant and *in situ* burn protocols, and bioremediation).
Dept. of Interior National Biological Service	Resource trustee. Key participant in NRDA process in inland areas.	Fate and effects research focusing on birds and inland habitats. Development of NRDA technologies.
Dept. of Interior Minerals Management Service	Develop and enforce prevention and contingency plan regulations for offshore oil and gas operations. Develop offshore response technology.	Prevention technology (for offshore facilities and pipelines). Oil spill behavior and trajectory modeling. Countermeasures and cleanup (particularly surveillance, mechanical recovery, *in situ* burning, and dispersants). Maintain and operate OHMSETT facility.
Dept. of Transportation Maritime Administration	Support maritime industry with guidance and technology in implementing equipment, systems, and operations to prevent spills.	Prevention technology (particularly advanced navigation, crew training, and evaluation, and human factors).
Dept. of Defense U.S. Navy	Provide prevention and response capability to fleet and facilities. Augment national response capability through SUPSALV.	Countermeasures and cleanup (particularly development, testing, and evaluation of mechanical recovery technologies).
Dept. of Commerce National Institute of Standards and Technology	Provide support for technology development.	*In situ* burning research.
Dept. of Commerce National Oceanic and Atmospheric Administration	Scientific Support Coordinators. Resource trustee for coastal areas. Key participant in NRDA process in coastal regions.	Spill planning and management (DSS development, trajectory and behavior models, and health and safety).Long-term fate, effects, monitoring, and restoration.
Dept. of Transportation Office of Pipeline Safety	Develop regulations for pipeline spill prevention. Develop pipeline technology.	Prevention (particularly pipeline failure studies and leak detection systems).

Interagency Oil Pollution Research and Technology Plan

The various agencies have been active in rebuilding the nation's research infrastructure, including the refurbishment and reopening of OHMSETT at The National Oil Spill Response Test Facility - located in Leonardo, NJ. This is the only facility in the world where full-scale oil spill response techniques and equipment can be tested, with oil, under controlled conditions. It is managed by the Minerals Management Service (MMS), and operated by a private contractor. A $1.5 million refurbishment program, funded by MMS, the Coast Guard, and Environment Canada, was completed in 1992, and extended the life of the facility by an estimated 15 to 20 years. To date, 16 separate test series have been carried out at the facility to test booms, skimmers, temporary storage devices, sorbents, and remote sensing systems. OHMSETT is a critical resource for continuing oil spill technology development.

The agencies have also been active in enlisting the capabilities of the nation's universities and non-profit organizations in oil spill research and technology development. In 1994 the Coast Guard initiated the OPA 90 Regional Grants Program, administered through the Volpe National Transportation Systems Center, with the distribution of $837K to fund ten projects.[5] An additional $584K was distributed in 1995 to fund seven additional research efforts. The Coast Guard also provided funding to Massachusetts Maritime Academy, Texas A&M University, and New York Maritime Academy ($1.25M each) for oil spill response training simulator development. Although the primary function of these facilities is hands-on training, there are research applications as well.

To further address regional technology development issues, the Coast Guard funded the establishment of the South Florida Oil Spill Research Center at the University of Miami to conduct research on oil spills in tropical and sub-tropical environments.[6] In addition, the Army Corps of Engineers is funding a research grant at the University of Miami to investigate restoration and remediation plans on the Gulf Coast. Various federal agencies also provided consultation to the Prince William Sound Research Institute, which focuses on oil spill research for Arctic and sub-Arctic regions. Focus areas for Arctic research include *in situ* burning, spill cleanup in broken ice, remote sensing for tracking oil in and under ice, incineration of wastes, and fate and effects on Arctic ecosystems.

Additionally, various agencies provided funding and support to small businesses and entrepreneurs through small business set-aside contracts and Small Business Innovative Research (SBIR) program grants for development of innovative oil spill prevention and response technologies. Logistic support was also provided to small companies for testing various technologies at OHMSETT and in the field.

The agencies are also addressing the issue of the public's perception of oil spill technology. The EXXON VALDEZ incident left the public with the perception that oil spill response technology was primitive and totally inadequate. As long as that perception persists, the success of R&D efforts will not be recognized. As a result, the National Research Council expressed the need for public education and involvement in formulating the federal oil spill R&D strategy. Various agencies have pursued programs to inform the public of the true capabilities of oil spill prevention and response technology through workshops, seminars, and publications. The Interagency Committee provided government agencies and the public the opportunity to learn about new technologies through the Port Demonstration Projects called for by OPA 90. Port Demonstrations were held in New Orleans (December 1994) and New York (October 1995).

In pursuing their oil pollution-related R&D programs, the agencies make every attempt to coordinate their efforts, and in many cases actually conduct projects, with the states and industry. This limits duplication of effort, and allows for the leveraging of funds. The state R&D programs were presented earlier in Table 8;

---

[5] Putukian, J., and K. Bitting, U.S. Coast Guard Oil Pollution Research Grant Program, (London: Intype, 1995).

[6] C.N.K. Mooers, South Florida Oil Spill Research Center, (London: Intype, 1995).

Interagency Oil Pollution Research and Technology Plan

Table 10 provides a summary of industry programs. Both state and industry programs are monitored by the Interagency Committee, and cooperative efforts are undertaken when possible. It should be noted that the state and industry programs look to the federal program for leadership and support, and that both state governments and industry are also experiencing the cyclic decline in research programs

due to budget reductions and the shift in Congressional and public emphasis. A healthy Federal Oil Spill R&D Program could help maintain the level of state and industry participation in oil pollution research.

Table 10. Industry R&D Activities

Industry Program	Research Focus
Marine Spill Response Corporation	MSRC conducted a $30M R&D effort which was terminated at the end of 1995. It addressed many of the planning and management areas, and most of the countermeasures and cleanup technology areas in the marine and coastal environments. Emphasis was placed on behavior modeling, worker health and safety, airborne remote sensing, mechanical recovery, dispersants, *in situ* burning, oil and debris disposal, and fate and effects.
American Petroleum Institute	While MSRC program was in place, API focused on inland/ freshwater spills. Specific research areas include chemical countermeasures, *in situ* burning for habitat restoration and oil removal, developing a manual for inland shoreline cleanup, and human and ecological effects of oil. A Marine Research Workgroup was formed in early 1996 to continue work in the marine environment and carry on promising projects from the MSRC program (i.e. dispersant field tests, collection of toxicity data, risk communication, and *in situ* burning.)
Petroleum Environmental Research Forum	PERF is an ad-hoc industry oil spill R&D group. Projects have focused on developing guidelines for studying oil spill effects, evaluation of oil solidifiers, and the evaluation of biosurfactants (joint project with EPA).

In addition to coordinating with the states and industry, the Interagency Committee has endeavored to maintain contact and cooperate with other countries' oil spill R&D programs. Communication, technology transfer, and joint project development have increased significantly since OPA 90. A worldwide oil spill R&D database now exists and is useful in identifying scientists and programs for cooperative efforts. Joint projects are routinely undertaken with Environment Canada, Warren Spring Laboratory and its successor, the National Environmental Technology Center in the United Kingdom, and SINTEF in Norway. In addition, two International R&D Forums have been held; one at Tyson's Corner, Virginia in 1993, and the second in London in 1995. The proceedings for these forums record international progress in oil spill R&D. These forums also have fostered cooperative programs and coordinating groups that leverage resources and accelerate R&D advances. In fact, the results of the London Forum were used as the basis for R&D priorities in this report.

Most notably, the Interagency Committee has registered a number of accomplishments in the prevention and response areas. These include specific advances in the various technology areas, and overall progress in rebuilding the national infrastructure and research capability in this area. Although this progress is encouraging, it also underscores the need for a sustainable level of oil pollution research as recommended by the National Research Council. This will stem the cyclic decline that is already underway as national interest shifts to other issues. Specific advances and future directions in the four technology areas are summarized below, and further described in the technology assessment and forecast summaries in Appendix A.

Spill Prevention

In the category of spill prevention, safety improvements have been made through the development of Electronic Chart Display Information Systems (ECDIS) and Shipboard Piloting Expert Systems (SPES) to facilitate vessel navigation, and Automated Dependent Surveillance Systems (ADSS) for vessel traffic monitoring and control. These technologies are well into the prototype development phase and are now moving into the test, evaluation, and implementation phases. Once fully implemented, these technologies could reduce major marine transportation accidents such as groundings and collisions.

Some progress has also been made in understanding the important role of human factors in spill prevention. A number of R&D initiatives are currently focused on this critical area, particularly relative to the marine transportation regime. These research efforts are being pursued primarily by the Coast Guard and Maritime Administration.

In the area of offshore operations spill prevention, the Minerals Management Service is carrying out an aggressive research program which focuses on the structural integrity of offshore structures and pipelines, well-control technology, risk-based management of offshore pipeline systems, and the role of human factors in offshore operations accidents.

Another important prevention area, but one which has received less attention, is spill prevention at onshore transfer, storage, and distribution facilities. A substantial volume of spilled oil originates from these facilities, often from easily preventable causes. This will be a key focus area for future projects.

Spill Response Planning, Training, and Management

In regard to spill response planning, training, and management, the Coast Guard is making advances in developing training and readiness evaluation systems using advanced computer technology. These systems are now providing basic spill response training at several locations around the country. Future efforts in the development process will fully integrate these systems into the national oil spill training and evaluation program. Computer technology has also been employed to develop prototype decision support systems (DSS) for contingency planning and response. Initial efforts, primarily by the Coast Guard, NOAA, and the Corps of Engineers have focused on developing the individual components of these systems, including advanced models and databases, as well as mapping and display tools. These components are being incorporated into a prototype DSS to provide accurate and accessible information to the spill responder. Future efforts will be directed at developing additional required components, refining the DSS system design, and fully integrating the technology into contingency planning, readiness training, and response management functions.

Spill Countermeasures and Cleanup

Advances in this area have centered on improving the effectiveness of various techniques, particularly those which can be employed at major spills. These efforts are being pursued primarily by the Coast Guard, Army Corps of Engineers, MMS, and EPA. For instance airborne remote sensing efforts seek to achieve a 24-hour, all-weather capability that allows response managers to not only map the perimeter of a spill, but to direct cleanup resources to the areas where they are most needed. The day/night, all-weather capability has been enhanced by upgrades and testing of synthetic aperture radar (SAR) and infrared sensors. In addition, a prototype laser fluorosensor has been developed and is being tested to positively discriminate between hydrocarbons and natural materials. Efforts are also continuing to develop a viable oil thickness sensor to allow mapping of heavier oil concentrations. The development, testing, and implementation of these sensors will provide a complete surveillance capability for oil pollution detection and enforcement, as well as oil spill response.

Since OPA 90, R&D in containment and removal technology has recognized the importance of containing the oil at the source and removing it from the water before it reaches shore, where environmental and cleanup costs are substantially greater. Mechanical recovery development efforts have produced viable Vessel of Opportunity Skimming Systems (VOSS), and a lightweight, high volume oil-water separator which increases the amount of oil recovered during skimming operations. Future R&D will focus on the recovery of oil in higher sea states and currents, and dealing with problematic oils, such as heavy Group V oils and orimulsions.

Advances have also been made in refining the technology of *in situ* burning. A multiyear R&D effort examining the potential of this technique culminated in an internationally funded and executed *in situ* burn experiment off Newfoundland in August 1993. This and other studies have demonstrated the fundamental soundness of *in situ* burning as an effective cleanup technique. However, to realize its operational benefits, research is needed to increase the durability of the required fire resistant booms, reduce smoke production, enhance other implementing technologies, and define the criteria for employment of this response technique.

The EXXON VALDEZ and other major spills of that period underscored the ineffectiveness of then available shoreline cleanup technologies. While some current methods remain expensive, labor intensive, and often environmentally damaging, significant progress has been made in this area. R&D efforts are defining which techniques should be used for various oil types and shoreline characteristics to achieve optimum removal, while minimizing environmental damage. For instance, findings from an EPA-funded Delaware study proved the effectiveness of bioremediation, and preliminary bioremediation implementation guidelines were developed based on the continued presence or absence of nutrients in the contaminated area. In addition, the minimum nutrient concentrations needed to maximize biostimulation were defined, and the frequency of addition of water soluble fertilizer was established based on water coverage in the inter-tidal zone. First order rates of biodegradation on sandy marine beaches in a temperate climate were developed for use in predictive models, and an important link between biodegradation rates measured in the field and those measured in the laboratory was established. More R&D is needed, however, before this technology reaches its full potential. Future efforts should address bioremediation of wetland ecosystems (both freshwater and saltwater), inland lacustrine and riverine shorelines, subsurface oil (for which no effective technique exists), and the development of alternative endpoints of risk to the ecosystem.

Fate, Transport and Effects, Monitoring and Restoration

Extensive research efforts, such as those undertaken by NOAA, EPA, and other federal agencies following the EXXON VALDEZ and Persian Gulf spills, are contributing greatly to the knowledge and understanding of the fate and effects of oil, different cleanup techniques, and longer-term ecosystem injury and recovery. However, follow-up studies are not conducted at most spills to evaluate the effectiveness of cleanup in mitigating impact and facilitating recovery. Monitoring of future spills must be conducted on a more routine basis in order to develop and refine cleanup protocols that maximize benefits to the environment. Additionally, future R&D must be directed at developing and testing viable and cost-effective ecosystem restoration techniques. Restoration activities are required by OPA 90, but technology and the scientific understanding to support this is minimal due to present funding constraints.

