U.S. Department of the Interior
Minerals Mangement Service

Arctic Oil Spill Response Research and Development Program

A Decade of Achievement

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Minerals Management Service

Executive Summary

This report provides a comprehensive summary of activities and accomplishments of the Minerals Management Service (MMS) Arctic Oil Spill Response Research (OSRR) program. The program directly supports MMS missions of ensuring safe and sound operations in the Outer Continental Shelf (OCS) through leadership in research and standards development for Arctic operations and in facilitating the use of science in making policy and leasing decisions.

From 1997 through 2008 the MMS has successfully developed and conducted thirty-one projects directly related to improving equipment and processes for the prompt identification and removal of oil from harsh Arctic environments. Rather than working independently, the OSRR program has reached out and partnered with state and federal government agencies, academia, private industry, and other countries who share similar interests in Arctic oil spill response research. As a product of these partnerships, over 40 per cent of these projects were jointly funded.

The OSRR projects highlighted in this document are examples of how the MMS has and continues to address the ongoing operational and environmental concerns associated with energy exploration and exploitation in the Arctic. Research projects, many of which were conducted at Ohmsett - The National Oil Spill Response Test Facility ranging from mechanical containment and recovery in ice conditions, to dispersant use in cold water, reflect an expanding body of work that has advanced knowledge of oil spill response capabilities in cold water environments. Quoted liberally in scientific literature, OSRR projects are helping drive cold water research both nationally and internationally. The MMS as well as U.S. and foreign government agencies and organizations world wide utilize the results from the OSRR program and Ohmsett in making planning, regulatory, and emergency response decisions.

The MMS has been the principal U.S. federal agency funding oil spill response research for the past 25 years and is now the leader in Arctic response research. The successes of the OSRR program are a result of appropriated funding from the Oil Spill Liability Trust Fund and continued support by MMS Management. Maintaining this momentum is critical to ensuring that the best available technologies for response are ready to support future oil exploration and exploitation in the Arctic.

Significant Accomplishments of the MMS Arctic Oil Spill Response Research Program include:

- Detection of Oil in and Under Ice
- Oil Spill Thickness Sensor
- Mechanical Containment and Recovery in Ice Environments
- In Situ Burn Research
- Dispersants in Cold Water/Broken Ice Environments
- Chemical Herders
- Operation of Ohmsett – The National Oil Spill Response Test Facility

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2. BACKGROUND

This report provides a comprehensive summary of the Minerals Management Service (MMS) Arctic Oil Spill Response Research (OSRR) program undertaken during the period following the Exxon Valdez oil spill and in response to the research and development provisions of Title VII contained in the Oil Pollution Act of 1990 (OPA-90).
The MMS OSRR program is an openly-cooperative effort bringing together funding and expertise from research partners in government agencies, industry, academia, and the international community for the sole purpose of participating in research and development (R&D) projects. Many of these projects are joint industry projects (JIP's) where MMS partners with other stakeholders to maximize the effectiveness of research dollars. From 1997 through 2008 the MMS successfully conducted thirty-one OSRR projects directly related to improving Arctic oil spill cleanup and to providing regulators with the scientific data necessary to support decisions. More than 40% of these Arctic projects were jointly funded with state and federal government agencies, academia, private industry and other Arctic countries.

The MMS OSRR program provides research leadership to improve the capabilities for detecting and responding to an oil spill in the marine environment. In the past decade, the OSRR program as well as the testing, training and research conducted at Ohmsett – The National Oil Spill Response Test Facility has been highly successful and has made substantive technological advances in the ability to clean up oil spills in Arctic environments. This includes development of systems, equipment and methodologies that can be used in extremely cold temperatures and in broken ice conditions. These substantive technological advances have allowed oil and gas exploration to advance in Arctic offshore environments and will produce real cost savings in the future.

The OSRR project highlighted in this document are examples of how the MMS has and continues to address the ongoing operational and environmental issues associated with Arctic offshore oil and gas activities. The document also demonstrates how the Ohmsett facility continues to be utilized in exciting new ways for comparative evaluation of response technologies for use in cold water/broken ice conditions.

Accomplishments are summarized for the following topics:

1. Fate and Behavior of Oil in Ice
2. Remote Sensing and Surveillance- Detection of Oil On, In and Under Ice
3. Remote Sensing and Surveillance - Oil Spill Thickness Sensor
4. Mechanical Containment and Recovery in Ice Environments
5. In Situ Burn Research
6. Dispersants in Cold Water/Broken Ice Environments
7. Chemical Herders
8. Ohmsett – The National Oil Spill Response Test Facility
9. Control of Underwater Noise
10. Arctic Oil Spill Research Outreach Efforts

Each summary includes a description of the technology, the present state of the knowledge regarding its capabilities and limitations, and the research projects the MMS has initiated and funded to support the development of the technology. The topic overview is not intended to be exhaustive, but rather a quick look at the adequacy of current scientific and technical information necessary to support decision-making directly related to Arctic oil spill clean up

Significant Accomplishments of the MMS Arctic Oil Spill Response Research Program

Detection of Oil in and Under Ice - Development of Ground Penetrating Radar into a useful operational tool to reliably detect and map oil trapped in, under, on, or among ice

Oil Spill Thickness Sensor - Development of an aerial sensor to measure and accurately map the thickness of oil on water and to rapidly transmit this information to response personnel in the command post. This includes the ability to determine the thickest portions of the oil slick and to operate effectively in bad weather or darkness

Mechanical Containment and Recovery in Ice Environments (Open Water, Broken Ice, and On or Under Ice) - More than a decade of MMS research has focused on methods to improve the effectiveness of equipment and techniques for the mechanical recovery of oil spills in ice-infested waters. This research has substantially improved mechanical recovery of oil spills in Arctic environments.

In Situ Burn Research - Development of in situ burning into a viable countermeasure for oil spills in Arctic environments.

Dispersants in Cold Water/Broken Ice Environments - Experiments at Ohmsett have demonstrated that dispersants are effective in near-freezing water temperatures but this is highly dependent on the properties of the crude oil. Dispersants can be effective in broken ice if there is some mixing energy present. Dispersants provide an invaluable third response option when strong winds and sea conditions make mechanical cleanup and in situ burn techniques unsafe and/or ineffective.

Chemical Herders - The use of chemical herding agents to extend the window of opportunity for oil spill response countermeasures in Arctic environments

Ohmsett – The National Oil Spill Response Test Facility

Ohmsett is an integral part of the MMS oil spill research program and is essential for fulfilling the agency's regulatory responsibilities under OPA-90. The facility directly supports MMS's mission of ensuring safe and environmentally sound oil and gas development on the Outer Continental Shelf. Ohmsett is not only a vital component of the MMS oil spill research, it is also a national asset where government agencies, private industry and academia can conduct full-scale oil spill research and development programs in a controlled environment with real oil. In addition, it is the premier hands-on training site for spill response personnel from state and federal government agencies, private industry and foreign countries.

To respond to the challenges of testing and evaluating the equipment required to respond to oil spills in ice infested waters the MMS upgraded the testing capabilities at Ohmsett in 2000 to provide a controlled environment for cold water testing and training (with or without ice). The facility is now able to simulate realistic broken ice conditions. These upgrades enable the Ohmsett facility to remain open year round offering cold water testing, training, and research opportunities during the winter months. Replications of cold water/broken ice conditions at Ohmsett open the way for:

- Remote sensing experiments conducted in, on and under ice
- Development and testing of mechanical containment and recovery equipment for use in Arctic environments
- Fireboom evaluations in cold water/broken ice using an air-injected propane burner system that realistically simulates in situ burning at sea.
- Large scale dispersant effectiveness testing in cold water/broken ice
- Cold water oil spill response training

- Testing instruments and equipment to locate and recover sunken and submerged oil
- Large scale testing of chemical herders in cold water/broken ice
- Testing and evaluating fire-resistant containment booms

Without Ohmsett, the research, testing and evaluation of equipment, systems and methodologies with real oil as well as responder training would have to be conducted during actual spills where conditions cannot be repeated and would interfere with response operations.

The MMS OSRR Program provides research leadership to improve the capabilities for detecting and responding to an oil spill in the marine environment.
The MMS is the principal United States federal agency funding OSRR. For more than 25 years, the MMS has maintained a comprehensive long-term program to improve oil spill response technologies. Consistent long-term funding has enabled the MMS to develop, implement, and successfully conduct a nationwide OSRR Program.

Funding for the OSRR program activities is specifically appropriated from the Oil Spill Liability Trust Fund (OSLTF). This long-term funding allows the MMS to plan and implement OSRR projects that have multiple phases and that can be conducted in a stepwise approach over a several year period. This enables the MMS to secure cooperative funding from private industry as well as countries that have offshore regulatory programs. This allows the MMS to foster collaborative research at the international level, optimize current and future research initiatives, minimize research duplication, and ensure that MMS's interests are addressed. The MMS OSRR program has been highly efficient, monitoring and capitalizing on the efforts of other agencies and industry whenever possible through active partnering. It has reinforced the MMS's leadership position in oil spill response R&D and encouraged oil spill technology development efforts by academia and industry.

Section 7001 of OPA-90 requires the Chairman of the Interagency Coordinating Committee on Oil Pollution Research (Interagency Committee) to submit a Biennial Report to Congress on the activities carried out under this section in the two preceding years. In the last two reports submitted to Congress (October 2005 and October 2007), almost fifty percent of the oil spill response research reported to Congress was initiated and funded by the MMS.

Results from MMS Arctic OSRR program have enabled the MMS to conduct lease sales in the Beaufort and Chukchi Seas. Results from dispersants testing in cold water/broken ice conditions at Ohmsett have been used by industry to gain regulatory approval for the use of this countermeasure for the Sakhalin Island project in Russia and for planned projects in the Canadian Beaufort Sea. This was a new countermeasure for Arctic spill response.

The MMS maintains and operates Ohmsett – The National Oil Spill Response Test facility in Leonardo, NJ. Ohmsett represents a necessary intermediate step between small-scale bench testing and open water testing of equipment. Many of today's commercially available oil spill cleanup products and services have been tested at Ohmsett either as off-the-shelf commercially available equipment, or as equipment or technology still under development. In North America, a large portion of existing independent performance data and information on containment booms and skimmers have been obtained through testing at Ohmsett. Without Ohmsett, the testing and evaluation of equipment, systems and methodologies as well as responder training would have to be conducted during actual oil spills where conditions cannot be repeated and would interfere with response operations

Ohmsett is not only a vital component of the MMS oil spill research, it is also a national asset where government agencies, private industry and academia can conduct full-scale oil spill research and development

programs in a controlled environment with real oil. It is the premier hands-on training site for spill response personnel from state and federal government agencies, private industry and foreign countries.

