Oil Spills and Oil Spill Research: A Perspective and Review of NAS Studies

Merv Fingas
Private Individual
Edmonton, Alberta
Fingasmerv@shaw.ca

Foreword: This is the personal testimony of Merv Fingas, a private individual from Canada. I have extensive background as an oil spill researcher and have participated in several NAS committees. I will describe briefly some NAS studies, one on oil-in-the-sea and one on oil spill dispersants. I had extensive involvement in these studies especially the oil-in-the-sea study. Further, I will give some of my impressions of where R&D emphasis should be placed.

1 Introduction - Oil Spills

Major oil spills can attract the attention of the public and the media. In past years, this attention had created a global awareness of the risks of oil spills and the damage they do to the environment. In recent years, major spill incidents are fewer in number however the recent Gulf spill may increase these spill numbers back to the previous high levels. The public becomes aware of very major spills, but generally is unaware that spills are a daily fact of life. Oil spills are a frequent occurrence, particularly because of the heavy use of oil and petroleum products in our daily lives.

Spill statistics are collected by a number of agencies around the world. Unfortunately these are sometimes not as accurate as they could be. They can sometimes be misleading to compare oil spill statistics, however, because different methods are used to collect the data. In general, statistics on oil spills are difficult to obtain and any data set should be viewed with caution. The spill volume or amount is the most difficult to determine or estimate. For example, in the case of a vessel accident, the exact volume in a given compartment may be known before the accident, but the remaining oil may have been transferred to other ships immediately after the accident. Some spill accident data banks do not include the amounts burned, if and when that occurs, whereas others include all the oil lost by whatever means. Sometimes the exact character or physical properties of the oil lost are not known and this leads to different estimations of the amount lost. Spill data are often collected for purposes other than future improvement of spill response. Further, reporting procedures vary in different jurisdictions and organizations, such as government or private companies. The number of spills reported also depends on the minimum size or volume of the spill. In Canada for example, there are about 12 such reportable oil spills every day, of which only about one is spilled into navigable waters. These 12 spills amount to about 40 tons of oil or petroleum product. In the United States, there are estimated to be about 25 spills per day into navigable waters and an estimated 75 spills on land.

The public often has the misconception that oil spills from tankers are the primary source of oil pollution in the marine environment. While it is true that some of the large spills are from tankers, it must be recognized that these spills still make up less than about 5% of all oil pollution entering the sea. The sheer volume of oil spilled from tankers and the high profile given these incidents in the media have contributed to this misconception. In fact, as stated earlier, half of the oil spilled in the seas is the runoff of oil and fuel from land-based sources rather than from accidental spills.

In conclusion, it is important to study spill incidents from the past to learn how the oil affected the environment, what cleanup techniques worked and what improvements can be made, and to identify the gaps in technology.

3 The Oil-in-the Sea Study by the National Academy of Sciences - 2003

(Note: this is my paraphrase of a NAS summary but all opinions are mine. NAS report recommendations are given in quotes.)

Oil in the Sea III is the third report from the National Academies on oil spill sources and fates, the last of which was published in 1985. Since the date of the last report, several governmental and private agencies have created databases with more information on petroleum releases and their impact on the environment. This 2003 report proposes a clearer methodology for estimating petroleum inputs to the sea and makes recommendations for further monitoring and assessment that will help policymakers prioritize next steps for prevention and response.

Sources of Oil in the Sea

Petroleum inputs into North American and worldwide marine waters were computed for four major sources – natural seeps and releases that occur during the extraction, transportation, and consumption of petroleum. The last three include all significant sources of anthropogenic petroleum pollution. This summary highlights the major findings about each major source.

Natural Seeps of Petroleum

Natural seeps occur when crude oil seeps from geologic strata under the sea floor into the water. Seeps are often used to identify potential economic reserves of petroleum. They contribute the highest amount of petroleum to the marine environment, accounting for 45 percent of the total estimated annual load to the world's oceans and 60 percent of the estimated total load to North American waters. The presence of these seeps, though entirely natural, significantly alters the nature of the local marine ecosystems around them. Seeps serve as natural sites for understanding adaptive responses of organisms over generations of oil exposure. The report recommends that programs be implemented to understand the fate of petroleum from natural seeps and ecological responses to them.