B. Assessment of Technology Advancement Potential

Since the rash of accidents that led to the passage of OPA 90, much of the research and technology development effort has been devoted to response, specifically response planning and management, countermeasures, and cleanup. This development was brought about in part by the public's attention being focused on the issue of oil spills primarily during the highly visible response phase. Much less attention has been given to prevention technologies which can also have a significant impact on the frequency and severity of oil spills. In developing a balanced oil spill research and technology plan, it is necessary to consider the relative role and significance of all technology areas.

Table 11 lists promising oil pollution technology areas identified by the Committee and other interested members of the oil pollution community, and makes a qualitative assessment (high, moderate, or low) of the relative impact of each. These assessments are based on the Committee's evaluation of the previously presented spill data, with a focus on the volume of oil spilled at different stages in the oil production and transportation system and the mode of transport. The Committee also considered response technologies that in their view had a significant impact at recent major spills, or could have had a greater impact if they had been more developed at the time. Detailed descriptions of each technology area is found in Appendix A.

Table 11. Oil Pollution Technologies and Their Advancement Potential

Technology Area	Recommended Research	Rationale	Anticipated Technology Advance	Potential Impact
Spill Prevention				
Human Factors	Develop crew training protocols and systems, focusing on "team" vs. individual performance. Test alternative work schedules to address impacts of fatigue and sleep loss. Develop training technologies for automated vessels. Develop instrumentation for real-time testing of fitness for duty.	Conservatively, 60-80% of marine casualties result from "human errors" occurring somewhere in the causal event chain. Anything that can be done from a training, operational, or managerial standpoint to reduce these errors will prevent spills and negate the need for response and restoration.	Improved and more readily available ship simulators and training programs that build teamwork. Work routines and manning schedules that minimize effects of fatigue. Clearer understanding of the role increased automation and reduced crew complements have on safety. Real-time testing could identify alertness problems before accidents occur.	High
Offshore Facility and Pipeline Design, Inspection, Monitoring, and Spill Prevention	Develop enhanced inspection, repair, leak detection, and well control technologies. Develop improved pipeline inspection, monitoring, and control technologies, ie. "smart pigs". Investigate ice hazards associated with operations in Arctic environment.	New domestic offshore oil/gas development is occurring in much deeper waters that requires new technologies. 98% of OCS related spills greater than 50 barrels are from pipelines. While most are from external damage, pipeline system is aging. The Arctic is being looked at to provide more domestic oil. The technical challenges posed by operating there, and in deep Arctic waters must be examined.	Improved capabilities to monitor and assess potential problem areas, particularly pipelines, and prevent spills.	High

Technology Area	Recommended Research	Rationale	Anticipated Technology Advance	Potential Impact
Onshore Facility and Pipeline Design, Inspection, Monitoring, and Spill Prevention	Develop improved leak detection and inspection technologies, ie. "smart pigs," acoustic examinations. (Work in concert with similar efforts in offshore applications)	Fixed facilities account for over 60% of oil spilled from inland sources with 50% due to equipment failure. 25% of oil spilled from inland sources is from pipelines. Undetected leakage from pipelines and storage tanks poses significant risks to drinking water, wetlands, and waterways.	Improved capabilities to monitor and assess potential problem areas, particularly pipelines and storage tanks, and prevent spills.	High
Navigation and Waterways Management	Integration of shipboard expert piloting systems (SEPS) and electronic chart display and information systems (ECDIS) Develop advanced automated dependent surveillance systems (ADS)	35% of spilled oil results from accidents while a vessel is underway, transporting, or moving in a congested waterway. 40% of major spills (1978-1992) resulted from grounding or collision. Improving the quality and availability of navigational information, as well as the ability to monitor vessel movements, can lower the risks of these accidents.	Improved vessel traffic systems at relatively low cost. Sensor and alarm systems to warn bridge personnel of potential danger and suggest corrective actions. Waterways risk assessment tools. Improved navigation tools integrated with ship onboard systems.	Moderate
Vessel Design	Develop advanced models for evaluating tanker design. Test and evaluate alternatives to double hulls.	40% of major spills (1978-1992) resulted from grounding or collision. Improving a vessel's ability to resist damage in these situations would minimize oil spillage. Much of the world tanker fleet needs replacing before 2015. New designs must be evaluated from a spill prevention standpoint. IMO accepts double hull alternatives. This issue remains open and alternatives should be evaluated.	Advanced models for evaluating a tanker and barge design's ability to resist damage in grounding or collision.	Moderate

Technology Area	Recommended Research	Rationale	Anticipated Technology Advance	Potential Impact
Spill Response Planning, Training, and Management				
Decision Support Systems for Contingency Planning and Response	Further development of "first generation" systems to incorporate expert systems and evolving artificial intelligence technologies.	Lessons learned from past spill responses provide valuable insights for planning and responding to new spills. These tools improve response efficiency, limiting impact and costs. Maintains knowledge base despite turnovers in command/control and response personnel.	Improved and accelerated decision making with a more comprehensive operations management system.	High
Spill Trajectory and Behavior Prediction	Link existing models with real-time data. Develop data input and verification protocols.	This information provides the framework for oil spill planning and response activities.	Improved models' predictive capabilities, risk assessment potential, and, thereby, effectiveness of response operations.	High
Training and Readiness Evaluation	Develop, test, and evaluate a "Spills of National Significance" (SONS) simulator.	OPA 90 mandates an ongoing evaluation of the nation's preparedness for response. Simulator technology permits a more realistic assessment of readiness and allows responders to hone their skills without spilling oil.	A simulator capable of testing spill response preparedness for a large geographic area, involving numerous agencies and organizations.	Moderate
Personnel Health and Safety	Perform toxicity studies of crude oils and hydrocarbons. Develop health and safety protocols and an associated database.	Federal On Scene Coordinators and private responders are responsible for safeguarding the immediate and long-term health of cleanup personnel.	Standardized site safety assessments, plans, and monitoring procedures.	Low

Technology Area	Recommended Research	Rationale	Anticipated Technology Advance	Potential Impact
Spill Countermeasures and Cleanup				
Dispersants	Field testing and evaluation of dispersants.	Dispersants can be very important in specific scenarios to protect sensitive resources. While not routinely used in the U.S, dispersants are being incorporated in many regional contingency plans. There is wider acceptance in Europe. Impact could be high if fate and effects for pre-approval and public awareness increases.	Refinement of dispersant application procedures and parameters for usage. Compilation of operational and technical data on dispersants.	High
In situ Burning	Improve fire boom design and materials, develop test protocols and test. Develop soot reduction techniques and simplified air plume models. Develop health and safety protocols and monitoring instrumentation.	Very promising technology for quick and efficient removal of large amounts of oil from water surface in offshore spills. Has coastal and inland applications as well. Technology is operational, included in many area contingency plans, and needs refinements to reach full potential.	More durable fire booms capable of operating in rough seas. Protocols for use and monitoring.	High
Oil Spill Surveillance	Develop sensor integration and data analysis techniques. Refine frequency scanning radiometer. Further development and testing of laser fluorosensor.	Development and integration of these tools can improve the efficiency of spill response by locating oil slicks, determining concentrations and properties, and tracking movements.	Integrated suite of sensors and analytical techniques to support spill response operations.	High

Technology Area	Recommended Research	Rationale	Anticipated Technology Advance	Potential Impact
Shoreline Countermeasures and Cleanup	Develop protocols and effectiveness database for shoreline cleanup techniques. Refine techniques for removal of subsurface oil.	The shoreline impacts of oil spills are often the most damaging, costly, and long-lasting. Removal techniques for subsurface oil are labor intensive, destructive to the environment, and often ineffective. Past research by government and industry should be built upon to refine techniques in this area and expand the knowledge base.	Clearer understanding of available cleanup techniques and their relative effectiveness, and the dissemination of this information. Techniques to remove or mitigate subsurface oil.	High
Oily / Oiled Waste Disposal	Develop criteria and guidelines for land farming of waste. Develop mobile incinerators.	Landfilling of oily wastes is becoming more difficult and expensive due to hazardous waste regulations. Waste from spills in remote areas pose significant logistical problems.	Wider array of options for disposing of oily waste through physical, biological, and chemical means.	Moderate
On-Water Containment and Recovery	Develop high seas and current booms and skimmers. Improve oil/water separators. Develop techniques for recovery of submerged oils and orimulsions.	Research in these areas indicates that significant improvements are feasible. The potential future importation of orimulsions as an energy source calls for preliminary research into response techniques. Advances here will lead to higher percentages of recovered oil.	Booms and skimmers capable of working in high seas and fast currents (up to 3 knots). Ability to respond effectively to sinking oils and orimulsions.	Moderate
Alternative On-Water Countermeasures	Field testing and evaluation of emulsion treating agents.	Oil emulsions significantly reduce the effectiveness of mechanical recovery, *in situ* burning, and dispersant applications.	Establishment of a testing and evaluation program for emulsion treating agents.	Low

Technology Area	Recommended Research	Rationale	Anticipated Technology Advance	Potential Impact
At-Source Containment and Countermeasures	Develop and test passive onboard countermeasures.	Minimizing the discharge of oil from a damaged vessel prior to arrival of outside response equipment will reduce cleanup cost and environmental damage. Prior studies have ruled out active measures due to manning, logistics, and safety concerns.	Operationally and economically viable passive response systems that can be integrated into vessel design.	Low
Vessel Damage Assessment and Salvage	Refine remotely operated vehicles (ROV) for underwater assessment of hull damage.	Initial study by Coast Guard indicates feasibility of a “hull crawling” vehicle. Primary application in adverse weather or other hazardous situations.	Functional prototype ROV for salvage assessment when divers or other tools are not practical.	Low
Fate, Transport and Effects, Monitoring and Restoration				
Restoration Methods and Technologies	Develop restoration indicators and measures of effectiveness. Develop restoration techniques, protocols, and an associated database. Establish “spill of opportunity” and laboratory research programs.	OPA 90 mandates restoration activities but current technology is primitive. Techniques are needed to address the wide range of shoreline types and conditions, as well as wetland areas.	Development of actual restoration methods and defining indicators of habitat impact and recovery.	High
Spill Impacts and Ecosystem Recovery	Establish monitoring protocols and procedures. Conduct laboratory and mesoscale studies of impact and recovery from different oil types. Establish integrated database of spill impact and recovery.	Long-term monitoring is essential for understanding the effectiveness of countermeasures and cleanup techniques, and assessing natural resource damage. Ecosystem impact and recovery may evolve over many years.	A coordinated and comprehensive long-term oil pollution effects monitoring program. Cost effective and environmentally sound cleanup measures tailored to environment, oil type, and incident conditions.	High

Technology Area	Recommended Research	Rationale	Anticipated Technology Advance	Potential Impact
Basic Fate and Transport	Determine behavior and transport, of subsurface oil. Refine understanding of transport/ behavior of subsurface oil.	Spills of low API gravity oils (LAPIO), Group V fuel oils, and orimulsions present unique problems. Behavior of subsurface oil must be understood to develop effective response plans and countermeasures.	Integration of information about LAPIOs and orimulsions into response plans. Operational methods to remove subsurface oil with acceptable environmental impact.	Moderate

3. Research and Technology Priorities

Recent government and industry data show that the volume of oil spilled in United States waters continues to remain far below that of the 1980s. Coast Guard figures indicate that the volume of oil spilled from maritime sources has dropped by approximately 77% since 1990, to an annual average of 1.4 million gallons for the 5 years . This is attributed primarily to the absence of any massive tankship spills since the Mega Borg in 1990. While this trend is encouraging, oil pollution is still a problem and must be addressed. The potential catastrophic damage that can result from a single major tankship or pipeline spill alone warrants continued investment in oil pollution R&D.

The Committee has identified many of the oil pollution technology gaps by examining the oil production and transportation system and the various factors which lead to and result from oil spills. While the technologies listed in Appendix A all constitute valid R&D, foreseeable budgetary constraints dictate that the areas be prioritized. Historically, a large percentage of available resources was used in the spill response category. The Committee agrees with the prevailing opinion that preventing spills is preferable to responding to them and that more resources should be shifted into the spill prevention area. Since it is unlikely that spills will ever be eliminated, preparedness, response, and restoration remain important research areas as advancements can minimize the impacts of spilled oil. Because this plan serves as a strategic planning document, the R&D requirements are identified at the program level. Project determinations will be made by the various program managers after the plan is approved and resource levels allocated.

In making this prioritization the Committee looked at the status of technologies to see which are either available now or should be available within five years if ongoing R&D is completed. These areas are grouped by a subjective estimate of their potential for either reducing the amount of oil spilled or its environmental impact over the next 5-10 years. (Level 1 represents the highest priority and Level 3 the lowest.) While the consensus of researcher opinions presented and discussed at the Second International R&D Forum in May,1995 were considered, the following priorities represent the views of the Committee.

Level 1 Priority:

- Human Factors;
- Offshore Facility and Pipeline Design, Inspection, Monitoring, and Spill Prevention;
- Onshore Facility and Pipeline Design, Inspection, Monitoring, and Spill Prevention;
- Decision Support Systems for Contingency Planning and Response;
- Spill Trajectory and Behavior Prediction;
- Dispersants;
- *In situ* Burning;
- Oil Spill Surveillance;

- Shoreline Countermeasures and Cleanup;
- Restoration Methods and Technologies; and
- Spill Impacts and Ecosystem Recovery.