The OSRR Program is responsive to the information and technological needs of MMS's regional and district offices.
Research and development needs come from a specific concern, problem, regulatory issue or data gap in a MMS region. Each issue has an identifiable obstacle that needs addressing, investigating or solving. These critical problems and issues determine the future research direction. Results obtained from the OSRR program are directly integrated into MMS's offshore operations and are used to make regulatory decisions pertaining to permitting and approving plans, safety and pollution inspections, enforcement actions, and training requirements.

Success from the OSRR program comes from a step-wise research approach to solve specific research needs that includes formation of joint industry projects to expand the scope and leverage program funds.
Many significant technical advances in Arctic spill response can be attributed to successful multi-phase research projects that involve scientists worldwide. Research into oil and ice behavior and the development of response strategies traditionally involves a combination of laboratory small-scale tests, meso-scale tank and basin experiments, and full-scale field trials. The MMS has used this approach to develop, initiate, and conduct many successful oil spill research projects.

Once the MMS has identified a research need or data gap in spill response we initiate and conduct a scoping project to define the current state-of-the-art for this technology or methodology. The results from these scoping projects are used to develop a systematic approach required to successfully address the data need.

Communicating the results from these projects to government agencies and private industry is the next step to build consensus on the future research direction. A carefully focused work plan or agenda encompassing a priority list of projects is developed. It is generally beyond the capabilities of any one organization to fund these projects in their entirety. International cooperation, including governmental and industry participants is needed to make substantial progress in the most important research and development areas. Given the specialized nature and limited number or researchers actively working on oil spill response, it is essential to involve different centers of expertise on a global scale. The MMS has initiated many successful joint industry projects (national or international) to leverage our program funds and expand the scope of the project to develop innovative or new technological advancements to detect, containment, and cleanup oil spills in Arctic environments. Examples of successes using the approach above are:

- Development of Ground Penetrating Radar into a useful operational tool to detect and map oil trapped in, under, on, or among ice
- Development of an aerial sensor to measure and accurately map the thickness of oil on water and that rapidly sends this information to response personnel in the command post. This includes the ability to determine the thickest portions of the oil slick and to operate effectively in bad weather or darkness
- Development equipment and techniques for the mechanical recovery of oil spilled in ice-infested waters
- Development of in situ burning into a viable countermeasure for offshore oil spills
- The use of chemical herding agents to extend the window of opportunity for oil spill response options in Arctic environments

1. Introduction

The MMS is the principal United States federal agency funding OSRR. For more than 25 years, the MMS has maintained a comprehensive long-term program to improve oil spill response technologies. The focus of the program is to improve the knowledge and technologies used for the detection, containment and cleanup of oil spills that may occur on the U. S. Outer Continental Shelf. Information derived from the OSRR program is directly integrated into MMS's offshore operations and is used to make regulatory decisions pertaining to permitting and approving plans, safety and pollution inspections, enforcement actions, and training requirements.

The MMS has maintained an active program to fund and conduct Arctic oil spill research for over a decade. These R&D projects were developed to improve the ability of responders to deal with oil spills in the Arctic marine environment and to provide regulators with the data necessary to support response decisions. Current MMS research is addressing oil spills that may occur on top of or underneath solid, stable ice, in broken ice, or in cold open waters. In the Arctic there are four distinct timeframes for oil spill response; open water, freeze up, over winter, and break up. Two priority areas identified for Arctic oil spill research are: to develop operational tools to detect and map oil in any ice type and to develop effective response options for spilled oil in moving, broken pack ice.

The MMS OSRR program is addressing these needs on two levels. First through direct applied research and second through testing, training and basic research conducted at Ohmsett – The National Oil Spill Response Test Facility in Leonardo, New Jersey. The OSRR program incorporates operational research experiments conducted with oil in small and large test tanks, at sea, and in ice to demonstrate and improve oil spill response technologies and methodologies. More than a third of the MMS OSRR projects were jointly funded with state and federal government agencies, private industry, academia and foreign countries. Participation in JIP's is the most effective and efficient means to leverage available research funds.

The OSRR projects highlighted in this document are examples of how the MMS has and is currently addressing ongoing operational and environmental issues associated with Arctic offshore oil and gas activities and how the Ohmsett facility is being utilized in new ways for comparative evaluation of response technologies for use in cold water/broken ice conditions. MMS Arctic OSRR projects are focused in five broad areas:

- Fate and behavior of oil in ice
- Remote sensing and surveillance
- Mechanical response,
- Chemical treating agents including dispersants
- In-situ burning.

There are definite results from these R&D efforts. The MMS maintains a website at http://www.mms.gov/tarprojectcategories/ArcticOilSpillResponseResearch.htm that contains a listing of all Arctic OSRR projects funded by the MMS as well as downloadable reports and film clips free of charge.

1.1 Countermeasures for Oil Spills Arctic Environments

Response options in Arctic environments vary depending on seasonal oceanographic and meteorological environments. The behavior of oil spilled in cold, ice covered waters is governed largely by the ice concentrations in the case of broken ice and the process of encapsulation and subsequent migration in the case of solid ice. Each season presents different advantages and drawbacks for spill response. During freeze-up and break-up, drifting ice and limited site access restrict the possible response options and significantly reduce recovery effectiveness. Mid-winter, although associated with long periods of darkness and cold temperatures, provides a stable ice cover that not only naturally contains the oil within a relatively small area but also provides a safe working platform for oil recovery and transport.

For the case of spills under or on fast ice, there is a range of effective countermeasure options that can result in very high recovery effectiveness. Countermeasures to deal with spills in moving pack ice are much more limited and will likely result in highly variable recovery values depending on a variety of natural conditions, logistical constraints, and the type of oil spilled. The focus of MMS oil spill research has been on marine (salt water) conditions representative of the arctic continental shelf regions (Chukchi Sea, Beaufort Sea, Barents Sea) and the marginal ice zones and subarctic areas such as the Bearing Sea, Labrador Sea, and the Sea of Okhotsk.

1.2 Funding

Consistent long-term funding has enabled the MMS to develop and implement a successful OSRR Program. Funding for MMS OSRR activities is specifically appropriated from the Oil Spill Liability Trust Fund (OSLTF). The OSLTF was initially funded through a tax of five cents per barrel of oil, collected from industry. Subsequent funding for the OSLTF is derived from:

- **Barrel Tax.** The largest source of revenue has been a 5-cent-per-barrel tax, collected from the oil industry on petroleum produced in or imported to the United States. The tax was suspended in July 1993 because the Fund reached its statutory limit. It was reinstated in July 1994, when the balance declined below $1 billion, but expired at the end of 1994 because of the sunset provision in the law. The 2005 Energy Policy Act again reinstated the tax (effective April 2006).
- **Transfers.** A second major source of revenue has been transfers from other existing pollution funds. Total transfers into the Fund since 1990 have exceeded $550 million. No additional funds remain to be transferred to the OSLTF.
- **Interest.** Currently, the largest recurring source of OSLTF revenue is the interest on the Fund principal from U.S. Treasury investments. As a result of historically low interest rates, interest income has declined significantly in recent years, falling to $13.5 million (or 45 percent of revenue) in 2004.
- **Cost Recoveries.** Another source is cost recoveries from responsible parties (RPs); those responsible for oil incidents are liable for costs and damages. The NPFC bills RPs to recover costs expended by the Fund. As these monies are recovered, they are deposited into the Fund.
- **Penalties**. In addition to paying for clean-up costs, RPs may incur fines and civil penalties under OPA, the Federal Water Pollution Control Act, the Deepwater Port Act, and the Trans-Alaska Pipeline Authorization Act. Penalty deposits into the OSLTF are generally between $4 million and $7 million per year.

As intended by OPA-90, the companies that produce and transport oil are funding MMS OSRR to improve oil spill response capabilities.

2. Fate and Behavior of Oil in Arctic Environments

Crude oils and oil products behave quite differently if spilled in the Arctic environment due to the physical and chemical properties of the oil spilled. These properties influence the selection of response equipment and methods applicable for spill cleanup. Knowledge of the ultimate fate and behavior of oil should drive countermeasure decisions. The fate and behavior of oil in ice-covered waters is governed by a number of important weathering processes have a direct bearing on oil recovery operations. Weathering is the combined effect of the processes taking place when oil is spilt to the sea (evaporation, water-in-oil emulsification, drift, spreading etc.) and will influence the fate and behavior of the oil. The physical distribution and condition of spilled oil under, within or on top of the ice plays a major role in determining the most effective response strategies at different stages in the ice growth and decay cycle. Before oil spill response plans are

developed or approved, it is important to understand the chemistry and physical behavior of the oil and how its characteristics change over time, once the oil is spilled.

In the early 1990's, the MMS and Environment Canada (EC) initiated a five-year research program know as BOSS – Behavior of Oil Spills. All facets of oil spill behavior were address including oil in ice. This program included laboratory, small-scale, large-scale and full-scale field experiments and resulted in a comprehensive collection of information on oil behavior. At the same time, the MMS, EC, and the American Petroleum Institute co-funded a project to analyze different types of crude oil and oil products and include this information in a searchable database. The database currently has information on 464 different oil types. It is available free of charge at http://www.etc-cte.ec.gc.ca/databases/OilProperties/oil_prop_e.html.

Current Technology Status - Fate and Behavior of Oil in Arctic Environments
The mechanisms for oil weathering in Arctic environments (evaporation, water-in-oil emulsification, drift, spreading etc.) have been studied and incorporated into various computer models that can predict long term spill behavior. The weathering rate is normally much slower for an oil spill in ice. This means that the emulsification rate and viscosity increase may be slowed down resulting in an increased "window of opportunity" for the use of most response techniques. The spreading of oil will normally be much slower resulting in increased oil film thickness that may be favorable for spill response. Oil with higher pour points can solidify in the cold, which will affect the response strategy. Under certain conditions, solidification could make recovery on land or water easier. Results from ongoing oil behavior research will be used to develop/calibrate new computer models/algorithms for the fate and behavior of spilled oil.
Research Projects – Fate and Behavior of Oil in Arctic Environments

2.1. Empirical Weathering of Oil
In 2004, the MMS initiated a four year research project focusing on fundamental weathering processes of oil in ice (spreading, evaporation, migration etc.). This program included laboratory testing, basin tests and large-scale experiments conducted at Ohmsett facility. In another project, SINTEF (Norway) performed a large number of laboratory and field tests to study the weathering of different oils in different ice conditions. The MMS and SINTEF data will be used to develop/refine weathering models to describe oil weathering in ice. Verification of this data will be conducted through an experimental field trial conducted in May 2009, offshore Svalbard, Norway. Results from this project will give a much better understanding of the fate and behavior of oil in ice.