Author's Comment - Few, if any studies on natural seeps have been carried out since the NAS study.

Extraction of Petroleum

World oil production continues to rise, from 8.5 million

tonnes (1 tonne equals about 294 gallons) in 1985 to 11.7 million tonnes in 2000. In that same time, the number of offshore oil and gas platforms rose from a few thousand to approximately 8,300 fixed or floating offshore platforms. Historically, oil and gas exploration and production of petroleum have represented a significant source of spills. The second largest marine spill in the world was a blowout that released 476,000 tonnes of crude oil into the Gulf of Mexico in 1979. The current Gulf blowout may soon approach this level of significance. The amount of oil transported over the sea continues to rise. Since 1985, the Middle East's exports of oil to the United States have almost tripled, and exports to the rest of the world have doubled. While the devastating impact of spills has been well-publicized with images of oil-covered shores and wildlife, releases from the transport of petroleum now amount to less than 4 percent of the total in North American waters and less than 13 percent worldwide. The four major sources of petroleum discharges in the transportation sector include pipeline spills, tank vessel spills, operational discharges
from cargo washings, and coastal facilities spills. Transportation-related spills are down for
several reasons. The enactment of the Oil Pollution Act of 1990 placed increased liability on responsible parties, and other regulations required the phase out of older vessels and the implementation of new technology and safety procedures. By 1999, approximately two-thirds of the tankers operating worldwide had either double-hulls or segregated tank arrangements – a vast improvement over older single hull ships. Operational discharges from cargo washing are now illegal in North America, a law that is rigorously enforced. However, there still remains a risk of spills in regions with less stringent safety procedures practices. The report recommends that federal agencies expand efforts to work with ship owners domestically and internationally to more fully enforce effective international regulatory standards that have contributed to the decline in oil spills. In the United States, nearly 23,000 miles of pipeline are used to transport petroleum. In some regions, much of this infrastructure is more than 30 years old, and unless steps are taken to address the problem, the likelihood of a spill from this source is expected to increase. The report recommends that federal agencies continue to work with state environmental agencies and industry to evaluate the threat posed by aging pipelines and to take steps to minimize the potential for a significant spill.

Author's Comment - The first recommendation on improving *discharges has certainly improved in North America. Both Canada and U.S.A. have increased surveillance efforts and enforcement efforts. This is resulting in decreased dumping.*

The second recommendation relates to the aging pipeline infrastructure. Although some effort has been undertaken an accelerated effort is required.

Consumption of Petroleum

From 1985 to 2000, global oil consumption increased from 9.3 to 11.7 million tonnes per day, an increase of more than 25 percent. Releases that occur during the consumption of petroleum, whether by individual car and boat owners, marine vessels, or airplanes, contribute the vast majority of petroleum as a result of human activity. Land-based activities contribute to polluted rivers and streams, which eventually empty to the sea. Consumption related inputs contribute one-third of the total load of petroleum to the sea and represent 85 percent of the anthropogenic load to North American marine waters and 70 percent worldwide. Land-based inputs are highest near urbanized areas and refinery production. More than half of the land-based inputs in North America are estimated to flow to the near shore waters between Maine and Virginia, a region with many urbanized areas and also many sensitive coastal estuaries. In North American marine waters, land runoff combined with marine boating and use of jet skis account for 22 percent of total petroleum inputs and 64 percent of inputs from human activity.

The threat of pollution from urban areas is expected to rise. Current trends indicate that by the year 2010, 60 percent of the U.S. population will live along the coast. Worldwide, two-thirds of the urban centers with populations of 2.5 million or more are near coastal areas. In 1990, heightened awareness of the large number and design inefficiencies of two-stroke engines commonly used in recreational vehicles led the U.S. EPA to begin regulating the “nonroad engine” population under the authority of the Clean Air Act. The marine industry responded by developing cleaner engines in the late 1990s, but the report recommends that federal agencies continue efforts to encourage the phase-out of the older inefficient two-stroke engines and establish a coordinated enforcement policy.