Level 2 Priority:

- Navigation and Waterways Management;
- Vessel Design;
- Training and Readiness Evaluation;
- Oily / Oiled Waste Disposal;
- On-Water Containment and Recovery; and
- Basic Fate and Transport.

Level 3 Priority

- Personnel Health and Safety;
- Alternative On-Water Countermeasures;
- At-Source Containment and Countermeasures; and
- Vessel Damage Assessment and Salvage.

While pursuing R & D in these specific technology areas, there is a need to address several general issues, which will aid in achieving the desired advances in oil spill research and acting on the recommendations of the National Research Council's Marine Board. To carry out the program of field testing that the Marine Board determined to be a vital component of the federal plan, work must continue to develop streamlined permitting procedures and protocols for carrying out experimental oil spills in the environment and capitalizing on spills of opportunity. To bridge the gap from laboratory testing to full-scale field testing and use, mesoscale testing of spill response equipment is critical. The National Oil Spill Response Test Facility provides the research and response communities with unique capabilities in this regard and the Committee supports the facility's continued operation and maintenance by the MMS.

Another recommendation of the Marine Board dealt with public perception of and participation in the decision-making process. One method of addressing this is to recognize the importance of universities and non-profit institutions in finding solutions to oil spill problems, and to encourage the creation of regional centers of expertise. Federal cooperation with various stakeholders should continue with the aim of leveraging both knowledge and resources.

Finally, a great deal of work remains to analyze and model the oil spill system. Success in this area would result in an improved understanding of events leading to oil spills and what actions can be taken to minimize their occurrence. Improving the quality of oil spill data available for building this model, conducting risk analyses, and developing pollution prevention policies, remains a topic for continued interagency action.

Appendix A. Assessments and Forecasts for Oil Pollution Technology Areas

SPILL PREVENTION

Human Factors

Description of Technology: This technology area focuses on how human performance and human factors contribute to marine casualties and other accidents in the oil production/transportation system. It includes the development of advanced methods and systems for training vessel crew members, basic research on vessel crew performance in preventing oil spills (as through safe navigation and proper oil transfer practices), and the development of methods and technologies to evaluate crew members' ability and knowledge in performing their duties.

Importance: Conservatively, between 60 and 80 percent of accidents in marine transportation and related industries are attributed to “human errors”. These errors can result from inadequate training, poor management, poor equipment maintenance, and problems in the interface between man and machine. Identifying and solving various human factors problems can significantly reduce oil spills at far less cost than more expensive technology-based solutions. *Potential impact is **high**.*

Current Development Status: Several research projects are being undertaken by the Coast Guard in the human factors area. The first project focuses on the impact of merchant marine operations and associated fatigue on crew performance. This involves collecting and analyzing data on merchant marine operations (length of tour, work schedule, and number of port stops and manning levels), and identifying practices which may predispose crew members to casualties. A second project looks at the impact of automation on crew performance. Efforts include measuring the mariner's understanding of automated equipment, and improving training to reduce the potential for error. A third project is investigating the impact of crew size on vessel safety. This includes development of models for simulating shipboard operations and estimating safe crew size.

Research is also underway to determine the human factors issues associated with Advanced Navigation and Waterways Management technologies, including Electronic Chart Display Information Systems (ECDIS) and Vessel Traffic Services (VTSs). A separate project is being conducted by the University of Miami under the OPA 90 Regional Grants Program to investigate the "human factors" contribution to oil transfers involving tank barges.

In addition, MARAD is undertaking cooperative research programs with industry to identify and address short-term and long-term research needs in human factors and vessel automation. These programs include the Ship Operations Cooperative Program (SOCA), which focuses on bridge layout and tasking, and the Vessel Pilots Cooperative Program, which is evaluating the use of a portable DGPS system in piloting operations. MARAD is also sponsoring a cooperative research program with the State and Federal maritime academies. Specific projects include development of a marine human factors bibliography, examination of the institutional awareness of regulatory changes, identification of operational trends into the 21st century, and a comparison of job training effectiveness and job satisfaction between male and female students. A Marine Board study is also underway on human performance, organizational systems, and maritime safety.

The Minerals Management Service has also initiated a joint industry project to consider human factors in oil well control. In addition they are sponsoring an international workshop titled “The Use of Human and Organizational Factors in the Management of Safety and Environmental Hazards for Offshore Operations” in December 1996.

Technology Advance Envisioned: The impact of vessel automation and reduced manning on crew performance and vessel safety will cause a significant change in the knowledge, skills, and abilities required of mariners. As a result, additional research is necessary to determine the training requirements for crew members operating in this automated environment. Training methods and technologies (such as ship simulators) must be assessed to determine their utility in providing training. Training programs that focus on shipboard “team” performance vs. individual mariner performance should be investigated. Development of operational instrumentation and protocols for real-time fitness-for-duty testing could supplement the training efforts as crew fatigue and alertness are certain to be primary factors in safe operations.

Required Research Focus Areas:

- Training technologies for automated vessels
- The impact of automation on alertness
- Impacts of fatigue, sleep loss, and shift scheduling
- Instrumentation for real-time crew performance testing
- Team performance in shipboard situations
- Maritime organizational culture and its impact on crew performance

References:

- Sanquist, T. F., et al., 1995.
- Rothblum, A. M., et al., 1995.

Offshore Facility and Pipeline Design, Inspection, Monitoring, and Spill Prevention

Description of Technology: This technology area includes the development of offshore platform and pipeline designs, techniques and equipment for facility inspection, and systems to detect and mitigate oil discharges. Pipeline research includes designs and technologies to prevent and detect failures, as well as monitor/control systems that minimize spillage when failure occur.

Importance: Offshore oil and gas facilities are responsible for 15% of oil production and 25% of natural gas production in the U.S. Important new discoveries continue to be made in increasingly deeper waters, creating new technical challenges. Associated with this is the continued aging of the existing offshore infrastructure of facilities and pipelines. Pipeline spills result from internal damage (i.e. chemical/mechanical corrosion) and external damage (i.e. electrochemical corrosion, mechanical damage, and structural failures of the pipeline system). Advanced system designs and the effective application of improved inspection technology have the potential to detect potential failures before they occur, while improved leak detection systems have the ability to identify leaks while they are still small. *Potential impact is **high**.*

Current Development Status: The Minerals Management Service research program in this area includes projects on:

- Structural integrity of aging structures and pipelines;
- Risk-based management of offshore pipeline systems;
- Corrosion of offshore pipelines;
- Well control;
- Human factors considerations for offshore facility operations; and
- Securing Mobile Offshore Drilling Units (MODUs) in storms

MMS also sponsored a workshop on damage to offshore pipelines, and supported the Marine Board study on Offshore Pipeline Safety.

The Office of Pipeline Safety is conducting research on mechanical failures of pipelines. Automated inspection probes which travel through the pipeline (called "smart pigs") have been developed to detect corrosion and measure pipeline wall thickness.

The EPA's National Risk Management Research Laboratory is participating in the Strategic Environmental Research and Development Project (SERDP) by constructing a full-scale test facility with pipelines up to twelve inches in diameter in order to investigate and improve acoustic methods for leak detection and location in pipelines. A related project involves the full-scale assessment of the effectiveness of long-term use of corrosion prevention technology

Technology Advance Envisioned: Additional projects planned by MMS include the development of improved systems for inspecting and monitoring aging shallow water platforms and pipeline systems, and development of advanced systems to address deep water operations.

No proven technology exists to detect the stress corrosion cracking which has led to past pipeline failures. Existing "smart pigs" can detect general corrosion, but not longitudinal stress corrosion flaws. A "smart pig" capable of detecting these flaws needs developing.

Required Research Focus Areas:

- Deep water, automated inspection and repair systems
- The role of hydrates in deep water failures
- Inspection techniques for flexible risers
- Improved leak detection systems for offshore pipelines
- The risk of ice-gouging in Arctic areas
- Well control technologies for deep water operations
- Inspection techniques for aging pipeline systems
- Stress corrosion cracking detection

References:

- Personal communication with Charles Smith, Minerals Management Service. September 15, 1995.
- Personal communication with Lloyd Ulrich, OPS. September 12, 1995.
- Science Advisory Board, 1994.

Onshore Facility and Pipeline Design, Inspection, Monitoring, and Spill Prevention

Description of Technology: This technology area includes the development of onshore facility and pipeline designs, techniques and equipment for facility inspections, and systems to detect and mitigate oil discharges. Pipeline research includes designs and technologies to prevent and detect failures, as well as monitor/control systems that minimize spillage when failure occur.

Importance: A significant number of discharges occur from onshore facilities in the coastal area. Approximately 20% of the volume of oil discharged is due to bunkering and cargo transfer. Storage tank leakage and failures add to this volume. An even greater portion of spills occur at facilities located further inland.

Storage tank and facility pipeline failures have resulted in major inland spills. Advanced system designs and the effective application of improved inspection technology have the potential to detect potential failures before they occur, while improved leak detection systems have the ability to identify leaks while they are still small. *Potential impact is **high***.

Current Development Status: Aside from pipeline research, only limited work has been done in this area since the passage of OPA 90. A small, Coast Guard-sponsored project is in progress at the University of Miami to look at the “human element” in oil transfers.

The Office of Pipeline Safety is conducting research on mechanical failures of pipelines. Automated inspection probes which travel through the pipeline (called "smart pigs") have been developed to detect corrosion and measure pipeline wall thickness.

The EPA’s National Risk Management Laboratory is participating in the Strategic Environmental Research and Development Project (SERDP) by constructing a full-scale test facility with pipelines up to twelve inches in diameter in order to investigate and improve acoustic methods for leak detection and location in pipelines. A related project involves the full-scale assessment of the effectiveness of long-term use of corrosion prevention technology

Technology Advance Envisioned: Develop advanced systems for facility monitoring and spill detection. Continue human factors R&D to determine the role of human error in facility spills, and procedures and technologies for prevention.

No proven technology exists to detect the stress corrosion cracking which has led to past pipeline failures. Existing “smart pigs” can detect general corrosion, but not longitudinal stress corrosion flaws. A “smart pig” capable of detecting these flaws needs developing

Acoustic technologies can be refined to inspect pipelines effectively without passing a “pig” through the pipeline or excavating the pipe. This technology may be extendible to the detection and location of leaks in oil handling facility storage tanks.

Required Research Focus Areas:

- Facility monitoring and spill detection systems
- Stress corrosion cracking detection
- Acoustic leak detection and location

References:

- Personal communication with Lloyd Ulrich, OPS. September 12, 1995.
- Science Advisory Board, 1994.

Navigation and Waterways Management Systems

Description of Technology: This technology area includes methods, equipment, and integrated systems designed to improve navigation at sea and in ports, rivers, and inland waterways. It includes both navigation systems on-board the vessel, such as bridge expert systems and collision avoidance systems, and systems external to the vessel, such as vessel traffic systems and piloting systems. It also includes general research into navigation risks and the impact of navigation safety programs, as well as the development of decision support tools for waterways management efforts.

Importance: Most major spills from vessels are caused by a navigation-related marine casualty such as a collision or grounding. Improving navigation and waterways management, particularly in congested port areas and the approaches to ports, can prevent many of these accidents. *Potential impact is* ***moderate***.

Current Development Status: Substantial progress has been made in this area since OPA 90 through refinements in the Global Positioning System (GPS) and the development of Electronic Chart Display and Information Systems (ECDIS). GPS provides worldwide satellite positioning to an accuracy of 100 meters, and has been refined by the Coast Guard through the Differential GPS project to provide accuracy to within 10 meters. ECDIS provides the capability for continuously updating and displaying vessel position and other navigation information on an electronic chart. These two technologies can be integrated through use of Automated Dependent Surveillance to provide electronic chart navigation on the bridge, and a reliable, low-cost VTS in ports. Such an ADS/VTS was implemented and tested in Narragansett Bay as mandated by OPA 90. Other advances include using GPS and ECDIS for high-accuracy positioning of aids-to-navigation.

Advances in artificial intelligence and expert systems have led to the development of Shipboard Piloting Expert Systems (SPES) to assist mariners on the bridge in planning and conducting safe navigation, particularly in congested areas. These systems include a series of alerts to inform the mariner of situations of potential concern and upcoming decision points, as well as alarms to warn of imminent danger. This research began in 1989 and was conducted by MARAD and the Coast Guard in cooperation with industry. Follow-on research is being conducted under the OPA 90 Regional Grants Program through a project to design, develop, and evaluate a SPES on the St. Lawrence Seaway for both shipboard and VTS installation. Additional research (under the Smart Bridge project) is also underway with support from the ARPA MariTech program. This project incorporates sophisticated sensor fusion and real-time knowledge-base and database management capabilities, leveraged with significant combat and sensor system developments, for the development of an advanced SPES for San Francisco Bay.

In the area of waterways management, an effort has been initiated to develop a waterways management evaluation DSS to support risk assessment and resource allocation functions. The development of a ship transit model and waterways evaluation tools have already begun.