3. Remote Sensing and Surveillance- Detection of Oil On, In and Under Ice
Although oil spills in ice-covered waters are generally contained within a much smaller area (compared with open water spills) the presence of ice in conjunction with limited daylight greatly complicates initial detection, mapping and subsequent monitoring and tracking of the oil.

Spills on Ice – The detection of oil spills on ice immediately following a spill is reasonably easy since the oil is generally thick and visible in sharp contract to the snow. Aerial reconnaissance is the best technique. Difficulties can arise when a fresh snowfall at the time of a spill covers the oil before aerial observers arrive on scene. It may then be necessary to take cores in a grid pattern to delineate the extent of the contaminated area.

Spills in Broken Ice – It is not easy to detect and map spilled oil among drifting broken ice. New ice, oil and calm water make aerial observations difficult.

Spills in and Under Ice – The detection and mapping of spilled oil encapsulated in and under ice is very difficult since the oil is hidden from view beneath a (generally) thick sheet of ice.

The ability to reliably detect and map oil trapped in, under, on, or among ice is critical to mounting and effective response in Arctic waters. In the past the only successful method for detecting the presence of oil in or under ice involved drilling holes through the ice sheet or by sending divers down under the ice to delineate the extent of a spill. This method is expensive, labor intensive, and exposes personnel to the vagaries of extreme weather. There is a strong motivation to identify and develop a reliable and safe means of remotely detecting oil trapped in and under ice.

Current Technology Status- Detection of Oil On, In and Under Ice

In 1999 the MMS initiated a project to evaluate potential remote sensing techniques to detect oil trapped within and under ice. Of the many technologies recently reviewed, only ground penetrating radar (GPR) showed potential. Between 2003 and 2008 the MMS initiated four international JIP's to develop GPR into a functional remote monitoring sensor. Two of these projects involved a permitted, intentional oil release for research purposes. The GPR system currently available is capable of detecting and mapping oil in ice over a broad operational time window from early to late winter, typically November to April in the Arctic. This window of opportunity covers approximately 70% of the near shore fast ice season in most years. The current generation GPR is capable of mapping oil under or trapped within growing winter ice from 30 to 210 cm (1 to 7 feet thick). Minimum oil thickness detection limit appears to be roughly 2 cm. From an airborne platform (helicopter) at a height of 20 meters the GPR could consistently image the ice water interface under 80 cm (3 feet) thick cold ice (equivalent to late December or January in the Beaufort Sea). GPR can now be considered as an operational tool in the Arctic to detect oil trapped on, within, and under ice.

The MMS is currently initiating a new international JIP that will use the results from four previous projects to build a new airborne GPR system that will incorporate a number of major technological improvements over currently available systems and significantly expand the practical operating window for oil detection in a wide range of ice and climate conditions.

Research Projects - Detection of Oil On, In and Under Ice

3.1. Detection of Oil under Ice

In October 1999, the MMS funded a research project to gather and evaluate all available knowledge about the subject of oil-under-ice detection with the objective of identifying the most promising technology or process for future development and testing. Results and data from this project were used to establish a baseline of information, which was used to plan field trials with prototype systems. TAR Project 348. http://www.mms.gov/tarprojects/348.htm.

3.2. New and Innovative Equipment and Technologies for the Remote Sensing and Surveillance of Oil in and Under Ice

In November 2003, the MMS initiated the first of four international JIP's to evaluate potential remote sensing techniques to detect oil trapped within and under ice. This project positively detected oil trapped in and under ice with two completely independent technologies, GPR and ultra-sensitive ethane sensor. Both sensors are capable of detecting ethane emissions associated with a real oil spill and have potential for further development. TAR Project 517. http://www.mms.gov/tarprojects/517.htm.

3.3. Developing New and Innovative Equipment and Technologies for the Remote Sensing and Surveillance of Oil in and Under Ice - Phase 2

In a follow-up research project to TAR 517, successful field tests of GPR and ultra-sensitive ethane sensors were conducted over a variety of sea ice conditions at the U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory (CRREL) in Hanover, NH. Results from this project indicated that only GPR had the potential for further development and large-scale field testing. In April 2005, the prototype GPR system was evaluated in realistic field conditions in Prudhoe Bay, AK. TAR Project 547. http://www.mms.gov/tarprojects/547.htm.

3.4. Svalbard, Norway Experimental Oil Spill to Study Spill Detection and Oil

Building on the success of TAR Projects 517 and 547, in March-April 2006, MMS working in cooperation with the Norwegian government and SINTEF Applied Chemistry obtained a permit to conduct an intentional oil spill with 3,500 liters of crude oil during a large scale field test in Svalbard, Norway. Experiments were conducted over solid land fast sea ice representative of the type of ice found in many near shore Arctic regions of the world including the Alaskan North Slope. The project successfully demonstrated the ability to detect oil under 65 cm of ice with a commercially available GPR system. It appears that the current "off the shelf" radar technology is a useful operational tool to quickly map oil under ice from the surface (a major improvement over drilling holes) and potentially to map oil buried under snow on top of the ice from a helicopter at low level. On May 30, 2006, after the oil was in and under ice for 2 months, a successful in situ burn was conducted culminating in a highly efficient (96 %+) oil removal rate. TAR Project 569. http://www.mms.gov/tarprojects/569.htm.

3.5. Detection of Oil on and Under Ice - Phase 3

The MMS, building on the results from TAR Projects 517, 547 and 569, initiated a research project in October 2006 to assess the technical feasibility and cost of developing and incorporating an airborne oil detection system in future field trials with oil and ice.

Results indicate there are no commercially available airborne radar systems with an operating frequency range of 500MHz to 1GHz. In April 2008, MMS working in cooperation with the Norwegian government and SINTEF Applied Chemistry obtained a permit to conduct an intentional oil spill during a large-scale field test in Svalbard, Norway. One aspect to be evaluated during the spill was the GPR system. The results are very promising in that they indicate that a currently available GPR system is capable of detecting and mapping oil in ice over a broad operational time window from early to late winter, typically November to April in the Arctic. This window of opportunity covers approximately 70% of the near shore fast ice season in most years. The current generation GPR is capable of mapping oil under or trapped within growing winter ice from 30-210 cm (1-7 foot thick). Minimum oil thickness detection limit appears to be roughly 2 cm. From an airborne platform (helicopter) at a height of 20 meters the GPR could consistently image the ice water interface under 80 cm (3 feet) thick cold ice (equivalent to late December or January in the Beaufort Sea). TAR Project 588. http://www.mms.gov/tarprojects/588.htm.

4. Remote Sensing and Surveillance - Oil Spill Thickness Sensor

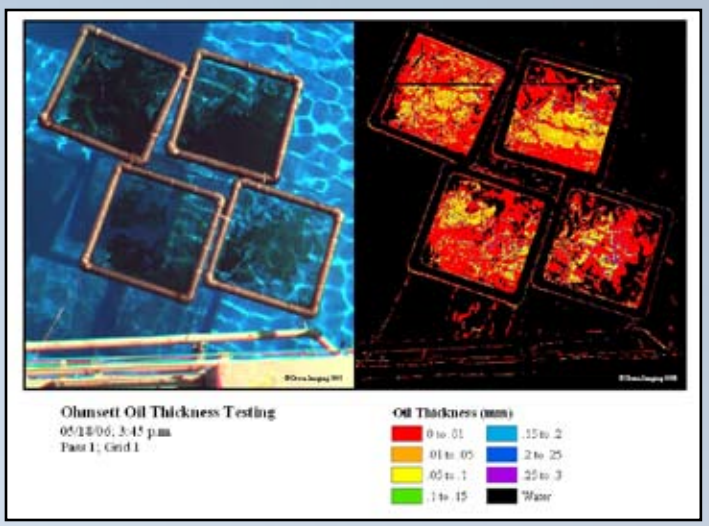
One of the most important initial steps in response to an oil spill at sea is the assessment of the extent of the oil slick and the quantity (i.e. thickness) distribution of oil within it.

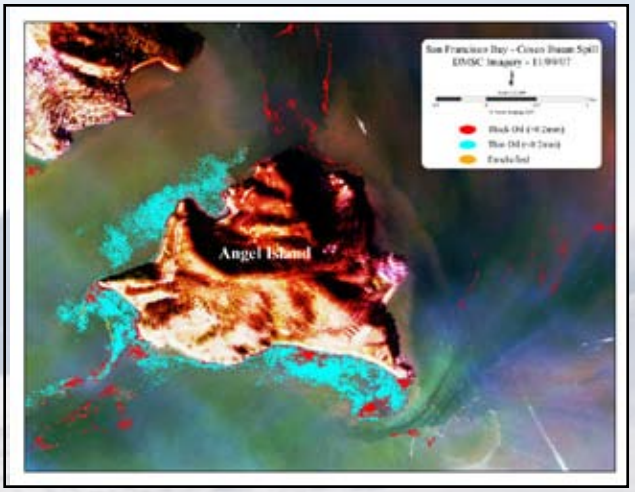
Since many types of hydrocarbons rapidly spread out to very thin layers when released at sea, accurate determination of which areas contain the most amount of oil is vital for efficiently guiding oil spill response efforts. This includes the ability to operate effectively in bad weather or darkness. A critical gap in sill response is the lack of capability to accurately measure and map the thickness of oil on water and to rapidly send this information to response personnel in the command post. This includes the ability to determine the thickest portions of the oil slick and to operate effectively in bad weather or darkness

The vast majority of oil quantity distribution assessments are presently done visually from helicopter or aircraft. Such visual observations from aircraft (sometimes supplemented by drawings or digital photographs) suffer from three main complications. First, documentation is usually based only on approximate geo-location information, second, visual estimation of oil film thickness distribution is highly subjective, is affected by varying light and background color conditions and, if not done by specially trained and experienced personnel, tends to be inaccurate, third, comprehensive visual assessments are impossible at night. An economical, portable and easy-to-operate oil slick detection and thickness measurement instrument that could be regionally owned and rapidly mounted and deployed in a variety of aircraft would provide the needed technology.