Author’s Comment - The recommendation that the old-style inefficient 2-stroke engine be increasing phased out has been partially carried out. Since the report, there have been many improvements in the efficiency of 2-stroke engines and many of these have been replaced.

Significant Cross-Cutting Issues

Studies completed in the last 20 years confirm that no spill is entirely benign. Further, there is no correlation between the size of a release and its impact. The effects of a petroleum release are a complex function of the rate of release, the nature of the petroleum, and the local physical and biological character of the exposed ecosystem. Some petroleum components are more toxic than others. Polycyclic aromatic hydrocarbons (PAH) are known to be among the more toxic components of petroleum, and their initial concentration is an important factor in the impact of
a given release. Growing evidence suggests that toxic compounds such as PAH in crude oil or refined products at very low concentrations can have adverse effects on biota. This suggests that PAH from chronic sources may be of greater concern than was thought 10 or 15 years ago and that effects of petroleum spills may last longer than expected. The report recommends that federal agencies take several actions to better understand the behavior and effects of petroleum hydrocarbon releases.
These actions include:

- Studying the fate and hydrodynamic transport of petroleum in the sea.

Author's Comment - This recommendation has not been addressed significantly, perhaps because of poor economic times.

- Developing and implementing a rapid response system to collect in situ information about spill behavior and impacts.

Author's Comment - This recommendation has not been addressed significantly.

- Significantly enhancing research efforts to more fully understand the risk posed to humans and the marine environment by chronic release of petroleum, especially the cumulative effects of petroleum-related toxic compounds such as PAH.

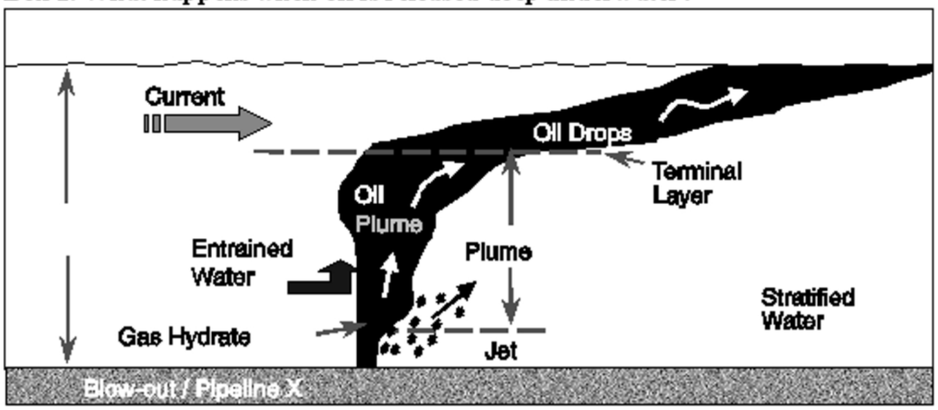
Author's Comment -This recommendation has not been addressed significantly.

- Continuing research on effects of releases on wild populations, including a program to assess ecosystems in areas known to be at risk from spills or other releases of petroleum.

Author's Comment - This recommendation has not been addressed significantly.

The oil in the sea report also summarized the overall behavior of a sub-sea blowout. The following two boxes summarize this behavior.

Box 1. What happens when oil is released deep underwater?



Surface oil slicks capture public attention, but a substantial percentage of accidental spills occur beneath the surface, typically from the seafloor. Examples include blowouts of exploration wells, such as the BP-Gulf of Mexico disaster, pipeline ruptures, and shipwrecks. Oil leaking from a pressurized underwater spill like a pipeline blowout doesn't simply rise to the surface— it forms underwater plumes of oil and natural gas that billow and drift beneath the oceans surface. Water temperature and salinity, the depth of the leak, and the density of the gas and oil all impact the physics of plume formation, but there are three distinct phases of any pressurized, underwater spill:

Jet Phase: The speed of the oil and natural gas being expelled from the pressurized, confined space of the pipeline to the open ocean makes the oil form droplets and the gas form bubbles.