Technology Advance Envisioned: The development of risk assessment models and tools must be continued. The next significant technology advance in this area will be the development and testing of an integrated SPES and ECDIS system, incorporating advanced sensor fusion input and integration capabilities. These SPES can be integrated with both shipboard and vessel traffic systems to produce intelligent information sharing and decision-making. Further VTS efforts include development and testing of Automated Dependent Surveillance Systems (ADSS) for waterways management.

Required Research Focus Areas:

- Development of advanced SPES, including sensor fusion and integration
- Integration of SPES with VTS
- Advanced Automated Dependent Surveillance Systems
- Comprehensive Waterways Management DSS
- Human factors component of SPES, ECDIS, and ADSS

Vessel Design

Description of Technology: This technology area includes the development and testing of advanced tanker and barge designs to make vessels more resistant to damage and less likely to spill their cargoes into the sea.

Importance: Although single hull tankers and barges are highly susceptible to damage from collisions and groundings, tanker designs are currently available which can significantly reduce the outflow of oil. For example, the double-hull tanker design is being required for vessels entering U.S. ports under OPA 90, while the IMO has accepted both the double-hull and mid-deck tanker design. Additional research and development is needed to verify these approaches and investigate other measures to reduce tanker and barge damage. *Potential impact is **moderate**.*

Current Development Status: The Coast Guard completed an extensive study of tanker design alternatives as mandated by OPA 90. This included the National Academy of Science study and an independent evaluation by Herbert Engineering Corporation. These two studies form the basis of the USCG double-hull policy under OPA 90. Follow-on research is proceeding at Massachusetts Institute of Technology, which includes the development of an advanced computer model to predict damage to tankers, and a "Handbook of the Grounding Protection of Ships," which addresses both Structural Analysis and Welding. Research is also underway at the David Taylor Naval Ship Research and Development Center involving model testing of tanker designs in grounding situations. Finally, efforts are also proceeding to test the "American Underpressure System" which is designed to provide a spill reduction capability for single hulled vessels.

Technology Advance Envisioned: The development of advanced models for predicting tanker and barge damage, and evaluating alternative designs. Continued testing of alternative designs will also be maintained as they are introduced.

Required Research Focus Areas:

- Advanced model development
- Testing and evaluation of underpressure system

References:

- Husain, M., 1995.
- Herbert Engineering Corp., 1992.
- National Research Council, 1991

SPILL RESPONSE PLANNING, TRAINING, AND MANAGEMENT

Decision Support Systems for Contingency Planning and Response

Description of Technology: This technology area involves the development of computer-based systems which would provide information more rapidly and facilitate decision-making during contingency planning and response. Development generally includes the development and integration of databases, models, geographic information, mapping systems, and expert systems tailored to oil spill response needs.

Importance: Acquiring the necessary information to make correct decisions, and keeping track of the results of these decisions is a significant challenge for responders during a major spill event. Accurate and accessible technical and operations management information must be provided in the proper sequence and format to facilitate the process. Decision Support Systems (DSSs) can provide this information to support both contingency planning and response activities. In addition, DSSs provide continuity in the overall "knowledge base" of the spill response community. This offsets problems associated with the influx of new people into this area, and the high turnover of personnel. *Potential impact is **high**.*

Current Development Status: Significant advances have been made in the past five years, including the development of specific databases containing information on response resources and capabilities, models to predict spill trajectory and behavior, guidance to evaluate countermeasures and cleanup options, and geographical information systems (GIS) and other mapping systems for interpretation and display of shoreline environmental data, sensitivity, the location of response resources, and appropriate deployment points. These components have been integrated into several complete DSS for use during contingency planning and response. USCG and NOAA have jointly developed the Spill Planning, Exercise and Response System (SPEARS), an integrated system of models, databases, and maps. The Coast Guard is evaluating functional characteristics of the Multi-Agency Response - Tactical Action Display System (MARTADS) for command post display of spill management information. These first-generation systems are being implemented by government agencies and industry, and are undergoing testing and refinement to improve operational support.

Technology Advance Envisioned: DSSs represent a powerful tool in improving oil spill response management. The next level in the development process is improving and expanding the databases and models to support the full range of contingency planning and response functions, and integrating these components using advanced expert systems and artificial intelligence technologies. The goal is to have a system that can evaluate the queries of the user, retrieve the most relevant information, and present the information in a sequence and format that enhances and accelerates decision-making, but does not mislead the user into false conclusions. In the longer term, such systems will automatically update their knowledge base through feedback on actual events, improving their utility over time and providing better data for use in simulator based training programs.

Required Research Focus Areas:
- Advanced DSS development
- Integration of DSSs into training programs
- Advanced user interface and presentation

References:
- Howlett, E., et al., 1995.

Spill Trajectory and Behavior Prediction

Description of Technology: This technology area involves the development and verification of numerical models to predict the movement of oil spills, the "weathering" (spreading, evaporation, dispersion, dissolution, and sinking) of spilled oil, and the resulting changes in the physical properties of the oil in different environments. It includes methodologies to provide accurate input data and verify model output.

Importance: Predicting the trajectory (movement) and the weathering of spilled oil, and its resultant physical properties, is critical to the mobilization and deployment of appropriate and adequate spill countermeasures. It is also important for developing risk assessments and contingency plans for spill response, and for evaluating potential environmental damage. *Potential impact is **high**.*

Current Development Status: Oil spill trajectory models are highly advanced and capable of accurately predicting spill movement under a variety of conditions. Several fully tested and verified models are in use within government, academia, and the commercial sector to cover ocean, coastal, estuarine, and river applications. However, these are generally limited by the quantity and quality of local meteorological and oceanographic input data. Another problem is the lack of real-time data on spill size and movement (as provided by observations and remote sensing) for validating and fine tuning the models.

Many models are available for predicting oil spill behavior and physical properties. Significant advances have been made in the past five years in refining these models, and verifying the results against oil spill behavior and physical properties data observed in the laboratory and the field. In addition, trajectory and behavior models have been combined into composite models which predict and graphically display spill movement and status. These are readily available from government and commercial sources.

Technology Advance Envisioned: Trajectory models themselves represent a fully-developed technology with only incremental refinements necessary at this time. The next significant technology advance in this area will be linking these models with sources of real-time input data (e.g. meteorological and coastal oceanographic monitoring stations, and airborne and satellite remote sensing systems), and verifying data for the output of the models. Although models have been linked with specific data sources in the past, no development program exists to establish a fully integrated modeling and observation capability with established input and verification protocols. Protocols were recently published by NOAA for model output.

Behavior models are also highly developed for common oils and open ocean environments, but must be linked to a comprehensive database containing input parameters and comparison data derived from laboratory studies, field studies in specific geographical areas, and past spill experience. Models should also be able to accept data on measured oil properties during the spill to verify results and adjust key parameters. The only areas where fundamental research and model development are required is in predicting the transport and sinking of heavier oil products (Low API Specific Gravity Oils - LAPIO) and shoreline transport and behavior for different beach types..

Required Research Focus Areas:

- Trajectory model input and verification
- Behavior model/database integration
- Model development for heavy oils
- Regionalize models by developing region specific parameters and input data

References:

- Galt, J. A., 1995.
- Spaulding, M., 1995.
- Michel, J., et al., 1995.

Training and Readiness Evaluation

Description of Technology: This technology area focuses on the development of oil spill simulators and computer-assisted tools to train personnel in oil spill response, and evaluate their knowledge and decision-making skills in a simulator setting, and during field exercises under the U.S. Coast Guard's Preparedness for Response Exercise Program (PREP).

Importance: Effective response requires that personnel be well-versed in the management doctrine and technical issues surrounding oil spill response. It also requires that personnel be able to translate this knowledge into effective decision-making during the spill, and be able to interact with other spill response participants. As major spills are infrequent events, it is difficult to maintain and verify this proficiency over time. Maintaining and evaluating this proficiency is a mandate of OPA 90 and the National Contingency Plan. Simulators and other technology based training and evaluation tools provide a cost-effective means of building, maintaining and evaluating this knowledge and proficiency. *Potential impact is* ***moderate.***

Current Status: The past five years have seen the rapid development, testing and operational implementation of oil spill response training simulators in key regional locations. This technology advance was enabled by previous development of computer-assisted training simulators for other missions (e.g. aviation, vessel navigation). With funding support from the U.S. Coast Guard, simulator development is proceeding at Massachusetts Maritime Academy, Texas A&M University, and New York Maritime Academy at Fort Schuyler. These simulators focus on developing tactical command and control decision-making during large spills. In addition, the Coast Guard is developing the methodology and technology to support the "annual response area management team exercises" under the PREP. To date, two systems are in various stages of development - the Multi-Agency Advanced Team-Building Enhancement System (MATES) and the Pollution Incident Simulation, Control and Evaluation System (PISCES). Research is underway to determine if the regional simulators can be adapted for readiness evaluation activities under the PREP. This should reduce the need for full-scale field exercises, and greatly decrease the cost of the PREP.

Technology Advance Envisioned: Simulator-based training and readiness evaluation programs have focused on command and control decision-making for major spills in a specific port area. The scenarios involve executing the response activities outlined in the Area Contingency Plans. There is a need to develop a training and evaluation program that will improve and evaluate readiness for Spills of National Significance (SONS) which can cover large geographic areas and involve numerous agencies and organizations. The next step is development of a SONS Command Post simulator, which exercises strategic decision-making at a higher level. The development process will include implementation and testing at the regional maritime academies currently providing simulator-based training.

Required Research Focus Areas:

- Develop, test and evaluate a SONS Simulator

References:

- Barry, D., et al., 1995.

Personnel Health and Safety

Description of Technology: This technology area includes studies on the effects of spilled oil and oil spill cleanup on personnel health and safety, and the development of monitoring instruments and protective equipment to protect personnel engaged in cleanup operations.

Importance: Oil is a hazardous substance. Hazards in dealing with crude oil include fire and explosion, vapor toxicity, and danger from dermal exposure. In particular, benzene vapors present a major concern. Certain cleanup techniques such as dispersant application, in situ burning, and bioremediation also present hazards. These hazards are added to the inherent dangers of carrying out operations at sea. It is a fundamental responsibility of the On-Scene Coordinator and other response supervisors to safeguard the health and safety of cleanup personnel. To date, there have been no long-term epidemiological studies that can provide comprehensive guidance for worker health and safety under a range of spill conditions. *Potential impact is **low**.*

Current Development Status: The topic of worker health and safety was addressed in a workshop organized by MSRC in January of 1993. The Coast Guard also conducted a study entitled "Condensed USCG Oil Spill Response Health and Safety Plans, which identified health and safety issues associated with oil spill response in order to develop information and protocols for use by response personnel. From these reports five priority topics for additional research were identified. These included:

- Procedures for spill site assessment and characterization
- Current field instruments for monitoring benzene
- Chemical composition of fresh and weathered crude oils
- Guidelines for decontamination and dermal exposure assessments
- Sponsor and support an industrial hygiene panel for spill response.

Another MSRC study reviewed the current literature and developed research needs focusing on the implications of crude oil exposure. In addition, ongoing research since OPA 90 has examined the levels of benzene encountered during spill cleanup and analyzed the health and safety implications of exposure.

Technology Advance Envisioned: Additional research is needed on the inhalation and dermal exposure hazards of crude oils, hydrocarbon mixtures, and hydrocarbon aerosols. Site safety assessment procedures and monitoring protocols should be standardized, and the necessary monitoring instrumentation specified, with additional application-specific instrumentation developed as needed. Protective clothing and equipment adequacy should also be assessed to determine additional technology needs. Finally, information on toxicity, site safety assessment procedures, monitoring protocols and instrumentation, and personal protection should be compiled into a comprehensive database for access during spill response.

Required Research Focus Areas:
- Toxicity of crude oils/hydrocarbons
- Health and safety protocols and technology
- Health and safety database

References:

- Science and Policy Associates, Inc., 1993.
- Holliday, M. G., and J. M. Park, 1993.

SPILL COUNTERMEASURES AND CLEANUP

Dispersants

Description of Technology: Dispersants are a specific type of oil spill chemical countermeasure which reduces oil/water interfacial tension so that the oil can disperse in small droplets into the water column. Development areas include increasing dispersant effectiveness, reducing the environmental effects of the chemicals themselves, developing vessel and aircraft application methodologies and equipment, and studying the distribution and impact of the chemicals and dispersed oil in the environment. An important supporting activity is the development of an information base on dispersant product effectiveness, application procedures, and effects.

Importance: Dispersants are an important tool in spill response when it is critical to prevent oil from reaching a sensitive resource (such as a coral reef, marsh area, or wildlife sanctuary). These situations justify the intentional dispersion into the water column as a tradeoff to prevent greater impact to the protected resource. Even though their use is pre-approved in various Area Contingency Plans, so much controversy surrounds dispersant use in the U.S. that they are seldom used. However, with refinements in dispersant formulations to improve their effectiveness and reduce environmental effects, and with the general acceptance of their use in other countries, dispersants remain a viable option to U.S. responders. *Potential impact is **high**.*

Current Status of Development: Since the EXXON VALDEZ spill, the development of dispersant technology has continued at a modest but steady pace. New dispersant formulations have been developed by government researchers (particularly Environment Canada with support from MMS), and industry (particularly Exxon). In addition, aircraft application procedures have been refined and field tested in a joint project between the U.S. Air Force, MSRC, and Texas General Land Office. Meanwhile, testing protocols have been refined and data recorded in the National Contingency Plan Products Schedule and a Chemical Countermeasures database developed by the Coast Guard and NOAA. A dispersants application calculator has also been developed by NOAA and USCG and integrated into the SPEARS decision support system. In summary, dispersant technology is a fully operational tool with additional research to be directed at refining the technique and gaining broader acceptance by the response community.