Current Technology Status - Oil Spill Thickness Sensor

In November 2005, the MMS initiated a research project to develop an algorithm that would enable the measurement of oil slick thicknesses using multispectral aerial imagery. The California Department of Fish and Game, Oil Spill Prevention and Response (DFG/OSPR) partnered with MMS on this project and provided technical expertise with the Geographic Information System (GIS) component of this project as well as services in kind (plane and pilot). Results from this project proved that the development and operational utilization of a portable multispectral imaging system for oil spill mapping is very feasible and could provide major improvements in oil spill response.





In October 2006, the MMS initiated a second research project to develop a portable, easy-to-operate, aerial sensor to detect and accurately map the thickness and distribution of an oil slick in coastal and offshore waters in real-time. CA DFG/OSPR partnered with MMS again on this project and provided technical expertise and similar services in kind. Over a three-year period the system was developed in a systematic approach. This included overflights of the Coal Oil Point, CA natural oil seeps. The full system integration flight was successfully completed in November 2008. The system was operationally used in December 2008 to respond to an oil spill in Santa Barbara Chanel, CA. The oil thickness mapping system is considered to be operational and available for use. Future research is planned to test and evaluate the operational capabilities of the thickness sensor during planned, intentional oil spill in Arctic environments.

Research Projects - Oil Spill Thickness Sensor

4.1. Real-time Detection of Oil Slick Thickness Patterns with a Portable Multispectral Sensor

In November 2005, the MMS initiated a research project with Ocean Imaging (OI) Corporation, Solana Beach, CA to develop an algorithm that would enable the measurement of oil slick thicknesses using multispectral aerial imagery. The project also examined the feasibility of developing a relatively economical, portable aerial oil spill mapping system. Such a system would enable rapid mapping of the extent and thickness of an oil spill

with greater quantitative and geographical accuracy than is presently possible using visual observations. The CA DFG/OSPR partnered with MMS on this project and provided technical expertise with the GIS component of this project and services in kind (the DFG aircraft and pilot, as platform to test the sensor). The sensor was successfully tested and evaluated during over flights of the Coal Oil Point, CA natural oil seeps on October 12-13, 2005. The sensor package was also successfully tested and evaluated at Ohmsett on May 8-12, 2006. TAR Project 544. http://www.mms.gov/tarprojects/544.htm.

4.2. Development of a Portable Multispectral Aerial Sensor for Real-Time Oil Spill Thickness mapping in Coastal and Offshore Waters

In October 2006, the MMS initiated a second research project with OI to develop a portable, easy-to-operate, aerial sensor to detect and accurately map the thickness and distribution of an oil slick in coastal and offshore waters in real-time. The system will acquire process and disseminate digital GIS compatible oil slick distribution products in near real time. The CA DFG/OSPR partnered with MMS again on this project and provided technical expertise and similar services in kind. The full system integration flight was conducted in November 2008 during over flights of the Coal Oil Point, CA natural oil seeps. The system was operationally used in December 2008 to respond to an oil spill in Santa Barbara Chanel, CA. TAR Project 594. http://www.mms.gov/tarprojects/594.htm.

5. Mechanical Containment and Recovery in Ice Environments

In most countries, mechanical recovery of spilled oil is the first and preferred response option. A containment boom is normally used in combination with an oil recovery skimmer. In ice-infested waters, an additional challenge for oil skimmers is their ability to process ice, meaning the skimmer should be able to deflect smaller floes and slush ice in order to have access to the oil. Broken ice conditions occur during short periods in the spring and fall. Oil spreads less and remains concentrated in greater thicknesses in broken ice than in ice-free waters. However, as the amount of broken ice in the water increases the efficiency of conventional mechanical recovery systems is reduced.

When responding to an oil spill in Arctic conditions, the first step is to identify the oil's physical properties particularly, the pour point. If the pour point is 5 to 10 degrees above the water temperature, there is a strong possibility that the oil has already solidified. Nets and other collection devices may be required for recovery. If the pour point of the oil is below the water temperature and if currents and wind conditions allow, then booms and skimmers may be applicable for use.

Most mechanical containment and recovery methods are technologies developed for open water conditions. Mechanical response in broken ice is limited by the ability of the skimmer to encounter and remove spilled oil. This is based on the type of spill (subsea blowout vs. above ground blowout) as well as the amount of broken ice. Efficiencies vary and are based on the amount and type of oil spilled, meteorological and oceanographic conditions. Available estimates from mechanical response in broken ice vary from 1% to 20% depending on the degree of ice coverage and if responding during freeze-up or spring break-up. This compares with estimates of 5 to 30% for open ocean response without broken ice. Recent barge trials on the Beaufort Sea demonstrated that even trace amounts of ice (less than 1/10 ice coverage) can cause significantly reduced efficiencies in mechanical recovery. One method for response during freeze-up would be to track oil in broken ice until it solidifies and becomes fast. Once it freezes solid, the oiled ice can be cut and mechanically removed.

Current Technology Status - Mechanical Containment and Recovery in Ice Environments (open water, broken ice, and on or under ice)

Spill response strategies in Arctic regions will depend almost entirely on the season during which the spill has occurred. Depending on the time

of year, responders can be facing a spill in open water, broken ice, or solid ice. Response considerations for each of these sea conditions are presented below.

Spills on open water

Spills in open water in Arctic regions are treated the same as in temperate and tropical climates. The only differences are the temperature of the water, associated safety issues, and the remoteness of the region. In a typical year, open-water systems are applicable from early July to mid-October. Efficiencies for the use of mechanical containment and recovery systems in open water vary from 5 to 30%.

Spills in broken ice

Broken ice seasons occur during early winter freeze-up and spring ice breakup, often called the "shoulder seasons". This ice is likely to be moving, not stationary. Oil spilled in broken ice will move with the ice. Oil spills tend to spread far less and remain thicker in broken ice than on open water.

Ice concentrations as low as 1/10 ice coverage inhibit large, open apex mechanical recovery systems. Skimmers work best when positioned in open water and in leads between ice pieces. The most appropriate skimmers for ice-infested waters are oleophilic rope mop and brush skimmers. These are preferred because other types of skimmers will quickly become clogged with smaller pieces of ice. Recovered fluids can contain significant amounts of slurry and/or slush ice. Sufficient storage or oil/water separation capacity is always a challenge. Mechanical containment and recovery in light ice conditions to 2 to 3/10 ice coverage is possible but with reduced oil encounter rates. There are limitations of access and safety. Ice concentrations of 3/10 are the generally accepted upper limit for advancing mode recovery systems. Booms are of little or no use in large moving ice floes or in ice concentrations greater than 30%. Boom material selection is extremely important for durability. Anchoring booms in broken ice can be difficult or impractical. Ice deflection and ice management are potential tactics for extending the window of opportunity for mechanical cleanup

As ice concentrations progress from open-drift to heavier pack ice concentrations, mechanical recovery systems experience progressively lower oil encounter rates as response crew's shift from large open apex booms to individual over the side skimmers to access pockets of oil between ice floes or in leads. In ice concentrations of 4/10 or greater mechanical recovery is possible but at low rates with over the side stationary skimmers (brush and rope mop). Pack ice concentrations exceeding 6/10 ice coverage preclude the use of any containment boom. The pack ice can be an effective natural containment barrier that slows the spread of oil helping to concentrate the oil for recovery from stationary skimmers dipped into discrete pools of oil.

At some point the ice cover would become too extensive for mechanical recovery of oil to continue. For high ice concentrations of 8/10 or more, most of the spilled oil (especially from a subsea blowout) will become immobilized and encapsulated within the ice. This oil is the effectively isolated from any direct contact with biological resources (marine or bird life) until the ice melts. Oil encapsulated within the ice is isolated from any weathering processes (evaporation, dispersion, emulsification). The fresh condition of the oil when exposed (e.g. through ice management or natural melt processes) enhances the potential for in situ burning.

For more than a decade MMS research has focused on methods to improve the effectiveness of equipment and techniques for the mechanical recovery of oil spills in ice-infested waters. The Mechanical Oil Recovery in Ice Infested Waters (MORICE) program was a seven-phase international effort, conducted over a six-year period (1995-2002) to develop technology for the recovery of oil spills in ice. Through a stepwise approach organized in seven separate, laboratory, small scale and mid-scale tests were completed as well as field testing to study various designs and concepts and to refine the ideas that were considered to have the best potential for removing oil from ice. In the five years since the MORICE results were released, many of the concepts tested and evaluated in this have been incorporated into the design of current, commercially available oil skimmers.

In 2004, the MMS initiated a research project with the University of California, Santa Barbara (UCSB) to study the process of oil adhesion to the surface of skimmers and to identify parameters affecting the efficiency of the recovery process. Results from this three-year project demonstrated that replacing recovery unit materials improves skimming efficiency by 20%. However, changing the surface pattern of the drum improved efficiency by over 200%. Results from this research project (grooved skimming drums) were patented by USCB and the principal investigator (PI). The PI was awarded her doctoral degree as a result of her research. Currently there are at least six types of grooved skimmers being commercially sold around the world.

Spills on and under ice

Current technology is considered capable of successfully cleaning up spilled oil on solid ice. For oil trapped on or within the ice sheet in mid-winter, direct pumping would result in almost complete removal of the spilled oil. Snow and ice can be used to contain oil. Snow is an effective sorbent. Ice can limit oil penetration on beaches.

Research Projects - Mechanical Containment and Recovery in Ice Environments

5.1. In-Situ Clean up of Oiled Shorelines; Svalbard, Norway Shoreline Project

In 1995, the MMS joined a JIP to investigate the effectiveness of mainstream in situ shoreline cleanup techniques (tilling, surf-washing), as well as some of the scientific aspects of oil behavior and oil removal by the clay-oil flocculation process. The Svalbard Shoreline Project was a full-scale and realistic field experimental oil spill research program with optional supplementary studies including meso-scale beach basin studies conducted at the Coastal Oil Spill Simulation System facility in Texas. The goal of the project was to deliver both operational and scientific information to help optimize oil spill cleanup in the Arctic by selecting the best technique to suit the conditions and secondly increased knowledge of the best natural processes at work. Results verified quantitatively that relocation of oiled sediment significantly accelerated the rate of oil removal from the shoreline. Mixing and tilling did not clearly stimulate oil loss and natural recovery. Oil biodegradation occurred in this arctic environment, both in oiled sediment and on the fine mineral particles removed from sediment by natural physical processes. None of the treatments techniques elevated toxicity in the nearshore environment at unacceptable levels, nor did they result in consequential alongshore or nearshore oiling. TAR Project 295. http://www.mms.gov/tarprojects/295.htm

5.2. Comprehensive Spill Response Tactics for the Alaska North Slope-Oil in Broken Ice Spill Response Scenarios

In 1998, the MMS initiated a JIP with Alaska Clean Seas (ACS) on behalf of the North Slope Spill Response Project Team to develop comprehensive oil spill response plans for petroleum operations on the North Slope of Alaska. The objective of the study was to evaluate the capabilities to recover spilled oil from very large oil well blowouts occurring during broken ice conditions in the southern Beaufort Sea. The task group considered six well-defined oil well blowout scenarios and determined in quantitative terms (1) The mechanical cleanup systems that are currently available on the North Slope are adequate to satisfy Alaska State requirements for cleaning up spills from blowouts in broken ice conditions (2) Whether additional resources would significantly improve the existing mechanical recovery capability, and to what extent and (3) What the maximum cleanup capabilities might be for dealing with blowout spills in broken ice if all possible cleanup techniques were considered.