Plume Phase: The momentum of these tiny droplets and bubbles drags significant volumes of sea water upward into the water column, forming a plume. In deeper water, so much water is incorporated into the plume that eventually, the oil-natural gas-water mix is no longer buoyant, and the plume will stop rising, suspended in the water column at the terminal layer. If heavier components sink out of the suspension, the plume may reform and begin to rise again past that terminal layer in a process known as "peeling".

Post-terminal Phase: Once the plume reaches the final terminal layer, the rise of the oil-gas-hydrates is driven purely by the buoyancy of the individual droplets and bubbles.

Once the oil reaches the surface, it tends to form a surface slick thinner than that seen during a typical shallow-water release, in part due to the diffusion and dispersal of oil droplets as they rise, and in part due to the layers of oil arriving at the surface at different stages. Much, if not all, of the gas associated with the oil be dissolved into the water column. Natural gas released at depths below 300 meters can form hydrates, a mix of natural gas and water similar to ice. Hydrates are dense, so if they form it is likely that the buoyancy of the plume would be greatly reduced, increasing the time that it takes for the oil and gas to reach the surface.

From: Oil in the Sea III: Inputs, Fates, and Effects, National Research Council, 2003.

4 The Oil Spill Dispersants by the National Academy of Sciences - 2006

(Note: this is my paraphrase of a NAS summary but all opinions are mine. Direct recommendations are given in quotes.)

Oil spill chemical dispersants are surfactant mixtures along with solvents which are intended to enhance the production of small oil droplets in the water. This is similar to the use of surfactants in oil-based or Italian salad dressings. There are many issues with oil spill dispersants including: the fact that the dispersions ultimately break down the oil rises; the toxicity of such dispersions and the effectiveness of products. These issues are covered in the main report. The major recommendations in the report are:

1. “Decisions to use dispersants involve trade-offs. Oil dispersants break up slicks, enhancing the amount of oil that physically mixes into the water column and reducing the potential that a slick will contaminate shoreline habitats or come into contact with birds, marine mammals, or other organisms in coastal ecosystems. At the same time, using dispersants increases the exposure of water column and sea floor life to spilled oil.”

2. “The window of opportunity for using dispersants is early, typically within hours to 1 or 2 days after an oil spill. After that, natural "weathering" of an oil slick on the surface of the sea, caused by impacts such as the heat from the sun or buffeting by waves, makes oil more difficult to disperse. Therefore, failure to make a timely decision regarding dispersant use can be a decision not to use dispersants.”

3. “Better information is needed to determine the length of the window of opportunity and the effectiveness of dispersant application for different oil types and environmental conditions. Given the potential impacts that dispersed oil may have on water-column and seafloor biota and habitats, thoughtful analyses are required so that decision makers can understand the potential impacts of a spill with and without dispersant application. A focused series of studies is needed to provide the information needed for an effective response to oil spills of all types and in various environments using both laboratory research and, in the event of a spill, field research in areas treated with dispersants.”

Author’s Comment - This recommendation has not been addressed significantly. Dispersant use in the Gulf has largely ignored any of the above considerations.

4. “More accurate methods of predicting the behavior of dispersed oil are needed to better predict the amount of oil that will mix into the water column. Limitations of current methods for predicting concentrations of dispersed oil in the water column include inaccurate representation of the natural physical processes involved in dispersal. Improved representations will allow.”

Author's Comment - This recommendation has not been addressed. Further, the significant issue of the re-surfacing of oil after dispersion has not been addressed.

8. "Exposure to the air, the heat of the sun, and the turbulence of the waves can "weather" oil on the surface of the water, creating an emulsion; but no wave-tank or laboratory studies have investigated how dispersants would work on an oil and water emulsion. Studies are needed to investigate the chemical treatment of weathered oil emulsions."

Author's Comment - This recommendation has not been addressed. Further, the researchers have not addressed the technical definition of emulsions.