Technology Advance Envisioned: An ongoing program of field testing is required to refine application procedures and study the effects and effectiveness of this technology. These results will facilitate acceptance of dispersants. In addition, an ongoing program should be established to compile operational and technical data on dispersants, and update the dispersants database for use in decision support systems.

Required Research Focus Areas:

- Dispersant technology testing and evaluation
- Dispersant database update

References:

- Fingas, M., et al., 1995.
- LaBelle, R., and E. Danenberger, 1995.
- Goodman, R., 1995.

***In situ* Burning**

Description of Technology: *In situ* burn technology includes the techniques and equipment required to ignite and sustain combustion of oil spills on the water and along shorelines. It includes development of equipment, such as fire resistant booms and ignition devices, and of a knowledge base containing both the conditions under which the technique can be effectively applied, and the impact of the use of such technique on the environment, including both human health and ecological considerations.

Importance: *In situ* burning is the most promising technique for removing large amounts of oil from the surface of the water as encountered during major and catastrophic spills. It can also be an effective method of mitigating spills on land and in coastal areas. *Potential impact is **high**.*

Current Development Status: The concepts, methodologies, and basic equipment for *in situ* burning were developed prior to the EXXON VALDEZ spill. During the past six years, an extensive test and evaluation effort was undertaken by government (both U.S. and Canadian) and private industry to demonstrate the technology, and document its effectiveness and effects under operational conditions at sea. One experiment, conducted off Newfoundland in August 1993, was successful in demonstrating operational feasibility and documenting the acceptability of the associated air and water contamination. Supporting research included laboratory and mesoscale studies of the effectiveness and contamination levels as a function of oil type and thickness, the impact of oil emulsification, and the utility of smoke reducing agents. Prototype air contamination monitoring equipment was developed and tested. Several smoke plume and dispersion models have been developed. Refinements have also been made to fire-resistant boom designs, with several designs now commercially available. However, problems still remain with boom durability for multiple burns, and the sea-keeping ability of fire-resistant booms in seas greater than 3 feet.

In situ burning is also being seriously considered for oil spills on wetlands (I.A. Mendelsohn of Louisiana State University), and on dry land (EPA) under certain conditions.

Technology Advance Envisioned: *In situ* burning has reached the operational implementation stage, and is being incorporated into Area Contingency Plans. The technology has a broad range of offshore, coastal, and inland applications.

Fire-resistant booms are being developed by the commercial sector which incorporate advanced materials to improve boom durability and handling. Government efforts should focus on developing a protocol for testing these designs, and encouraging and supporting further industry efforts, specifically keeping in mind that fire-resistant booms are needed which will operate in greater sea states.

In addition to equipment development, a knowledge base must be created of the spill conditions (primarily oil physical properties) and environmental parameters (e.g., wind, wave, type of vegetation, season, downwind land use, etc.) under which the technique is viable. This knowledge base will be developed through further mesoscale testing and data collection at actual spills (both experimental spills and spills-of-opportunity).

In situ burning can present hazards to the health of personnel carrying out the operation, as well as populations downwind. Additional research is needed to fully document these hazards. Improved monitoring protocols and equipment are also needed to ensure these hazards are minimized.

Required Research Focus Areas:

- Fire-resistant boom protocol and testing
- Fire-resistant boom development
- Simplified air plume models
- *In situ* burn knowledge base
- Health and safety protocols and monitoring
- Emulsion breaking and soot suppression techniques
- Effects of burning on soils and wetlands and guidelines for use of this remediation tool

References:

- Fingas, M., et al., 1995.

Oil Spill Surveillance

Description of Technology: Oil spill surveillance includes devices, sensors, and systems for detecting and tracking oil spills, determining the area and thickness of the oil slick, and measuring the physical properties of the oil. Current efforts are focused on developing oil spill tracking buoys and airborne (aircraft mounted) remote sensors and data analysis systems, and investigating the use of satellite remote sensing data to detect and track larger spills.

Importance: Surveillance technologies are required for effective prevention and response. Prevention is promoted by enhancing the ability to detect illegal discharges of oil (as per MARPOL 73/78) and produce evidence to support litigation. Response operations are supported by the ability to locate concentrations of oil and track slick movement for countermeasures and cleanup planning. Thickness and physical properties measurement allow responders to determine the feasibility of mechanical recovery, *in situ* burning and dispersant use, and facilitate the efficient deployment of resources in conducting operations. *Potential impact is **high**.*

Current Development Status: Significant progress has been made in developing this technology in the past five years. For instance, various oil spill tracking buoy designs have been tested and evaluated, placing this technology at the operational stage with commercial units readily available.

In addition, existing airborne sensors, such as synthetic aperture radar, and infrared and ultraviolet imagers, have been refined and integrated with state-of-the-art data processing and display systems. Various low-cost, portable infrared sensors have been evaluated for aircraft use, and concept evaluation versions of the frequency scanning radiometer and laser thickness sensor have also been built. The frequency scanning radiometer has been tested to verify a thickness measuring capability, and a prototype airborne laser fluorosensor was developed and tested under simulated field conditions, and also during actual spills. The laser fluorosensor was highly successful in providing positive identification of hydrocarbons, and discriminating between hydrocarbon types. An operational scanning laser fluorosensor is currently under construction.

Studies of the utility of satellite remote sensing show promise for future application of this technology. Coverage, false positive discrimination, and resolution are still problems. However, satellite sensors and systems show promise in detecting and tracking illegal discharges, and supplementing airborne surveillance for response, especially with new satellites coming on line.

Technology Advance Envisioned: The next important development in airborne remote sensing will be the development and full-scale testing of sensors to determine oil thickness (frequency scanning radiometer or laser thickness sensor), and sensors to verify hydrocarbon presence at sea and on shorelines (scanning laser fluorosensor). This will require the integration of frequency scanning radiometer data with current infrared imagery to provide acceptable spatial resolution. The laser fluorosensor is farthest along in the development process, which is proceeding in cooperation with Environment Canada. Meanwhile, the thickness sensors are still in the first prototype phase, but represent a key advance in overall surveillance capability. Of the two thickness sensors, the frequency scanning radiometer appears to be the lower cost, more versatile option.

Required Research Focus Areas:

- Advanced sensor integration and data analysis techniques
- Laser fluorosensor refinement and testing
- Frequency scanning radiometer development

References:

- Engelhardt, F., 1995.
- Goodman, R., 1995.
- Hover, G., 1995.
- LaBelle R., and E. Danenberger, 1995

Shoreline Countermeasures and Cleanup

Description of Technology: This technology area covers methods, treating agents, and equipment for removing oil from shorelines and mitigating the environmental impact of oil that cannot be removed. Specifically, it includes water washing and flooding techniques, the use of chemical treating agents, mechanical removal, processing, and disposal of oiled material, and bioremediation.

Importance: Most major oil spills in coastal waters result in the oiling of the shoreline. This includes oiling of natural resources (e.g. beaches, marshes, coral reefs, mangroves), and man-made structures (e.g. breakwaters, seawalls, piers, and vessels). Removing or mitigating the impacts of the oil requires a range of technologies that are effective (remove/mitigate while minimizing environmental damage from the technology) and efficient (cost of the technology is reasonable). Implementing technologies also requires knowing the relative benefits of foregoing cleanup activities and allowing natural processes to remove the oil. *Potential impact is **high**.*

Current Development Status: Although few new concepts have been developed, significant progress has been made in refining the state-of-the-art since the EXXON VALDEZ spill. For instance, a new laboratory surface washing agent effectiveness screening test is under development (EPA), chemical treating agents (e.g. surfactants) have been reformulated and tested on actual spills and in the lab, bioremediation application procedures and monitoring protocols have been improved and documented, and bioremediation effectiveness has been studied extensively by government (EPA and NOAA) and industry (MSRC and EXXON), often under joint projects. In addition, several updated shoreline assessment and cleanup manuals have been developed to provide technical guidance to responders, and several research efforts have focused on the question of cleanup vs. natural recovery, providing additional insight on when shoreline cleanup should be initiated, to what extent it should be pursued, and when it should be terminated.

Technology Advance Envisioned: Technologies developed to date are generally effective in removing oil from the upper surface and near surface layers of shoreline. As experienced after the EXXON VALDEZ spill, no effective method currently exists for removing sub-surface oil, short of physical removal, followed by cleaning or disposal. Technologies should be investigated for removing and mitigating the impacts of sub-surface oil. There is also a need to examine the results of combined physical, biological, and chemical methods, and to develop protocols for more effective application.

In addition to developing new technologies, additional research is required to fully understand the effectiveness and efficiency of currently available techniques. This research should proceed in the laboratory, at facilities such as the Coastal Oil Spill Simulation System (developed by the Texas General Land Office and Texas Water Commission, the Marine Spill Response Corporation, and Texas A&M University), and in the field, through planned experiments and documentation of results at actual spills, with the results of this research documented in a comprehensive database. Research is also needed to define the mechanisms and rates for shoreline self-cleaning, particularly through the interaction of the oil with fine mineral particles.

Required Research Focus Areas:

- Detailed protocols for each clean up technique for oil removal from shorelines
- Removal of subsurface oil
- Guidelines for sequential shoreline cleanup using multiple techniques
- Mechanisms and effectiveness of shoreline self-cleaning

- Validation of new surface washing agent effectiveness test protocol

References:

- Scott, R., 1993.
- Owens, E., and B. Humphrey, 1995.
- Venosa et al., 1996.

Oily / Oiled Waste Disposal

Description of Technology: This technology area includes procedures and equipment to dispose of oil and oiled debris recovered during spill cleanup. Specific technologies include solidification and stabilization prior to landfill disposal or recycling, oil reclamation, incineration, and biological treatment (such as land farming and composting).

Importance: Disposal of oil and oiled debris can be a severe problem during major spills, particularly in remote areas. Large quantities of waste may be collected in a very short time, and the types of waste are extremely variable in physical and chemical characteristics. In addition, the waste often generates public interest and media attention. In the past, much of this waste was disposed of in landfills. However, as this waste often qualifies as a hazardous material, and hazardous materials regulations are becoming more strict, landfill disposal is becoming less of an option. *Potential impact is* ***moderate****.*

Current Development Status: Activity in this area has been limited since OPA 90. The Coast Guard developed an oil flaring device to incinerate oil in remote locations in the mid 1980s, and Environment Canada developed incinerators capable of disposing of oiled debris and cleaning shoreline material. In addition, land farming techniques have been developed by the oil industry to clean up contaminated storage and production sites.

Technology Advance Envisioned: Better technologies for segregating hazardous from non-hazardous oily waste will facilitate disposal. Meanwhile, stabilization and solidification techniques may render waste non-hazardous and suitable for disposal in landfills, and advanced mobile incinerators could eliminate the need for oil and waste transport, and be particularly useful in remote regions. Selection criteria and guidelines should be developed for expanded use of land farming, and additional biological methods investigated.

Required Research Focus Areas:
- Solidification and stabilization techniques
- Advanced mobile incinerators
- Criteria and guidelines for land farming
- Advanced biological treatment methods

References:

- McDonagh, M., et al., 1995.

On-Water Containment and Recovery

Description of Technology: This technology area includes the development of methods, equipment, and materials for physically containing and removing oil from the surface of the water, the water column, or the bottom. Equipment to support this technique includes booms, skimmers, oil/water separators, temporary storage devices, and sorbent materials.

Importance: Mechanical containment and recovery is often the only viable response option since it is not subject to pre-approval constraints (as are dispersant use and in situ burning). On-water recovery effectiveness for larger spills (total recovery is on the order of 20% of the oil spilled) is limited by the cleanup equipment's speed of advance and by sea conditions. Specifically, containment booms and many of the skimmers in use are limited to speeds of one knot or less and sea heights of three feet or less. However, since the cost of on-water recovery is an order of magnitude less expensive than shoreline cleanup, improvements in speed of advance and seakeeping capabilities of mechanical systems would significantly decrease the overall costs of oil spills. *Potential impact is* ***moderate.***

Current Development Status: Boom and skimmer designs have been developed and tested within the limitations outlined above. Much of this testing was conducted at the National Oil Spill Response Test Facility using different oils and realistic environmental conditions. In addition, new boom and skimmer designs are being built and tested to expand the capability to contain and recover oil in fast currents and heavier seas. Two Coast Guard grant projects are focused on this area. The University of Rhode Island is numerically modeling oil/water/boom systems, and the University of New Hampshire is modeling varied boom configurations. Both of these university efforts should lead to improvements in boom design. Although this area poses difficult challenges, progress is being made, and the resulting advances should yield improvements in overall mechanical recovery efficiency.

Significant advances have also been made in developing supporting equipment, particularly oil/water separators and temporary storage devices. These devices are critical to the overall mechanical recovery system, which requires removing oil from the water, followed by transport to shore, and proper disposal. An aggressive oil/water separator testing and development program undertaken as a joint government/industry project has produced several compact, lightweight oil/water separator prototypes capable of handling up to 250 gallons per minute. In addition, a second generation of temporary storage devices has been produced through industry development efforts supported by government test and evaluation, which incorporate modern materials and advanced designs. These designs are commercially available and have been added to equipment inventories.