The results describe in detail the behavior and fate of the six blowout scenarios and the likely effectiveness of countermeasures in recovering the resulting spill on water and ice. The effectiveness of the mechanical recovery systems that exist on the North Slope was assessed. Then the possible benefits were evaluated of adding more mechanical systems to the response and of adding dispersant use and in situ burning to the mix of response options available. Also discussed was the potential benefit of igniting and burning the blowout at the source and thus preventing a major marine spill from occurring. TAR Project 297. http://www.mms.gov/tarprojects/297.htm

5.3. MORICE (Mechanical Oil Recovery in Ice Infested Waters) Program

Initiated in 1995, the objective of the Mechanical Oil Recovery in Ice Infested Waters (MORICE) program was to improve the effectiveness of equipment and techniques for the mechanical recovery of oil spills in ice-infested waters. MORICE was a seven-phase multi-national effort, conducted over a six-year period that has involved Norwegian, Canadian, American and German researchers. TAR Project 310. http://www.mms.gov/tarprojects/310.htm

Phase 1 of the MORICE Program involved an extensive literature review to identify available information from previous efforts to develop oil-in-ice recovery technologies. Information collected included a history of oil spills in cold areas, oil behavior, ice conditions and operational experience attained during recovery of oil in these conditions. Following this, a series of brainstorming sessions and technical discussions were held to evaluate past ideas and generate new ideas for potential solutions to the problem. As a result, ten concepts were suggested and discussed in detail by a Technical Committee. These concepts are described in the MORICE Phase 1 report.

Phase 2 of the Program focused on qualitative laboratory testing of most of the concepts suggested in Phase 1. Laboratory experiments in Phase 2 were conducted at SINTEF's Cold Climate Testing Facility in Trondheim, Norway. Ice-infested conditions were simulated. This phase reduced the number of concepts that warrant further evaluation and development. Phase 2 was described in a final report.

Phase 3 took the two most promising concepts (brush drum skimmer and the lifting grated belt) and performed quantitative testing at the Hamburg Ship Modeling Basin (HSVA), Hamburg Germany in June 1998. Ice-infested conditions were simulated. Phase 3 was described in a final report.

Phase 4 developed the two concepts from Phase 3 to a prototype level. Built a harbor-size prototype, designed and built a support vessel, and field tested the prototype skimmer during freeze-up offshore Prudhoe Bay, Alaska in October 1999. Phase 4 was described in a final report.

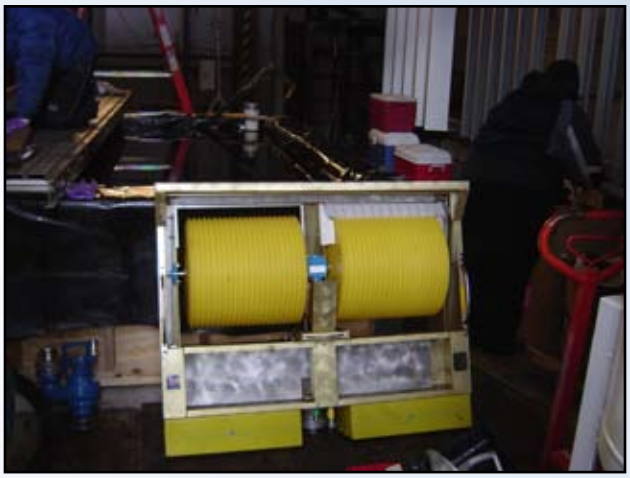
Phase 5, evaluated four different internal oil recovery units for the lifting grated belt at the HSVA test tank in Hamburg Germany in May 2000. Upon completion of these tests, the prototype skimmer was shipped back to Prudhoe Bay, AK where it received further equipment modifications, installation of more powerful hydraulics and a larger power pack. Selected skimmer manufacturers were invited to participate and provide an internal recovery system for evaluation. The complete prototype skimmer was evaluated for ice processing on the Alaskan Beaufort Sea during October 2000. Phase 5 was described in a final report.

Phase 6, the prototype skimmer was considered ready for oil in ice testing. The unit was shipped to Svalbard, Norway in May 2001 for testing, however due to complications, the unit was not field tested.

Phase 7, the prototype skimmer was successfully tested and evaluated at Ohmsett in January 2002. The unit was tested in cold water/broken ice conditions with oil and two different internal recovery systems. The MMS purchased 400,000 pounds of sea ice for use in these experiments. The final report from Phase 7 as well as the entire project is complete. The MORICE Steering Committee agreed to release results of the project and post the results from all phases of the MORICE project on the Internet in May 2003 following the 2003 International Oil Spill Conference.

5.4. Use of Ice Booms for the Recovery of Oil Spills from Ice Infested Waters
In 2000, the MMS, seeking new and innovative methods and equipment for the cleanup of accidental oil spills in the Arctic conducted a research project to study the design and use of ice booms for recovering spilled oil in ice-infested waters. Results defined the operating window in which an ice boom could be deployed when towing or pulling in a broken ice field. The work also defined the likely scenarios where an ice boom could be used effectively. TAR Project 353. http://www.mms.gov/tarprojects/353.htm

5.5. Improved Oil Skimmer Performance: In October 2004, the MMS initiated a research project with the University of California, Santa Barbara (UCSB) to study the process of oil adhesion to the surface of oleophilic skimmers and to identify parameters affecting the efficiency of the recovery process. This information was used to increase the efficiency of mechanical oil spill recovery equipment by introducing modifications to the shape and material of the recovery surfaces that would result in a greater amount of oil recovery. These changes will result in faster oil spill cleanup and greater environmental protection. TAR Project 511. http://www.mms.gov/tarprojects/511.htm



The success of TAR project 511 led to a follow-up research project with UCSB. In 2005, full-scale testing was conducted of novel oleophilic recovery surfaces tailored for oil spill recovery to determine the relation between selection of the recovered material and recovery efficiency. A comprehensive study of all aspects of the recovery process allowed us to select the materials with highest oil spill recovery potential; analyze the effects of the initial oil properties, oil weathering and emulsification on the recovery efficiency; and develop a surface pattern that yields a very high recovery efficiency. Prototype interchangeable oleophilic skimmer surfaces with candidate polymeric materials were fabricated and tested with different oil at full-scale at Ohmsett. TAR Project 528. http://www.mms.gov/tarprojects/528.htm

In 2006, the MMS partnered with the Prince William Sound Oil Spill Recovery Institute (PWS OSRI) to conduct a third phase of this research program. The objective was to use the results from TAR project 528 to substantially increase the efficiency of mechanical oil spill recovery equipment by replacing traditional recovery unit materials with polymeric materials and various surface patterns that have the highest affinity for oil and are specifically tailored to collect oil from waters surfaces. Research results demonstrated that replacing recovery unit materials improves skimming efficiency by 20% and that changing the surface pattern of the drum will improve efficiency by over 200%. Oil spill recovery testing was conducted in February 2007 at CRREL in Hanover, NH. This provided valuable information about the correlation between the laboratory tests and full-scale experiments. The tests demonstrated the potential of the proposed skimmer modifications under conditions similar to response operations. The results from this research project were patented by USCB and the principal investigator (PI). The PI was awarded her doctoral degree as a result of her research. There are at least six types of grooved skimmers being commercially sold around the world. TAR Project 573. http://www.mms.gov/tarprojects/573.htm.

6. In Situ Burn Research

The use of in situ burning as a spill response technique is not new, having been researched and employed in one form or another at a variety of oil spills since the 1960's. Burning as a response tool for oil spills in broken ice has been researched since the early 1980's using both tank tests and medium to large-sized experimental spills. Many scientists and responders believe this technique is among the best option for oil spill response in the Arctic, especially with a high degree of ice coverage. The burning of spilled oil in broken ice is quite

feasible under most conditions in the Arctic since there is little concern that the burning oil might move and threaten any offshore or shoreline activities. Also the immediate impacts on air quality are less of a concern than in more populated regions. In situ burning can be conducted using the ice as a natural boom or with the use of fire-resistant boom to contain and thicken the oil. Burning requires the use of ignition devices and possibly sorbent material to remove any burn residue. Burn efficiencies vary and are based on the amount and type of oil spilled, meteorological and oceanographic conditions. Individual burn efficiencies between 55% and 98% have been achieved in cold water and broken ice.

MMS was designated as the lead agency for in situ burn research in the Oil Pollution Research and Technology Plan prepared under the authority of Title VII of the Oil Pollution Act of 1990 (OPA-90). Between 1995 and 2003, the MMS conducted more than ten different ISB research projects. Many of these projects were JIP's. http://www.mms.gov/tarprojectcategories/insitu.htm. Emphasis was placed on the emissions to air and water, burn equipment evaluations, smoke plume modeling, and research to extend the "Window of Opportunity" through the use of chemical emulsion breakers and chemical herding agents.

Current Technology Status – In Situ Burn Research

Research and development efforts intensified in the years following the Exxon Valdez to improve fire-resistant boon design, refine operational procedures and to resolve issues associated with air pollution from burning. These research efforts culminated in an international, multi-agency research burn in August 1993, offshore St. Johns, Newfoundland known as the Newfoundland Offshore Burn Experiment or NOBE. The experiment verified that in situ burn operations can be conducted safely and effectively with burn efficiencies exceeding 90%, addressed many of the uncertainties regarding air contamination and confirmed the overall viability of in situ burning as a legitimate response countermeasure.