5. "The recent introduction of safer chemical dispersants means that the toxicity of dispersed oil now typically results primarily from compounds within the oil itself. It is known that breaking up oil slicks into smaller droplets exposes more of the toxic compounds in oil, such as polynuclear aromatic hydrocarbons (PAH), but in general the mechanisms of toxicity are poorly understood. With a better understanding of the toxicity of dispersed oil to marine organisms, data can be generated on toxic levels and thresholds for use by decision makers."

Author's Comment - This recommendation has not been addressed.

6. "The factors controlling the biological and physical processes which determine the ultimate fate of dispersed oil are poorly understood. Dispersed oil could accumulate in more stagnant areas, or could be consumed by plankton in the water column and enter the food chain. More detailed information on weathering rates and on the ultimate fate of dispersed oil are needed."

Author's Comment - This recommendation has not been addressed.

7. "Data from field studies on the concentration and behavior of dispersed oil are needed to validate models and provide real-world data to improve knowledge of oil fate and effects. Detailed plans should be developed, including the pre-positioning of equipment and human resources, for rapid deployment of a monitoring effort for dispersant applications in the event of a spill so that the consequences can be recorded."

Author's Comment - This recommendation has not been addressed.

5 Spill Research

Spill research is an important facet to develop capability to deal with oil spills. Many of the current capabilities to deal with oil derive from research programs. Research programs/projects may be divided into 12 general areas:

a) Recovery - This includes physical recovery methods such as skimmers, booms, and sorbents. While there was extensive development in this area in the 1970's, there has been little research other than commercial activity in this area. Since physical recovery is the prime recovery method suggested by several governments, this area should receive much more attention.

b) Treatment - This includes chemical treatment such dispersants, solidifiers, surface washing agents, biodegradation agents, etc. It is felt that far too much effort has been put into this area compared to the other areas resulting in generally disappointing outcomes. The agents have never performed as hoped and have consumed great amounts of resources that could have otherwise been devoted to other priority areas.

c) Arctic spills - This includes countermeasures in special areas such as the Arctic and the tropics. Performing a variety of countermeasures and understanding spill behavior in special areas such as the Arctic and tropics, requires special efforts and special studies. Similar to recovery projects, extensive efforts had been carried out in the late 1970's and early 1980's, but funding stalled out quickly and little work has been done since.

d) Burning - In-situ burning has been use sparsely in the past 20 years. Several studies have examined emissions and other factors. Some work has been carried out on other facets such as ignition and the use of fire-resistant booms. Only a moderate amount of work would be needed in the future.

e) Fate - The fate of oil includes long-term behavior and effects. This area has mostly been studied by post-assessment of spills. Problems with this include the lack of good starting data and the inability to measure critical parameters - especially at the start. Good experimental studies of this are very few. Since this is a very important area for assessing the long-term effects of oil spills on the environment, priority resourcing is suggested.

f) Behavior - The behavior of oil includes processes such as evaporation, emulsification, dissolution, dispersion, and many others such as plume rise and behavior during sub-sea blowouts. While evaporation and emulsification are now reasonably understood, there remains a large gap in knowledge of the other behaviors. These are fundamental studies and thus in-depth academic/research study is required. It is suggested that this is also an area where more research is required.

g) Effects - this includes the toxicological effects of oil on various biota and ecosystems. It is indeed a broad area. Much of the work in the past has consisted of acute toxicity testing on typical test organisms. Much more work is needed on specialized toxicity testing such as genotoxicity, endocrine disrupting capacity, and studies of sub-lethal effects. Long-term studies are particularly insufficient. This area is felt to be a priority for the future.

h) Analysis - this includes the development, improvement and testing of chemical and in some cases, biological test methods for oil. This area has received little attention in the past. Further, several groups are still using nonstandard and in some cases, inappropriate methods, in their work. Some research efforts are needed in this area.

i) Remote Sensing - This includes the detection, tracking and remote sensing of oil spills. In the past this area had received moderate funding in the 1970's and early 1980's, after which resources fell off. More efforts in this important area are needed.

j) Modeling - Modeling includes the prediction of oil location and state in the future as well as backtracking, evaluating environmental damage and predicting sub-sea rise and behavior. Modeling inputs are highly depending on information gathered in other categories such as

behavior, fate and effects. This area had some funding in the past and is suggested to receive similar funding in the future.
k) Risk Analysis and Planning - This is a broad category including such studies as various forms of risk analysis, contingency planning, management analysis, etc. It is suggested that this area receive similar funding in the future, with emphasis on developing new methods.
l) In-Situ Remediation - This includes studies of bioremediation and natural attenuation. This area has received some funding in the past. It is suggested that similar funding should be placed in the future.