Another advance has involved the integration of various boom, skimmer, and support equipment refinements into a second generation of vessel-of-opportunity skimming systems (VOSS). These systems allow vessels designed primarily for other purposes (buoy tenders, offshore supply vessels, and fishing vessels) to be converted quickly to oil spill response vessels. Several systems have been assembled and tested, and are available in the national spill response inventory.

Only minor refinements have been made in sorbent materials and booms. The major accomplishment in sorbents has been the development of a comprehensive sorbents testing protocol and database under a joint US/Canadian project. In addition, efforts are underway through ASTM to develop protocols for testing mechanical recovery equipment.

Unresolved problems involve the development of techniques to recover submerged oils and orimulsions. Recovery strategies for submerged oils (which may drift at mid-depth in the water column or sink to the bottom) are limited to blind “trawling” or dredging in the spill area. Technology for detecting or tracking subsurface oils are needed to accurately guide mechanical recovery efforts. Orimulsions (which may behave as a submerged oil or disperse rapidly in the water column) present unique challenges to recovery efforts. Until the behavior of this inexpensive fuel in the water column is understood and recovery methods developed, permits for its import will remain scarce.

Technology Advance Envisioned: Four major development efforts should be pursued in this area. The first is an ongoing effort to develop and test high seas and high current boom and skimmer designs. Present work indicates that while recovery capability in currents up to three knots has been achieved, containment (in contrast to diversion) with conventional booms in currents much above one knot is extremely difficult outside a test facility. Further research has the potential to achieve a doubling of the present capability in each area. The second effort is development and full-scale testing of a compact, lightweight oil water separator design in the lab and at-sea, with a maximum capacity of 250 gpm. As with the initial development of the first generation prototypes, this could be undertaken as a joint government/industry effort. The third area is fundamental development and testing of technologies for recovering submerged oils. Experience in past major spills indicates that this can be accomplished by adapting technologies used for other purposes (e.g. surface recovery, salvage, hazardous materials remediation, *and* mineral extraction). The fourth area is the development of recovery systems (consisting of skimming and containment/diversionary technology) for rivers and tidal areas with currents above three knots. For many important areas, conditions are beyond the capability of existing equipment. In addition, sweeping oil at less than 1.5 knots inhibits ship handling, resulting in low coverage factors. Increasing the sweep speed will significantly increase cleanup efficiency, reducing both cleanup costs and environmental impacts of oil spills.

Required Research Focus Areas:

- Fast water boom and skimmer development
- Oil/water separator development
- Submerged oil recovery technology
- Orimulsion recovery technology

References:

- Bitting, K., and A. Nordvik, 1995.
- Michel, J., et al., 1995.

Alternative On-Water Countermeasures

Description of Technology: This technology area includes the development of various chemicals used to treat oil slicks on the surface of the water by concentrating the oil and making it more amenable to other techniques, such as mechanical recovery and *in situ* burning. These chemicals include herding agents, solidifiers, elasticity modifiers, and emulsion treating agents. Emulsion breakers can also be used on recovered oil to decrease the amount of material for disposal. Development activities include improving chemical formulations, refining application techniques, and conducting studies of effectiveness and environmental effects.

Importance: These chemicals are not frequently used, but in certain cases can be very effective in improving oil recovery and oil impact mitigation. Because of the logistics involved in transporting and applying the chemicals on-scene, they are usually employed on smaller spills close to shore. Their use for larger spills is limited. *Potential impact is* ***low***.

Current Development Status: Although these chemicals have been under development since the 1970s, efforts since the EXXON VALDEZ spill have been modest, and undertaken primarily by the commercial sector. MSRC conducted a detailed study of the state-of-the-art for such products, looking at the physical and chemical processes involved, application and recovery technologies, effectiveness determination, and environmental fate and toxicity. Their study concluded that additional research and development for herders, solidifiers and elasticity modifiers was unwarranted. Additional testing of emulsion treating agents was recommended to determine optimum injection point, refine application procedures, and document effectiveness and toxicity. Emulsion breakers are an important tool in spill response, as emulsions drastically decrease the effectiveness of mechanical recovery, *in situ* burning, and dispersant application. The report also recommended that information on effectiveness and effects be captured during actual use in the field, and compiled in a database for future reference.

Technology Advance Envisioned: The only additional research and development effort envisioned is establishment of a testing and evaluation program (including protocol development, laboratory testing, and field testing) for emulsion treating agents.

Required Research Focus Areas:
- Emulsion treating agents test and evaluation

References:
- Michel, J., et al., 1995.

At-Source Containment and Countermeasures

Description of Technology: This technology area includes the development of methods and equipment for mitigating oil flow from a vessel once the spill has begun, and for containing and recovering the oil at the source without substantial outside support. Such technologies include vacuum systems to reduce oil flow from tanks, automatic on-board oil transfer systems to remove oil from the damaged tank, rapid lightering systems to transfer the oil to another vessel, patching and plugging systems, booms and skimmers deployed from the vessel, and on-board dispersant application systems. Vessel destruction techniques are also included in this area.

Importance: The logistic difficulties, enormous costs, and limited success experienced during on-water and shoreline cleanup operations make clear the advantages of keeping oil within, or at least near the source. Despite the lack of past technological breakthroughs, advances in this area could provide substantial return on the R&D investment. *Potential impact* ***low.***

Current Status of Technology Development: Although substantial effort has been devoted to this area in the past, progress has been minimal in operational prototype development, testing, and implementation. The most beneficial advance to date has been development of the Coast Guard Air Deployable Anti-Pollution Transfer System (ADAPTS) which is used routinely to offload oil from damaged tankers and barges. Follow-on research has been conducted at the Coast Guard R&D Center to investigate the potential for using advanced composites in transfer pumps, and other equipment to enhance performance, improve reliability, and extend service life.

An in-depth review of various tanker self-help countermeasures was conducted as a joint project between the U.S. government (Coast Guard) and Canadian government (Environment Canada and Transport Canada), with participation from private industry. This review indicated that passive countermeasures, such as rapid transfer from damaged tanks to designated storage tanks, were the most viable alternative. Active countermeasures such as deployment of booms and skimmers from the vessel were not recommended due to crew manning, logistics, and safety considerations.

Technology Advance Envisioned: Future development should focus on the refinement, laboratory testing, and full-scale testing of passive countermeasures, such as the rapid transfer systems and onboard systems for plugging penetrations of the vessel's hull. These systems should be integrated into the double-hull design mandated by OPA 90.

Required Research Focus Areas:

- Develop and test passive tanker on-board countermeasures

References:

- Battelle Memorial Institute, 1992.
- Gallagher, J., 1995.

Vessel Damage Assessment and Salvage

Description of Technology: This technology area includes the development of methodologies and equipment to assess the extent of damage to a stricken vessel (caused by collision, grounding, or explosion), and implement measures that will stabilize the vessel's condition, reduce the potential for further pollution, and allow it to be moved safely for repairs or disposal.

Importance: A critical consideration in responding to a vessel casualty is stabilizing the condition of the vessel to prevent loss of life, minimize loss of property, and prevent or minimize the spillage of oil. To accomplish this, on-scene personnel must rapidly assess the overall structural integrity and hydrodynamic stability of the vessel to determine the appropriate response measure. *Potential impact is* ***low.***

Current Status of Technology Development: Development efforts in this area have focused in two areas. The first is the development of computer programs to rapidly compute structural integrity and hydrodynamic stability. The second is the development of technologies to rapidly detect structural damage (particularly below the waterline), and determine the extent of flooding and oil loss.

Several damage and stability assessment programs were developed prior to OPA 90 and have since been refined and made readily available. As a result, further development in this area is not critical to effective response. Instead, efforts since OPA 90 have focused on the second area, including the development of remote sensors and underwater vehicles for surveying underwater damage. The Coast Guard completed a study of these tools in 1993 and found that a hull-crawling, remotely operated vehicle (ROV) would meet Coast Guard mission requirements. Based on this finding, the Coast Guard provided functional specifications for such a system.

Additional efforts have focused on determining damage and flooding from aboard the ship. Some of the methods and equipment developed for this purpose can be applied to routine marine inspection activities to check structural integrity, and, hence, prevent spills.

Technology Advance Envisioned: Functional prototype ROV for oil spill response.

Required Research Focus Areas:

- ROV system for vessel damage assessment

References:

- Battelle Memorial Institute, 1993.

FATE, TRANSPORT AND EFFECTS, MONITORING AND RESTORATION

Restoration Methods and Technologies

Description of Technology: This technology area includes methods and technologies to facilitate and accelerate the recovery of resources impacted by oil.

Importance: Restoration activities are mandated by OPA 90, which specifically requires that funds obtained through damage assessment and compensation litigation be expended on actual restoration activities. However, very few proven methods, technologies, or monitoring protocols exist to support such efforts. *Potential impact is **high**.*

Current Development Status: This technology area is in the formative stages, because there have been few efforts to actively restore habitats after oil spills. While methods for restoring certain habitats (e.g., salt marshes and sea grass meadows) exist, most have not been rigorously tested under varying environmental conditions. For other habitats (e.g. coral reefs, and inter-tidal and sub-tidal substrates), only limited methodology exists. Consequently, many restoration actions are viewed with skepticism. The development of indicators of habitat/living marine resource impact and recovery is critical for managers judging the "health" of an impacted ecosystem and the need for corrective action.

Habitat restoration is being addressed in a broader sense by the National Marine Fisheries Service, which outlined a research strategy focusing on five areas: ecosystem structure and function; effects of alterations; development of restoration methods; development of indicators of impact and recovery; and information synthesis and distribution. The Army Corps of Engineers is also investigating how restoration and remediation are addressed in spill contingency plans for the Gulf of Mexico.

Technology Advance Envisioned: The highest priority research areas for habitat restoration are development of actual restoration methods and defining indicators of habitat impact and recovery. General restoration research topics include: further development of bioremediation; experiments on species transplant as a viable technique for habitat restoration; the evaluation of the role and size of buffers; and the importance of habitat heterogeneity in the restoration process. The methods of research for development of restoration indicators will include comparative research on the structure and function of disturbed, natural, and/or restored habitats of different ages and geographical locations for a suite of biological, chemical, and physical parameters; time-dependent biotic population analyses; and contaminant level follow-up evaluation for sediment, biota, and water. This research will be conducted both on a laboratory-scale and at actual spill sites. Finally, data on restoration technologies and monitoring protocols would be collected in a national database.

Required Research Focus Areas:

- Technology-based restoration techniques
- Species transplant techniques
- The role of buffers and habitat heterogeneity
- Restoration indicators and measures of effectiveness
- Restoration spill-of-opportunity research program
- Restoration database

Spill Impacts and Ecosystem Recovery

Description of Technology: This technology area includes basic laboratory research, field studies, and modeling efforts to better understand and predict the long-term impacts of oil spills at the ecosystem level. This impact includes the impact of both the oil itself, and the countermeasures and cleanup techniques used to remove the oil. It also includes basic research, field monitoring activities, and modeling to determine the rate of ecosystem recovery both with and without countermeasures and cleanup.

Importance: This research provides important feedback on the effectiveness of past efforts, forms the basis for future decision-making during spill response, and provides input for damage assessment and restoration planning. *Potential impact is **high**.*

Current Development Status: Several recent research efforts have focused on longer-term impacts and recovery of ecosystems, and how this recovery is facilitated or hindered by countermeasures and cleanup activities, particularly shoreline cleanup operations. This includes the extensive research effort in Prince William Sound to document the impacts of the EXXON VALDEZ spill and cleanup effort, research carried out subsequent to the Persian Gulf oil spill during Operation Desert Storm, and a comprehensive study completed in the United Kingdom to review and document the impact of spills and recovery of shorelines over the past three decades. These efforts and similar research both in the laboratory and the field indicate that knowledge and understanding of ecosystem impacts and recovery is limited, and that much of the information available on the topic is incomplete, anecdotal, and not comparable. In particular, available data is inadequate to permit discrimination between the impacts of the oil, and the impacts of countermeasures and cleanup techniques to remove the oil.

Technology Advance Envisioned: A comprehensive long-term research program is required to properly document and quantify oil spill impact and ecosystem recovery. This includes the development of procedures for establishing "set aside" areas to provide baseline data on recovery without cleanup and countermeasures, the establishment of long-term monitoring protocols and documentation procedures, and the establishment of a national network for compiling and preserving this information. Field monitoring efforts following major spills should be supplemented by laboratory-scale and mesoscale testing (including small experimental spills in the field), to sort out the impacts of the oil alone, from the impact of cleanup operations. Field monitoring procedures and protocols should be established as soon as possible, as valuable data are lost each time a major spill occurs and monitoring efforts are inadequate.

Required Research Focus Areas:

- Establish monitoring protocols and procedures
- Conduct laboratory and mesoscale studies of impact and recovery
- Establish integrated database of spill impact and recovery

References:

- Mearns, A., 1995.
- Sell, D., et al., 1995.

Basic Fate and Transport

Description of Technology: This technology area includes laboratory research, field studies, and modeling efforts aimed at understanding and predicting the behavior and transport of petroleum oils in the environment, their physical interaction with other materials in the environment (e.g. rock and sediments), their impact on living marine resources, and the partitioning of the various hydrocarbon constituents.