Oil may be more difficult to ignite at low temperatures but once burning begins, it will continue regardless of ambient temperature. Most crude oils should still be burnable within 2 to 5 days of the spill and may be burnable for extended periods, as low temperatures will slow weathering. Burning is an optimum strategy for spills in broken ice and may be the preferred option if it is not safe to work in or on the ice. Deployment of fire-resistant boom may not be feasible in broken ice. In some cases this may be unnecessary as some of the oil may be contained by the ice or thickened through the use of chemical herders. Typically oil contained between ice floes and along the edges burns at a rate faster than skimmers can recover it.

If oil has solidified, burning should be applicable as long as the conditions are appropriate. Burning is a preferred technique for dealing with spills on ice and snow-covered surfaces. If the release is under ice equipment (ice augers, pumps, ice breaking vessels) can be used to provide access to it. Once the oil has been exposed it can be burned. Burning is extremely feasible and efficiencies can exceed 90%. Oiled snow with as much as 70% snow by weight can be burned. Burning is also a sound approach for oil that rises through brine channels into melt pools in the ice during spring thaw.

The performance of fire-resistant booms has improved. Containing and burning the oil in place has been developed into a viable response technique with special emphasis on the development of stronger, reusable fire-resistant containment boom as well as improved in situ burn protocols and methodologies. Advanced boom designs, such as the stainless-steel boom pocket and water-cooled booms may permit extended burn

operations. Prior to the Exxon Valdez, virtually no fire-resistant booms were pre-staged. Now, several in situ burn equipment stockpiles exist in the continental United States and Alaska.

There are a number of compounds, devices and systems for igniting oil slicks at sea. The current system of choice for igniting oil during in situ burn operations, particularly for large oil spills at sea is the Helitorch system. The ignition of an oil spill is a straightforward procedure with devices and systems already developed and available.

Research is ongoing to extend the window of opportunity for burning in Arctic environments through the use of chemical herders to thicken oil spills in broken ice to allow them to be effectively ignited and burned in situ. Laboratory, small-scale and large-scale wave tank research is complete. Two full-scale burn experiments were conducted in May 2008 offshore Svalbard, Norway. In one burn 650 liters of crude oil were intentionally released at sea and allowed to spread for fifteen minutes. Chemical herders were sprayed around the perimeter of the oil slick and the slick was allowed to contract for 10 minutes. The oil was then ignited and burned with an estimated 90% efficiency. The remaining oil and residue were recovered mechanically.

The technology to effectively predict downwind smoke plume trajectories and monitor particulate concentrations has evolved with the in situ burn research program. Smoke plume models and monitoring protocols have been developed and are available. A large Outdoor Fire Plume Trajectory model (ALOFT) was developed to predict and analyze the downwind distribution of smoke particulates and combustion products from large burns in Alaska. Two versions are available one for flat terrain and the other for mountainous terrain. The monitoring capability can be readily deployed to support in situ burn operations.

To disseminate results of eight years of intensive in situ burn research, the MMS assembled a comprehensive compendium of scientific literature on the role of in situ burning as a response option for the control, removal and mitigation of marine oil spills. All operational aspects of burning are covered in detail. It contains more than 350 documents with over 13,000 pages and nearly one hour of video. The MMS has distributed more than 2,000 ISB-CD sets worldwide.

In situ burning is now considered a viable countermeasure for offshore oil spills. Regional Response Teams (RRT) and Area Committees are integrating the use of in situ burning into their response protocols and contingency plans. Overall the opportunity for use, growing inventory of equipment resources and the trend for Federal On Scene Coordinators (FOSC's) and RRT's to seriously consider and more readily approve its use indicate and expanded role for in situ burning in the Arctic.

Research Projects – In Situ Burn Research

6.1. Outdoor Wave Tank and Program of Mid-Scale In Situ Burn Testing in Alaska

In 1996, the MMS initiated a JIP to design and construct an outdoor wave tank and conduct a series of mid-scale burn tests. A custom tank was built was conducted in August/September 1997 at the BP Fire Training Grounds in Prudhoe Bay, AK. It is of all-steel construction and is road-transportable. The outside dimensions are 12 m (40 ft) long x 2.4 m (8 ft) wide x 2.25 m (7.4 ft) high. The tank is fitted with a simple hydraulically driven wave paddle at one end and a passive wave absorber at the other end. This portable tank has been used numerous times over the past 10 year for different series of in situ burn experiments. TAR Project 288. http://www.mms.gov/tarprojects/288.htm

6.2. Re-Engineering of a Stainless Steel Fireproof Boom for Using in Conjunction with Conventional Fireboom

Many refractory fabric fire booms will deteriorate quickly in use and may require frequent replacement in a large-scale burn operation. These problems can be minimized, or even eliminated, by using a highly durable and

fire-resistant material in the pocket of the boom where the highest heat and stress loads exist. A large stainless-steel fire-resistant boom, known as the "Dome Boom" was designed and successfully tested in the early 1980s. However, this boom was expensive, heavy and cumbersome to deploy. In 1997, the MMS initiated a JIP to re-engineer the "Dome Boom" to reduce its size, weight and cost. The project was completed in nine phases: (i) the existing boom was redesigned to reduce its cost, size, weight, and handling problems, and to make it compatible with existing boom systems; (ii) a prototype section of the re-engineered boom was constructed for testing; (iii) the boom was tested in Lake Erie to evaluate its towing and sea-keeping characteristics; (iv) the prototype was tested at Ohmsett to quantify its oil-containment capability; (v) three hours of burn tests in waves were conducted in a diesel fire at the USCG Fire and Safety Test Detachment in Mobile, AL; (vi) post-burn tow tests were performed at Ohmsett to confirm the containment capability of the boom after the diesel-fire exposure; (vii) three hours of burn tests in waves were carried out in enhanced propane flames at Ohmsett; and, (viii) destructive testing was used to estimate the operational life of the flexible connector sections and the tensile strength of several key load-bearing components. Finally, the design of the boom was refined and final detailed engineering drawings and a technical paper was produced. The boom successfully passed all the required engineering and burn tests. The final design is freely available to interested parties. TAR Project 289. http://www.mms.gov/tarprojects/289.htm.

6.3. Mid-Scale Tests to Determine the Limits to In-Situ-Burning In Broken Ice

In 2001, the MMS initiated a research project to conduct mid-scale experiments to determine the limits to in situ burning in broken ice. The burn experiments were successfully conducted from October 21- November 1, 2002 at the BP Fire Training Ground, Prudhoe Bay, AK. The crude oils used in the burn experiments were Alaska North Slope, Endicott, Northstar and Pt. McIntyre. Fresh and weathered samples of the crude oils were tested. These same crude oils were used in the cold-water dispersant experiments that were conducted in February 2003 at Ohmsett. Results from the experiments were used to verify the results from laboratory and small-scale tests. The completed experiments in broken ice and the 2003 cold water dispersant experiments provided researchers a complete dataset and a direct documented comparison of how each crude oil responds to burning and to the use of dispersants. TAR Project 452. http://www.mms.gov/tarprojects/452.htm.

6.4. In-Situ Burning of Oil Spills: Resource Collection, 2-CD Set

The MMS assembled a comprehensive compendium of scientific literature on the role of in situ burning as a response option for the control, removal and mitigation of marine oil spills. All operational aspects of burning are covered in detail. The 2 two-CD set includes a substantial percentage of the scientific and technical literature on research, development, planning and implementation undertaken by hundreds of individuals and dozens of organizations. It contains more than 350 documents with over 13,000 pages and nearly one hour of video. The MMS has distributed more than 2,000 ISB-CD sets worldwide.

7. Dispersants in Cold Water/Broken Ice Environments

Dispersants are used in many parts of the world as a primary response strategy, and to compliment other techniques. In cold-water environments where there is ice, dispersants have been viewed with skepticism. Concerns include the lack of natural mixing energy due to the dampening effects of the ice, and the tendency for oils to become viscous at low temperatures. Results from small-scale testing however, do not incorporate sufficient environmental realism (variables and scale) to permit confident predictions about real-world situations. Controlled field studies, while valuable for realism, are expensive and often very difficult to implement because of regulatory barriers. The MMS upgraded the testing capabilities at Ohmsett in 2000,

to provide a controlled environment for cold water testing and training (with or without ice). Large-scale tank experiments, conducted at Ohmsett can provide a critical link between small-scale laboratory and full-scale field studies because they can simulate real-world exposures without the cost of a field release or needs for permits. The National Research Council strongly supported the use of wave tank testing in their recent review of chemical dispersants. The Ohmsett facility is rapidly becoming a world leader in realistic dispersant effectiveness testing through the design and development of a calibrated, referenced and realistic test protocol and subsequent testing under cold and temperate conditions using fresh and weathered crude and fuel oils. Ohmsett is the world's largest wave-tank complex presently conducting such research and is the logical venue for bridging the gap between laboratory and field testing.

Current Technology Status – Dispersants in Cold Water/Broken Ice Environments

The use of chemical dispersants in the United States is on the verge of achieving a similar acceptance status to that of mechanical containment and recovery countermeasures. Various laboratory, small and mid-scale dispersant effectiveness test series have been completed at low temperatures in the past with mixed results. Generally, these results have indicated that dispersants can be effective in cold conditions. There are regional concerns that dispersants may not be effective on spills of Alaskan crude oils in cold water/broken ice, especially those that could take place in the colder months and that dispersants should not be or cannot be used in these conditions.

Results from laboratory, small and mid-scale experiments do not incorporate sufficient environmental realism (variables and scale) to permit confident predictions about real-world situations. Larger-scale testing was required. Controlled field experiments, while valuable for realism are expensive, uncontrollable in many instances, and very hard to implement due to regulatory barriers. Large tank experiments conducted at Ohmsett provide a critical link between small-scale testing and full-scale field experiments because they can simulate real world conditions without the cost. The MMS upgraded the testing capabilities at Ohmsett to provide a controlled environment for cold water testing and training (with or without ice). The facility is now able to simulate realistic and varying broken ice conditions. Since the development of a calibrated, referenced and realistic testing protocol at Ohmsett, MMS funded test series have been conducted to examine the effectiveness of dispersants on a wide variety of crude oils (including Alaskan and Canadian oils) and fuel oils under near freezing conditions and with ice. Dispersant testing at Ohmsett has proved the effectiveness of dispersants in near-freezing temperatures but this is highly dependent on the properties of the crude oil. The crude oil should have a viscosity less than 10,000 cSt and the water temperature should be above the oil's pour point. Most dispersants are formulated to be fluid and to spray smoothly even at temperatures below freezing.