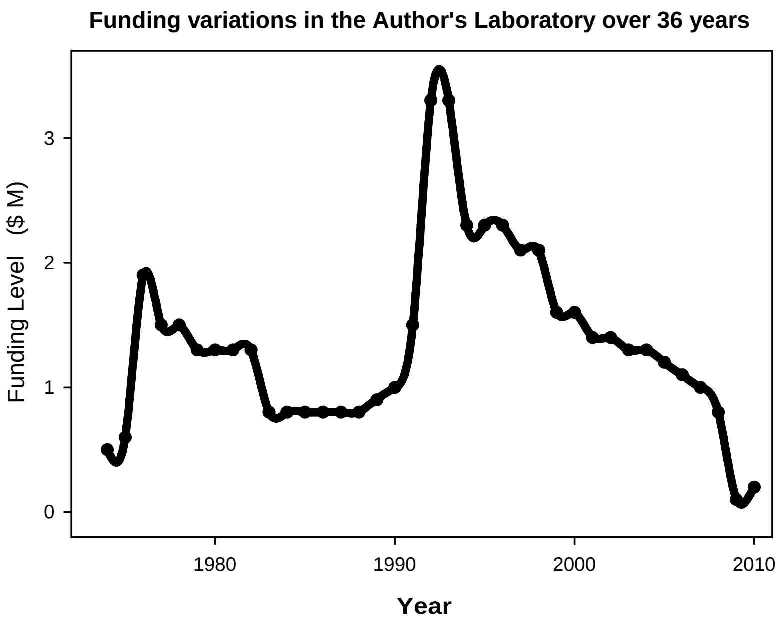
My own summary assessment of these research areas appears in the attached table along with assessments of project costs, durations, and input from the private sector.

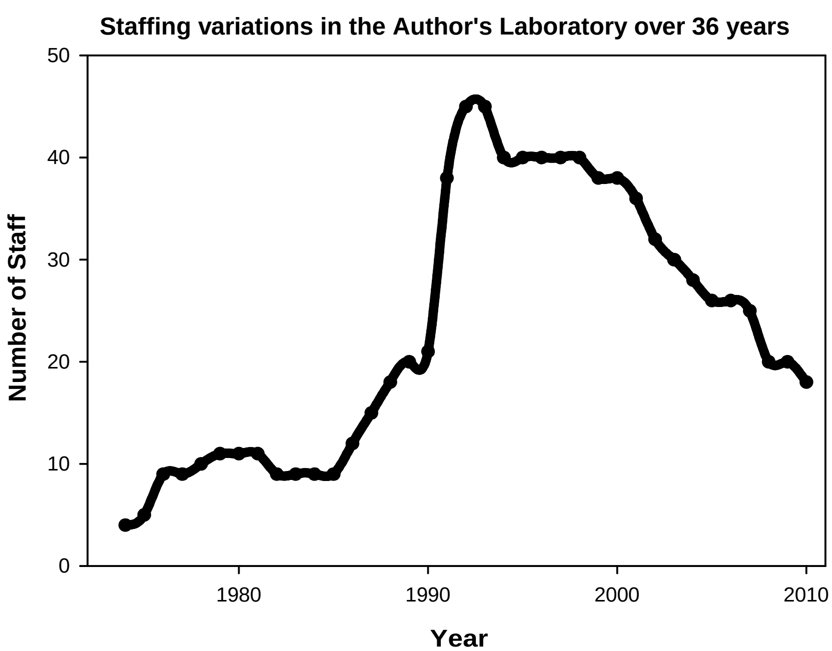
6 Issues in Spill Research

There are a number of issues in spill research for which I wish to present my views.