Importance: A fundamental understanding of the fate and effects of oil in the environment is critical to effective contingency planning, response operations management, and long-term monitoring and restoration. Contingency planning requires knowledge of oil behavior for countermeasures selection and response resource allocation. Knowledge of short-term behavior, transport in the water column, and interaction with shorelines is necessary for effective and efficient management of response operations. In addition, knowledge of longer-term fractionation and transport of hydrocarbons, and their impacts on marine resources, is also required to focus monitoring efforts and develop restoration plans. Finally, understanding the toxicological impacts of oil and its intermediate degradation products, as well as any beneficial transformations of oil, is necessary to assess bioremediation possibilities. *Potential impact is **moderate**.*

Current Status of Technology Development: Research in this area has been ongoing since the late 1960's, with numerous reports and articles devoted to the subject. This research has focused on the oil's weathering (evaporation, dispersion, dissolution, and sedimentation), interaction with shoreline materials and surfaces, and toxicity to specific species of marine plants and animals.

A number of transport, behavior, and effects models have been developed for use in spill response planning and management, and natural resource damage assessment. Renewed interest has been in the transport and behavior of heavier residual oils (Low API Oil or LAPIOs), which may sink below the surface, and orimulsions, which disperse immediately in the water column. Some insight into the transport, behavior, and cleanup of submerged heavy oils was acquired during the 1993 Tampa Bay spill and the MORRIS J. BERMAN spill in Puerto Rico. A research effort to study the behavior of heavy residual fuel oils is currently underway in Florida with funding from the Coast Guard, Florida Power and Light, and MSRC. Research is also being conducted by the U.S. Fish and Wildlife Service to determine the effectiveness of cleaning oiled birds and mammals.

Technology Advance Envisioned: Additional research and testing is required to fully understand and predict the transport and behavior of LAPIOs and orimulsions. This includes research on physical behavior to support countermeasures development, and research on chemical behavior and toxicity, especially for orimulsions, to predict environmental effects. The Coast Guard has commenced studies into LAPIOs and orimulsions, however, the technology for these products lags behind the understanding and prediction capability for other crude oils and refined products.

Required Research Focus Areas:

- Transport and behavior of heavy oils, orimulsions, and subsurface oil.
- Countermeasures effectiveness for orimulsions

Appendix B. Oil Spill Data Base Comparison

IRIS The Incident Reporting Information System is a relational database operated by the National Response Center (NRC) at the U.S. Coast Guard Headquarters. While it is used primarily for emergency response notification, IRIS supports the information needs of various National Response Team (NRT) agencies. The NRC collects information from reports (usually by telephone) on releases of oil and other hazardous substances from fixed facilities or during transit. The NRC relays the information immediately to the Federal On-Scene Coordinator who coordinates any potential federal response to the incident. The data are also entered directly into the database. Because of its use in immediate reaction, every report is entered as a record and none of the records are ever destroyed. Since records are initial notifications made during or immediately after a release occurs, exact details of the release are often incomplete, preliminary, or inaccurate. Updates to the notifications are occasionally provided. These, however, may be entered as a separate, duplicate record (leaving the initial record uncorrected if it is an update). IRIS forms the core of several of the other databases that collect more detailed or follow-up information to support release prevention, enforcement, and policy decisions. In addition to emergency notification, IRIS is useful for learning about a specific incident and performing statistical analyses on large data sets. When used for analyses, its inherent limitations must be considered.

ERNS The Emergency Response Notification System (ERNS) is an EPA database that contains release notifications made to the NRC, as well as reports made to EPA regional offices. The EPA reports may be updates of or in addition to the NRC notifications. ERNS includes data from all transportation modes and facility types and uses an expansive definition of reportable oil release. Its uses and limitations are similar to those of IRIS.

HMIRS The Hazardous Materials Incident Reporting System (HMIRS) is managed by DOT/RSPA. All releasing carriers must submit a written report whenever there is an unintentional release of a hazardous material during transportation. These reports make up the heart of HMIRS and are supplemented by the notifications that are in the IRIS database. Because the HMIRS database is based on written reports submitted by the carrier, details of each release are usually accurate. The majority of the information is validated, as fatality and injury information are verified through follow-up reports.

HLPAD The Hazardous Liquid Pipeline Accident Database (HLPAD) is another DOT/RSPA database. Like HMIRS, it expands on IRIS with survey data for a targeted area. The database contains information on any failure in a pipeline system where the release meets certain threshold criteria. Telephone notifications to NRC that meet these criteria are entered in this database as well as IRIS. Pipeline operators must also submit written reports on these releases. This information is verified and entered into the database.

MSIS The Marine Safety Information System (MSIS) is maintained by USCG. This database is based on investigations, rather than notifications or surveys. The Coast Guard collects information on about 10,000 fixed facilities and transportation accidents each year, including releases of petroleum and other substances. MSIS gathers a wide array of data to support the Coast Guard's overall mission. Therefore, the information goes well beyond pollution incidents. This additional information can add to analyses (for example, for a vessel that is involved in an incident, the database contains past releases and violations of that vessel). The Coast Guard uses the information to prioritize activities to maximize use of Coast Guard resources for prevention, response, investigations, facility inspections, and vessel boardings and inspections.

WTSD The Worldwide Tanker Spill Database (WTSD) is run by MMS. MMS uses the database to evaluate fully the risk of oil spills from the Outer Continental Shelf Gas and Oil Program, other domestic oil movements, and the tankering of imported oil. MMS updates and maintains a comprehensive database of accidental tanker and barge oil spills in coastal and offshore waters worldwide, greater than or equal to 1,000 barrels. It compiles the information from a variety of public and private databases and listing services, including MSIS.

OPAC The Offshore Pollution and Accident Compilation (OPAC) system is maintained by MMS. The database is used to track accidents including pollution incidents that have occurred as a result of OCS oil and gas activities which were investigated by the MMS. Historically, very little OCS oil has been transported by tanker, most of the transportation spills in the OPAC are from offshore pipelines. Nearshore platforms have been served by barge but few reports on barge spill are included in the database. The database is not user-friendly and queries of specific types of incidents are difficult to execute. Information is based on reports from responsible parties, and MMS District and Regional Offices with a minimum level of validation. The database is updated periodically.

Table B- 1. Database Comparison - Scope

Federal Databases							
Field	**IRIS**	**ERNS**	**HMIRS**	**HLPAD**	**MSIS**	**WTSD**	**OPAC**
Chemicals Covered	Petroleum and other substances	Petroleum and other substances	Petroleum and other substances	Petroleum and other substances	Petroleum based products and other oil products, chemicals, garbage and natural substances	Petroleum	Petroleum and other substances
Transportation modes and fixed facilities covered	All modes, all fixed facilities	All modes, all fixed facilities	All modes, all fixed facilities	Pipeline only, no fixed facilities	All modes, all fixed facilities	Marine barges and tankers only, no fixed facilities	Offshore oil and gas platforms, pipelines, work boats, barges, tankers
Geographic coverage	US and its territories	US and its territories	US and its territories	US and its territories	US navigable waters	Worldwide	U.S. Outer Continental Shelf, Gulf of Mexico and Southern California
Criteria that trigger inclusion in database (for an oil spill)	Oil release that violates applicable water quality standards, causes a film, or causes a sludge/ emulsion beneath the surface of the water	Oil release that violates applicable water quality standards, causes a film, or causes a sludge/ emulsion beneath the surface of the water	Any unintentional release of oil during the course of transportation	(1) Explosion or fire; (2) loss of 50 or more barrels of liquid; (3) release of more than 5 barrels per day of liquefied gas; (4) death; (5) property damage of at least $50,000	A release that violates applicable water quality standards, and in the case of an oil spill causes a film, or sludge/ emulsion beneath the surface of the water	An accidental tanker or barge spill inland, coastal or offshore waters world wide that is at least 1,000 barrels of the vessel's cargo or own fuel	Spill greater than one barrel investigated by DOI/ MMS (Explosion, fire, death, large property loss always investigated)

Table B-1. Database Comparison - Scope (cont.)

Federal Databases

Field	IRIS	ERNS	HMIRS	HLPAD	MSIS	WTSD	OPAC
Information gathering: (1) Who provides	By person associated with the facility or transportation vehicle that had the release, or government official, or private citizen	By person associated with the facility or transportation vehicle that had the release, or government official, or private citizen	Representa-tive of the releasing carrier	Pipeline operators	A person associated with the vessel or facility, anyone witnessing the incident, a private citizen, or USCG investigator	Data collected from secondary sources.	Initial report by operator (responsible party)
(2) How provided or obtained	NRC Incident notification system (telephone reports during or immediately after release)	IRIS, plus reports by EPA regions	IRIS, plus written report to DOT	IRIS, plus written report to DOT	USCG Investigations	MMS collection of information from a variety of other databases and secondary reporting services	Written report to DOI/.MMS from operator, plus any follow-up investigations by operator/ USCG/MMS
Limitations of the data	May not be complete, accurate, or finalized since based on immediate reports by an observer. May be duplicates or multiple notifications about a single release since all reports are recorded	May not be complete, accurate, or finalized since based on immediate reports by an observer. May be duplicates or multiple notifications about a single release since all reports are recorded			The size, richness, and complexity of the database make data extractions and analyses laborious	International reporting of barge and inland spills is limited.	May not be complete. The richness, and complexity of the database make data extraction and analyses laborious
Availability of database updates	Continuously	Continuously	Quarterly	Every 2 - 4 weeks	Every 3 months	Continuously	Quarterly to annually

Table B-1. Database Comparison - Scope (cont.)

Federal Databases							
Field	**IRIS**	**ERNS**	**HMIRS**	**HLPAD**	**MSIS**	**WTSD**	**OPAC**
Government Agency	NRC	EPA	RSPA	RSPA	USCG	MMS	MMS
Access	General access by request	General and wide access	General access by request	General access by request	Requests can only be made through the Coast Guard; data available only as tape extraction	Reports made available periodically	Reports made available periodically
Years covered	1974 - present	1986 - present	1971 - present	1985 - present	1985 - present (pollution data from 1973 on PIRS data base with all information collected in the same manner	1974 - present (with less rigorous from 1955)	1971 - present

Table B- 2. Database Comparison - Data Elements

Data Category	Data Elements	Federal Databases						
		IRIS	ERNS	HMIRS	HLPAD	MSIS	WTSD	OPAC
Event reporting information	Reporting party	*	*	*	*	*	*	
	Date and time reported	*	*	*	*	*	n/a	
Facility / release location	Facility name and address	*	*	*	*	*	*	*
	Release location	*	*	*	*	*	*	*
Release data	Date	*	*	*	*	*	*	*
	Transportation mode	*	*	*	*	*	*	*
	Type of vehicle			*	*	*	*	
	Vessel/vehicle number	*	*		*	*		
	Vehicle/container information			*	*		i	
	Shipment information			d			e	
	Quantity	*	*	*	*	*	*	*
	Quantity in water	*	*			*		
	Type of medium effected	c	d			*	e	
	Name of waterway effected	b	b			*	b	
	Type of release (spill, fire,etc.)	b		*	*	*		*
Release cause	Primary cause	a, b	a, b	a	a	c	c	*
	Contributing factors			*		*	h	*
Damages	Deaths	*	*	*	*	*	*	*
	Injuries	*	*	*	*	*		*
	Amount of property damages	*	*	*	*	*		
	Extent of environmental damage	b		b			b	
Additional Comments	Additional Comments	*	*	*		*		*

Notes: a) Laundry List
b) Description Field Available
c) Chain of Events
d) Origin/Destination
e) Level of Load
f) Distance From Coast
g) Air, Groundwater, Land, Water
h) Severe Weather Only
i) vessel size
n/a) not applicable

References and Bibliography

Allen, A.A., and R.J. Ferek. 1993. Advantages and Disadvantages of Burning Spilled Oil. Proc. of the 1993 International Oil Spill Conference. American Petroleum Institute. Washington: API, 1993. pp.765-772. (*Spill Costs*)

Anderson, C. M., and R. P. La Belle. "Comparative Occurrence Rates for Offshore Oil Spills." Spill Sciences and Information Bulletin 1 (*OCS Spill Data*)

Arctic Research Commission. Research Needed to Respond to Oil Spills in Ice-Infested Waters. Washington: Arctic Research Commission, 1992. (*Arctic R&D*)

Arctic Research Commission. Goals and Priorities to Guide United States Arctic Research. Washington: Arctic Research Commission, 1993. *(Overview of Accomplishments)*

Aurand, D. Current Status of the MSRC Environmental Health Research Program. Proc. of the Second International Oil Spill Research and Development Forum. 23-26 May 1995. London: Intype, 1995. 669-677.*(General)*

Barry, D. C., et al. Oil Spill Simulation: An Advancement in Response Preparedness. Proc. of the Second International Oil Spill Research and Development Forum. 23-26 May 1995. London: Intype, 1995. 301-308.*(Training and Readiness)*

Battelle Memorial Institute. Investigation of Self-Help Oil-Spill Response Techniques and Equipment. USCG R&D Report CG-D-21-92. Publishing location: Battelle, 1992. *(At-Source Containment and Countermeasures)*

Battelle Memorial Institute. Technical Survey and Evaluation of Underwater Sensors and Remotely Operated Vehicles. USCG R&D Report CG-D-21-93. Columbus: Battelle, 1993. *(Damage Assessment & Salvage)*

Bitting, K.R., and A.B. Nordvik. Tests of Lightweight Oil/Water Separators for Spilled Oil Recovery Operations. Proc. of the Second International Oil Spill Research and Development Forum. 23-26 May 1995. London: Intype, 1995. 95-102. *(Mechanical Recovery - Oil Water Separation)*

Bragg, J., and E.H. Owens. Shoreline Cleansing By Interactions Between Oil and Fine Mineral Particles. Proc. of the 1995 International Oil Spill Conference. American Petroleum Institute. Washington: API, 1995. *(Shoreline Cleanup)*

Daidola, J. C., and C. J. Reyling. Oil Outflow Estimates for Tankers and Barges. Proc. of the Second International Oil Spill Research and Development Forum. 23-26 May 1995. London: Intype, 1995. 212-222. *(At-Source Containment and Countermeasures)*

Engelhardt, F.R. The Marine Spill Response Corporation Research and Development Strategy and Program. Proc. of the Second International Oil Spill Research and Development Forum. 23-26 May 1995. London: Intype, 1995. 678-686. *(General)*

Etkin, D.S., The Financial Costs of Oil Spills. Arlington, MA. Cutter Information Corporation. 1994.