Dispersants can be effective in broken ice if there is some mixing energy present. The presence of broken ice does indeed dampen wave energy in a broad sense, but at the "micro" level, energy may in fact be amplified by the reflection of waves amongst ice floes and brash ice. The pumping action of waves in brash ice and between ice floes can actually stimulate dispersant action. Vessels can be used to provide added energy by moving through and churning the surface ice and water. Tests at Ohmsett have proven the effectiveness of dispersants in and up to 8/10 th ice with low amplitude wave conditions.

There is growing evidence from scientific testing that dispersants can play a significant role in future Arctic

oil spill contingency plans. Dispersants provide an invaluable third response option when strong winds and sea conditions make mechanical cleanup and in situ burn techniques unsafe and/or ineffective. Results from dispersant testing at Ohmsett are being used by local, state and federal regional response teams and regulators to make justifiable decisions on the use of dispersants as an oil spill response tool in their jurisdictions. Results from dispersant testing in cold water/broken ice conditions at Ohmsett have been used by industry to gain regulatory approval for the use of this countermeasure for the Sakhalin Island project in Russia and for planned projects in the Canadian Beaufort Sea.

Research is ongoing to develop a next generation dispersant that would be effective on more viscous crude oils and that remains associated with oil for longer periods.

Research Projects – Dispersants in Cold Water/Broken Ice Environments

7.1. Effects of Chemically Dispersed and Biodegraded Oils
In 2003, the MMS initiated a JIP to determine the effects of chemically dispersed and biodegraded oils. Research provided a quantitative assessment of the rate of biodegradation of the components under a range of conditions found in the UK and cold US waters. The experiments showed that although chemically dispersed oil may initially impact mussels and amphipods to a greater extent than would untreated oil, the organisms are mostly able to recover to the same extent as control organisms or to those exposed to oil alone. Decision makers will use this information when choosing appropriate response options for Arctic spill response. TAR Project 449. http://www.mms.gov/tarprojects/449.htm.

7.2. Dispersant Effectiveness Testing in Cold Water
In 2001, the MMS initiated a JIP with Exxon Mobil Research and Engineering Co. to conduct a series of research experiments to evaluate the effectiveness of Corexit 9500 and Corexit 9527 dispersants on Hibernia and Alaska North Slope (ANS) crude oils in cold water/broken ice conditions. The experiments were successfully conducted between February 25 and March 14, 2002 at Ohmsett. The results from the Ohmsett experiments were significant because they demonstrate that Corexit 9500 and Corexit 9527 are effective in dispersing Hibernia and ANS crude oils in very cold water and verify the results collected from identical laboratory and small-scale wave tank tests. TAR Project 450. http://www.mms.gov/tarprojects/450.htm.

7.3. Ohmsett 2003 Cold Water Dispersant Effectiveness Experiments
Building on the results from TAR 450, in February 2003, the MMS conducted a series of experiments to evaluate the effectiveness of Corexit 9500 and Corexit 9527 dispersants on Alaskan and Canadian crude oils. These crude oils have a wide range of physical and chemical properties and were tested both fresh and when weathered. A total of fourteen large-scale dispersant effectiveness experiments test were completed at the Ohmsett facility with various combinations of oil type and dispersant-to-ratio (DORs). The Ohmsett tank water temperature was between -0.4 to -1.8C throughout the experiments without the need to use artificial chilling. This was due to the unusually cold weather experienced during the test period. The dispersant effectiveness trends identified in the smaller scale testing were mirrored in the large-scale test results. The heavily evaporated Northstar and evaporated Endicott crude oils were resistant to chemical dispersion in both the small-scale and Ohmsett experiments. TAR Project 476. http://www.mms.gov/tarprojects/476.htm.

7.4. Research at Ohmsett on the Effectiveness of Chemical Dispersants on Alaskan Oils in Cold Water.
Using results from TAR Projects 450 and 476, the MMS initiated additional research to determine the dispersibility of fresh and weathered Alaskan crude oils in cold water. Dispersant effectiveness (DE) experiments were successfully conducted between February 20 and March 10, 2006 at Ohmsett. Four high-risk Alaskan crude oils and one dispersant were tested. The oils were tested fresh, weathered by removal of light ends using air-sparging and weathered by placing the oils on the water surface in the tank and subjecting them

to both breaking wave conditions (high energy) and non-breaking waves. The dispersant had 90% efficiency with all crude oils tested. This data confirmed the results of the 2003 Ohmsett DE tests. On February 28, 2006 MMS conducted a Visitor's Day at Ohmsett to see DE testing, observe the dispersant test protocol, and tour the Ohmsett facility. More than 50 observers participated and saw a control test (no dispersant applied) and a dispersant test using ANS crude oil and Corexit 9527 dispersant applied at a 1:20 dosage. In addition 20 scientists including the USCG-Atlantic Strike Team, the National Oceanic and Atmospheric Administration, Scientific Support Coordinators and the U.S. Environmental Protection Agency, Emergency Response Team used the experiments as a training exercise for the SMART dispersant monitoring protocol. TAR Project 569. http://www.mms.gov/tarprojects/568.htm.

7.5. The Effect of Warming Viscous Oils Prior to Discharge on Dispersant Performance
Experiments were conducted in 2002 and 2003 at Ohmsett to assess the dispersibility of fresh and weathered Alaskan and Canadian crude oils in very cold water. Results from these experiments indicate that the crude oils tested were dispersible at near freezing water temperatures. However, there was criticism of the findings. Prior to two experiments, the viscous crude oil was warmed to get it to flow before it was discharged onto the cold waters surface and subsequent dispersant application. This project, conducted at Ohmsett in 2004, addressed this criticism. The research determined empirically that warming viscous oil prior to testing did not influence dispersant performance in the Ohmsett tests. TAR Project 527. http://www.mms.gov/tarprojects/527.htm

7.6. Understanding the Effects of Time and Energy on the Effectiveness of Dispersants
This international JIP, funded in 2005, was designed to gather data to support decision makers in the process of determining whether dispersants should be used in low energy environments. This information will be useful for dispersant decision making in ice cover (an ice field reduces wave motion) or other calm conditions. Questions addressed were (1) Will the dispersant stay with the oil until there is enough energy to disperse the slick? (2) How much energy is needed to disperse the slick after dispersants are applied? (3) If energy is provided to facilitate dispersion, will the droplets stay in the water column after mixing or will they resurface? The main conclusion from the effectiveness testing of dispersants on the four oils used in this study is that dispersants may be effective for long periods of time but this is dependent on the rheological properties of the crude oil and on the environmental temperature. TAR Project 568. http://www.mms.gov/tarprojects/563.htm.

8.0 Chemical Herders

The use of specific chemical surface-active agents, sometimes called oil herders or oil collecting agents, to clear and contain oil slicks on water is well known. These agents have the ability to spread rapidly over a water surface into a monomolecular layer, as a result of their high spreading coefficients, or spreading pressures. Consequently, small quantities of these surfactants will quickly clear thin films of oil from large areas of water surface.

Field deployment tests of booms and skimmers in broken ice conditions in the Alaskan Beaufort Sea highlighted the severe limitations of conventional equipment in even trace concentrations of broken ice. In situ burning may be one of the few viable options to quickly remove oil spilled in such conditions. One fundamental problem with the application of in situ burning to oil well blowouts or subsea oil pipeline leaks is that the slicks are initially too thin, or they can thin quickly, preventing effective ignition and burning. In loose broken ice (less than 6 to 7 tenths) conditions, even with no possibility of booming, if these slicks could be thickened to the 2- to 5-mm range, effective burns could be conducted. The intention of the herding is to thicken the slicks sufficiently to allow them to be ignited and burned in situ without the need for mechanical containment systems. The MMS selected the U.S. Navy herder formulation (65% Span-20 and 35% 2-ethyl butanol) for use in all experiments because it proved to be the best suited for the cold conditions.

Current Technology Status – Chemical Herders
Since 2004, the MMS and ExxonMobil have been jointly funding research to evaluate the use of chemical

herding agents to extend the window of opportunity for oil spill response options in Arctic environments. Recent research efforts have focused on the use of chemical herding agents to thicken oil spills in broken ice to allow them to be effectively ignited and burned in situ. Three years of laboratory, small-scale and large-scale wave tank research is complete. In May 2008, two full-scale burn experiments were conducted during a field exercise offshore Svalbard, Norway. Approximately 650 liters of crude oil were intentionally released at sea and allowed to spread for fifteen minutes. Chemical herders were sprayed around the perimeter of the oil slick and the slick was allowed to contract for 10 minutes. The oil was then ignited and burned with an estimated 90% efficiency. The remaining oil and residue were recovered mechanically.

The MMS is currently conducting research to extend the use of herders in pack ice conditions, in open water and in salt marshes. In October 2008, the MMS funded three different experimental test series on the use of chemical herders to (1) enhance mechanical recovery in pack ice, (2) to clear oil slicks from salt marshes, and (3) on the use of chemical herders to improve dispersant operations at sea. Experiments to clear oil slicks from salt marshes were conducted in Ottawa, Canada in November 2008. Experiments to enhance mechanical recovery in pack ice were conducted at Ohmsett in February 2009. Results from both of these test series are currently being analyzed. Experiments on the use of chemical herders to improve dispersant operations at sea will be conducted at Ohmsett in October 2009. Initial results from laboratory, small-scale and large-scale wave tank and field exercise offshore indicate that use of chemical herders can play a significant role in extending the window of opportunity for Arctic oil spill response countermeasures.

Research Projects – Chemical Herders

8.1. Mid-Scale Test Tank Research on Using Oil Herding Surfactants to Thicken Oil Slicks In Broken Ice
Beginning in 2004, the MMS and ExxonMobil have jointly funded several research efforts on the use of chemical herding agents to thicken oil spills in broken ice to allow them to be effectively ignited and burned in situ. Laboratory, small and large wave tank research and field testing have been completed. TAR Project 554 http://www.mms.gov/tarprojects/554.htm

- 7 experiments at the scale of 100 m2 in the indoor Ice Engineering Research Facility Test Basin at the CRREL facility in Hanover, NH in November 2005

- 10 experiments at the scale of 1000 m2 at Ohmsett in artificial pack ice in February 2006

- 20 burn experiments at the scale of 50 m2 with herders and crude oil in a test basin containing broken sea ice in November 2006 at the Fire Training Grounds in Prudhoe Bay, AK.

- Two full-scale burn experiments were conducted in May 2008 offshore Svalbard, Norway. 650 liters of crude oil were intentionally released at sea and allowed to spread for fifteen minutes. Chemical herders were sprayed around the perimeter of the oil slick and the slick was allowed to contract for 10 minutes. The oil was then ignited and burned with an estimated 90% efficiency. The remaining oil and residue were recovered mechanically.