A) Highly Variable Funding Researchers in oil spills have, in the past, received highly variable funding. This is largely due to management perception about the priority of this area. A funding cycle typically goes up to high levels after a major spill such as the recent Gulf spill. Then two years later, ‘other priorities’ siphon off funding and soon the researchers are scrambling just to keep the labs operating. It is more typical that the research unit is then closed. New units are then opened after the next big spill. This type of cycling obviously does not lead to productive research, rather it is a waste of resources. It would be much better to fund the programs at a moderate level of funding for at least 10 years. It requires 2 years to have a new researcher become familiar with the oil spill field and 5 years to become fully productive. Many funding cycles do not enable new researchers to become productive in the field.

To illustrate the variability of funding the following two charts show my own research funding over more than 25 years. This is the funding given to the group by their own government agency. These figures show the high variability in resources over time. During this time the mandate and expectations of the program were about the same.





B) Impartial 'Research' An issue that does arise in the oil spill field is that of 'biased studies'. There are cases, particularly in chemical oil dispersants, where there are results completely contrary to those from similar studies. One of the problems is that proponents, often oil companies, have funding some of the studies. While this in itself is actually good, there are too many cases in which the 'opposing' points of view are funded by persons or groups having an interest in the matter. Rules might be established such as in the pharmaceutical industry, to ensure studies are conducted in a conflict-of-interest-free environment.

C) Re-Invention Because research is often started and stopped with the various funding cycles, there is much re-invention occurring. The start of many research groups is often marked by starting projects which had already been done in the past. Often 3 years are wasted in this type of re-invention. This is usually due to poor communication, lack of proper literature review (topics that will also be covered) and sometimes due to regional or local pride.

D) Literature The literature on oil spills and oil spill research is not used by some researchers. The reasons for this are not apparent. Currently most important literature is indexed on the searching program SCOPUS, to which can be accessed in almost all libraries or institutes in the world. Further SCOPUS also accesses important conferences on oil spills such as AMOP and IOSC. A personal story illustrates the issue. The author of this was recently present at a spill conference in Europe and presented a paper in an oil spill behavior session. Upon reading the proceedings it was noted that all of the other four authors had no references newer than 1982! These were more than 20 years old and many significant findings had been made in the meantime. Needless to say, all four of these presentations and papers were irrelevant.

E) Scientific Communication There are few communication fora for scientists - especially on an international basis. There are the annual AMOP seminars in Canada, the annual Environment Canada Research meetings and after that tri-annual conferences in USA, Europe and South East Asia. This has also created somewhat of a problem in that often communication occurs in only one of these three world areas and little communication sometimes occurs between scientists in the three world areas. Unfortunately many scientists, especially those from state or local organizations, are unable to attend these fora. Sometimes researchers never have the opportunity to meet their counterparts in other parts of the world or country in their lifetimes. Collaborative research is a good way to improve communication. It must be recognized that researchers need to directly communicate with each other and to attend the usual conferences and meetings as well as to engage in collaborative research.

F) Myths and Re-evaluation A number of myths have been developed regarding oil spills, and because of the many communication issues noted above, these myths persist to this day. Examples of these include: that dispersing oil improves biodegradation, that pour point is solidification point, etc. The opposite of these is true. It is important that new researchers to the field consult with experts long in the field to begin their work on a solid footing. It is important to avoid re-invention, but at the same time it is important to ensure that essential information is re-evaluated before proceeding.

G) Transient Research Because the funding for research is transient, often research institutes come and go within 5 to 8 year periods. This causes several problems. First there is a massive loss of resources with much output. Second, the new research institutes often draw away resources from older existing institutes. Thus, there is a net loss in research.

H) Good Field Data For most projects there is a strong need for good, reliable field data. 'Real' spill data would be particularly good. Plans have been developed for data collection, but never implemented. Collection of such field data was also a recommendation of both of the NAS studies noted above. Because of response priorities, research data is rarely collected during actual spills. This data would be priceless for future work. Further, access to good, qualified data should be given to any researcher with a legitimate need.