Fingas, M., et al. *In situ* Burn Studies--The Newfoundland Offshore Burn Experiment and Future Research. Proc. of the Second International Oil Spill Research and Development Forum. 23-26 May 1995. London: Intype, 1995. 465-471. *(In situ Burning)*

Fingas, M., et al. Research Projects of the Emergencies Science Division. Proc. of the Second International Oil Spill Research and Development Forum. 23-26 May 1995. London: Intype, 1995. 687-695. *(General)*

Gallagher, J.J. An Emergency Cargo Pumping System for Damaged Tank Vessels. Proc. of the Second International Oil Spill Research and Development Forum. 23-26 May 1995. London: Intype, 1995. 223-230. *(At-Source Containment and Countermeasures.)*

Galt, J. A. The Integration of Trajectory Models and Analysis Into Spill Response Information Systems: The Need for a Standard. Proc. of the Second International Oil Spill Research and Development Forum. 23-26 May 1995. London: Intype, 1995. 499-507. *(Trajectory and Behavior Models)*

Giammona, C. P., et al. Enhanced Spill Response Using New Airborne Multisensor and Image Processing Technology. Proc. of the Second International Oil Spill Research and Development Forum. 23-26 May 1995. London: Intype, 1995. 566-576. *(Remote Sensing)*

Golub, R. "Tanker Spills in the United States." Oil Pollution Bulletin IV (1992). *(Tanker Spills)*

Goodman, R. "Overview and Future Trends in Oil Spill Remote Sensing." Spill Science and Technology Bulletin 1 (1994): 11-21. *(Remote Sensing)*

Goodman, R., et al. Tracking Buoys for Oil Spills. Proc. of the 1995 International Oil Spill Conference. American Petroleum Institute. Washington: API, 1995.

Goodman, R. Remote Sensing of Oil Spills: What Works, What Is Useful, What Is Needed and Who Cares. Proc. of the Second International Oil Spill Research and Development Forum. 23-26 May 1995. London: Intype, 1995. 577-585. *(Remote Sensing)*

Guenette, G.. et al. *In situ* Burning of Water-In-Oil Emulsions. SINTEF Report STF21 A94053. Rpt. as MSRC Tech Report Series 94-001, 1994.

Herbert Engineering Corp. Probabilistic Oil Outflow Analysis of Alternative Tanker Designs. San Francisco: Herbert Engineering Corp., 1992. USCG R&D Report CG-D-14-92. *(Vessel Design)*

Holliday, M. G., and J. M. Park. Occupational Health Implications of Crude Oil Exposure: Literature Review and Research Needs. Washington: Marine Spill Response Corp., 1993. *(Health & Safety)*

Hover, G. Recent U.S. Coast Guard Research in Tactical Oil Spill Surveillance Technology. Proc. of the Second International Oil Spill Research and Development Forum. 23-26 May 1995. 586-597. *(Remote Sensing)*

Howlett, E., et al. New Generation of Software Systems and Applications. Proc. of the Second

International Oil Spill Research and Development Forum. 23-26 May 1995. London: Intype, 1995. 797-805. *(Leak Detection and Mitigation)*

Husain, M. Analysis of a Dynamic Underpressure System for Oil Spill Prevention. Proc. of the Second International Oil Spill Research and Development Forum. 23-26 May 1995. London: Intype, 1995. 241-249. *(Leak Detection and Mitigation)*

LaBelle, R., and E. Danenberger. Oil Spill Research Program of the U.S. Minerals Management Service. Proc. of the Second International Oil Spill Research and Development Forum. 23-26 May 1995. London: Intype, [1]1995. 701-706. *(General)*

Lamarche, A., et al. The Use of Knowledge-Based Software To Identify Shoreline Treatment Options. Proc. of the 1995 International Oil Spill Conference. American Petroleum Institute. Washington: API, 1995.55-60. *(Shoreline Cleanup)*

Lee, K. Bioremediation Studies in Low-Energy Shoreline Environments. Proc. of the Second International Oil Spill Research and Development Forum. 23-26 May 1995. London: Intype, 1995. 27-36. *(Shoreline Cleanup - Bioremediation)*

Lunel. T. Research Requirements To Determine Dispersant Effectiveness at Sea. Proc. of the Second International Oil Spill Research and Development Forum. 23-26 May 1995. London: Intype, 1995. 271-285. *(Dispersants)*

McDonagh, M., et al. Handling and Disposal of Oil Waste From Oil Spills At Sea. Proc. of the 1995 nternational Oil Spill Conference. American Petroleum Institute. Washington: API, 1995. 589-593. *(Oil & Debris Disposal)*

McMahon, O., et al. Oil Thickness Detection Using Wideband Radiometry. Proc. of the 1995 International Oil Spill Conference. American Petroleum Institute. Washington: API, 1995. 15-19. *(Surveillance)*

Mearns, A.J. Assessing the Effectiveness and Effects of Shoreline Countermeasures. Proc. of the Second International Oil Spill Research and Development Forum. 23-26 May 1995. London: Intype, 1995. 362-368. *(Shoreline Cleanup)*

Michel, J., et al. Chemical Treating Agents: Response Niches and Research and Development Needs. Proc. of the Second International Oil Spill Research and Development Forum. 23-26 May 1995. London: Intype, 1995. 717-724. *(Alternative On-Water Countermeasures)*

Michel, J., and B.L. Benggio. Testing and Use of Shoreline Cleaning Agents During the MORRIS J. BERMAN Oil Spill. Proc. of the 1995 International Oil Spill Conference. American Petroleum Institute. Washington: API, 1995. 197-202. *(Shoreline Cleanup)*

Michel, J., et al. Group V Fuel Oils: Source, Behavior and Response Issues. Proc. of the 1995 International Oil Spill Conference. American Petroleum Institute. Washington: API, 1995.559-564. *(Mechanical Recovery)*

Mooers, C. N. K. South Florida Oil Spill Research Center. Proc. of the Second International Oil Spill Research and Development Forum. 23-26 May 1995. London: Intype, 1995. 725-731. *(General)*

National Research Council. Tanker Spills: Prevention By Design. Washington, DC. National Academy Press. 1991. (*Vessel Design*)

National Research Council. Review of the Interagency Oil Pollution Research and Technology Plan. Washington, DC. National Academy Press. 1993. (*General*)

Nordvik, A.B., et al. At-Sea Testing of Fire Resistant Oil Containment Boom Designs. Proc. of the Second International Oil Spill Research and Development Forum. 23-26 May 1995. London: Intype, 1995. 479-490. *(In situ Burning)*

Owens, E., and B. Humphrey. Research Activities To Investigate the Role of Natural and Accelerated Shoreline Cleaning by the Interaction of Oil with Fine Particles. Proc. of the Second International Oil Spill Research and Development Forum. 23-26 May 1995. London: Intype, 1995. 438-443. *(Shoreline Cleanup)*

Putukian, J., and K. Bitting. U.S. Coast Guard Oil Pollution Research Grant Program. Proc. of the Second International Oil Spill Research and Development Forum. 23-26 May 1995. London: Intype, 1995. 732-736.*(General Overview)*

Pritchard, H.P., and C.F. Costa. "EPA's Alaska Oil Spill Bioremediation Project." Environmental Science and Technology 25 (1991): 372-379. *(Shoreline Cleanup - Bioremediation)*

Reilly, T.J., et al. The Development of the Coastal Oil Spill Simulation System. Proc. of the Second International Oil Spill Research and Development Forum. 23-26 May 1995. London: Intype, 1995. 444-450. *(Shoreline Cleanup)*

Rothblum, A. M., et al. Identifying the Effects of Shipboard Automation on Mariner Qualifications and Training and Equipment Design. International Symposium--Human Factors on Board. 15-17 November 1995. (*Human Factors Research for Spill Prevention)*

Sanquist, T. F., et al. United States Coast Guard Alertness and Fatigue Research Program. Proceedings. of the International Symposium--Human Factors On Board: The Influence of the Man-Machine Interface on Safety of Navigation. 15-17 November 1995 (*Human Factors Research for Spill Prevention)*

Science Advisory Board. Rev. of Underground Storage Tank Research Program, by theUnited States Environmental Protection Agency. Strategic Environmental Research and Development Program (1994): A-201-205.

Science and Policy Associates, Inc. MSRC Workshop Report: Research on Worker Health and Safety. Washington: Marine Spill Response Corp., 1993.

Science and Policy Associates, Inc. MSRC Workshop Report: Research on Bioremediation of Marine Oil Spills. Washington: Marine Spill Response Corp., 1993.

Scott, R.D. Technical Evaluation of the Coastal Oilspill Simulation System Prototype. Washington:

Marine Spill Response Corp., 1993.

Sell, D. The Effects of Oil-Spill Clean-Up on Shore Recovery Timescales. Proc. of the Second International Oil Spill Research and Development Forum. 23-26 May 1995. London: Intype, 1995. 369-387. *(Shoreline Cleanup)*

Sergy, G., et al. Recent and Emerging Canadian Studies Addressing Oil-On-Shoreline Issues. Proc. of the Second International Oil Spill Research and Development Forum. 23-26 May 1995. London: Intype, 1995. 388-395.*(Shoreline Cleanup)*

Spaulding, M. Oil Spill Trajectory and Fate Modeling: A State-of-the-Art Review. Proc. of the Second International Oil Spill Research and Development Forum. 23-26 May 1995. London: Intype, 1995. 508-516. *(Trajectory and Behavior Models)*

Thomas, G., and J. Duffy. An Overview of Revisions To Support Subpart J of the National Contingency Plan. Proc. of the Second International Oil Spill Research and Development Forum. 23-26 May 1995. London: Intype, 1995. 294-298. *(Dispersants)*

United States. Dept. Of Commerce. National Oceanic and Atmospheric Administration. Hazardous Materials Response and Assessment Division. Shoreline Countermeasures Manual-Temperate Coastal Climates**,** 1992. *(Shoreline Cleanup)*

United States. Dept. of Commerce. National Oceanic and Atmospheric Association. . Hazardous Materials Response and Assessment Division. Shoreline Countermeasures Manual-Tropical Coastal Climates**,** 1993. *(Shoreline Cleanup)*

United States. Dept. of Interior. Minerals Management Service. Federal Offshore Statistics: 1993. By D. K. Francois. OCS Report MMS 94-0060. Herndon: MMS, 1994. *(OCS Spill Data)*

United States. Dept. of Interior. Minerals Management Service. OCS Oil Spill Fact Sheet. Herndon: MMS, 1995. *(OCS Spill Data)*

United States. Dept. of Transportation. Office of Pipeline Safety. Annual Report on Pipeline Safety--Calendar Year 1992. Washington: 1995. *(Pipeline Spill Technology)*

United States. Dept. of Transportation. U. S. Coast Guard. Condensed USCG Oil Spill Response Health and Safety Plans. Groton: U. S. Coast Guard Research Center, 1995. USCG R&D Report CG-D-15-95. *(General)*

United States. Dept. of Transportation. U. S. Coast Guard. Prevention Through People. Washington: 1995. *(Human Factors)*

United States. Dept. of Transportation. U. S. Coast Guard. Report To Congress --Alternatives to Double Hull Tank Vessel Design. Washington: 1993.

United States. Dept. of Transportation. U. S. Maritime Administration. Petroleum Transportation Systems Assessment and Modeling - Base Year Traffic Patterns. Washington: 1995.

United States. Environmental Protection Agency. Data Obtained from EPA Emergency Responsive Notification System. Washington: 1995. *(Inland Spill Data)*

United States. Environmental Protection Agency. National Response Team. The Efficacy of Fire Resistant Containment Boom. Washington: 1995. *(In situ Burning)*

Venosa, A.D., M.T.Suidan, B.A.Wrenn, K.L.Strohmeier, J.R.Haines, B.L.Eberhart, D.W. King, and E. Holder.1996. "Bioremediation of an Experimental Oil Spill on the Shoreline of Delaware Bay." EnvironmentalScience and Technology 30(5): 1764-1775. (*Shoreline Cleanup* - *Bioremediation*)