8.2. Employing Chemical Herders to Improve Oil Spill Response Operations
The objective of this research program is to extend the research on herders in pack ice conditions, in open water and in salt marshes. This project is a continuation of TAR Project 554. There are two separate tasks in this project.

Task 1: Using Herders to Enhance Mechanical Recovery of Oil in Pack Ice - Experiments were conducted in February 2009 at Ohmsett to explore the capabilities and limitations of using herding agents to thicken oil in loose pack ice for recovery by skimmers. The MMS purchased 400,000 pounds of sea ice for use in these experiments.

Task 2: Using Herders to Clear Oil Slicks in Salt Marshes - A parallel to the situation in pack ice exists in salt marsh environments: access for mechanical recovery equipment is almost non-existent due to concerns over damaging the marsh substrate. This task involved laboratory experiments in small-scale simulated marshes to determine if chemical herders might play a role in clearing spilled oil from the marsh. The experiments were conducted in October 2008 using different types of crude oil, three water temperatures, and three salinities. TAR Project 617 http://www.mms.gov/tarprojects/617.htm

9. Ohmsett – The National Oil Spill Response Test Facility

Ohmsett is an integral part of the MMS oil spill research program and is essential for fulfilling the agency's regulatory responsibilities under OPA-90. The facility directly supports MMS's mission of ensuring safe and environmentally sound oil and gas development on the Outer Continental Shelf. Ohmsett is not only a vital component of the MMS oil spill research program it is also a national asset where government agencies, private industry and academia can conduct full-scale oil spill research and development programs in a controlled environment with real oil. It is also the premier hands-on training site for spill response personnel from state and federal government agencies, private industry and foreign countries.

To respond to the challenges of testing and evaluating the equipment required to respond to oil spills in ice-infested waters the MMS upgraded the testing capabilities at Ohmsett in 2000 to provide a controlled environment for cold water testing and training (with or without ice). The facility is now able to simulate realistic broken ice conditions. These upgrades enable the Ohmsett facility to remain open year round offering cold water testing, training, and research opportunities during the winter months. Replications of cold water/ broken ice conditions at Ohmsett open the way for:

- Remote sensing experiments conducted in, on and under ice
- Development and testing of mechanical containment and recovery equipment for use in Arctic environments
- Fireboom evaluations in cold water/broken ice using an air-injected propane burner system that realistically simulates in situ burning at sea.
- Large scale dispersant effectiveness testing in cold water/broken ice
- Cold water oil spill response training
- Testing of instruments and equipment to locate and recover sunken and submerged oil
- Large scale testing of chemical herders in cold water/broken ice
- Testing and evaluating fire-resistant containment booms

"Ohmsett's mission is to increase oil spill response capabilities through independent and objective performance testing of equipment, providing realistic training to response personnel, and improving response technologies through research and development". Many of today's commercially available oil spill cleanup products and services have been tested at Ohmsett either as off-the-shelf commercially available equipment, or as equipment or technology still under development. In North America, a large portion of existing independent performance data and information on containment booms and skimmers has been obtained through testing at Ohmsett.

Without Ohmsett, the testing and evaluation of equipment, systems and methodologies as well as responder

training would have to be conducted during actual oil spills where conditions cannot be repeated and would interfere with response operations. Each year, the MMS sponsors and conducts "Visitors Days" at Ohmsett to demonstrate the use of new technologies and upgrades to the facility. Over the past four years the visitor's days have focused on dispersant effectiveness testing of Alaskan crude oils in very cold water.

Research Projects – Ohmsett

The Ohmsett website is located at http://www.ohmsett.com/. A summary of activities that lists all tests that have been conducted at Ohmsett since the facility reopened under MMS management is located at http://www.ohmsett.com/Summary_of_Activities.html.

10. Control of Underwater Noise

Underwater noise associated with oil and gas activities in the Beaufort and Chuckchi Seas has been a topic of discussion among many groups and individuals. Particular concerns were the underwater noise propagation from seismic exploration vessels and the underwater noise generation that is created by gravel islands where oil and gas production activities take place. The MMS research is examining methods to reduce noise propagation from seismic exploration activities and ways to reduce noise from gravel islands during production activities.

Current Technology Status – Control of Underwater Noise

In 2004, the MMS initiated a research project to identify and measure significant noise sources, paths and radiators generated from shallow water drilling and production operations on a gravel island in the Alaskan Beaufort Sea and to determine and recommend the most effective treatment for each source type. Northstar Island, operated by BP Exploration (Alaska) Inc., was used as the primary case study to uncover the pertinent mechanisms of underwater noise radiation from gravel islands. One aim from this project is to develop noise control treatments that can reduce the underwater radiated noise from future gravel islands as compared with current designs. Results from this study are recommendations to reduce the underwater radiated noise from future gravel islands relative to existing designs.

The MMS initiated a research project in October 2007 aimed at creating methods and equipment for reducing the lateral noise proposition from seismic exploration vessels operating in the Alaskan Beaufort and Chukchi Seas. Preliminary results demonstrate that deploying bubble curtains outboard of the seismic arrays towed by the same exploration vessel can potentially produce sought-after noise reduction, while minimizing the impact on the traditional seismic exploration operations. A second phase of this project is planned (late 2009) that will conduct a more rigorous 3D acoustic analysis of the preferred configuration of bubble curtain design and conduct a small scale physical test to confirm the 3D analysis results.

Research Projects – Control of Underwater Noise

10.1. Measurement and Control Underwater Noise from Oil Drilling and Production Operations.

In 2004, the MMS initiated a research project to identify and measure significant noise sources, paths and radiators generated from shallow water drilling and production operations on a gravel island in the Alaskan Beaufort Sea and to determine and recommend the most effective treatment for each source type. The purpose of this study is to develop noise control treatments that can reduce the underwater radiated noise from future gravel islands as compared with current designs. Knowing the equipment currently being used on a gravel island that is conducting drilling and production operations, what could be done to decrease the radiated noise entering the environment? What remedies could be implemented at the front end when developing a gravel island for drilling and production operations that could decrease the radiated noise entering the environment? Northstar Island, operated by BP Exploration (Alaska) Inc., was used as the primary case study to uncover the pertinent mechanisms of underwater noise radiation from gravel islands. Results from this study are

recommendations to reduce the underwater radiated noise from future gravel islands relative to existing designs. This research project was conducted with the cooperation and assistance of BP and Greeneridge Sciences, Inc. TAR Project 538 http://www.mms.gov/tarprojects/538.htm.

10.2. Methods to Reduce Lateral Noise Propagation from Seismic Exploration Vessels

The MMS initiated a research project in October 2007 aimed at creating methods and equipment for reducing the lateral noise proposition from seismic exploration vessels operating in the Alaskan Beaufort and Chukchi Seas where oil exploration activities are currently taking place or are planned. Included in the scope of the project are an evaluation, assessment and comparison of noise reduction technologies that could be used to reduce the lateral propagation of sound from seismic exploration vessels. Excluded in this project is an investigation of specific effects of acoustic noise on marine mammals. Results to date demonstrate that deploying bubble curtains outboard of the seismic arrays towed by the same exploration vessel can potentially produce the sought-after noise reduction, while minimizing impact on the traditional seismic exploration operations. A second phase of this project is planned that will conduct a more rigorous 3D acoustic analysis of the preferred configuration of bubble curtain design and conduct a small scale physical test to confirm the 3D analysis results. TAR Project 608 http://www.mms.gov/tarprojects/608.htm.

11. Arctic Oil Spill Research Outreach

The MMS collaborates with state, federal and international governmental agencies, organizations, and private industry to coordinate oil spill response research and Ohmsett testing. Participation in JIP's allows MMS to leverage research funds and accomplish program objectives. We participate in international, regional and local conferences, workshops and meetings to present the results of MMS funded OSRR projects. We publish and disseminate the results of OSRR projects as widely as possible in peer reviewed scientific papers and articles, in technical journals and reports and in public information documents. The MMS sponsors and participates in Arctic related oil spill response workshops and conferences to disseminate results from the OSRR program and from Ohmsett testing, training and research activities to the public. The MMS maintains a website at http://www.mms.gov/tarprojectcategories/ArcticOilSpillResponseResearch.htm that contains a listing of all Arctic OSRR projects funded by the MMS as well as downloadable reports and film clips free of charge.

The Ohmsett facility also plays an important role in environmental outreach by informing the community of oil spills, environmental contamination, cleanup methods and testing.
The recently renovated conference room enables various federal, state, academic and private organizations to conduct on-site committee meetings and conferences. Facility tours and presentations are given to upon request. Regular attendance at both US and International environmental conferences plays an important role in getting the information, the analysis and the results achieved from the research projects to the public.

Publication of The Ohmsett Gazette, the facility's bi-annual newsletter, keeps the oil spill community abreast of recently conducted facility activities. Ohmsett's website (located at www.ohmsett.com) describes the testing that the facility conducts and gives objective results of the research conducted. Staff members also participate in environmental education projects such as school science fairs, college work study programs, and student mentorship programs. Through this type of public interaction, Ohmsett is able to increase public awareness by educating the community of the importance of marine safety and environmental protection.

Research Projects – Arctic Oil Spill Research Outreach

11.1. International Oil and Ice Workshop 2000

In 2000, the MMS participated in a JIP to conduct a workshop on Arctic oil spill response. The workshop assembled experts on oil fate and behavior, ice environments, and Arctic oilfield development to present the leading edge technologies in a seminar and field setting. Conducting the workshop in the operating oilfields on

the Alaskan North Slope added a level of realism to the key topics that cannot be duplicated elsewhere. The workshop provided a forum to showcase the results of MMS's Arctic oil spill response research. It provided an international forum for presentation and discussion of key environmental, operational and logistical topics associated with oil exploration and development in ice prone environments. It delivered state of the art information on a variety of oil and ice related topics to an international audience. The proceedings will guide future Arctic oil spill response research and development programs. The workshop was successfully completed with more than 225 attendees from the U.S., Canada, Norway, Russia, Japan and several other countries. The current state of the art in Arctic spill response was presented at the conference. TAR Project 354 http://www.mms.gov/tarprojects/354.htm

11.2. Production of a White Paper and Workshop Regarding a Full Scale Experimental Oil Release in the Barents Sea Marginal Ice Zone

Discussions with government agencies and oil companies in the United States, Canada and Norway have indicated their interest in conducting a research program involving a full-scale experimental oil release in the Arctic Marginal Ice Zone (MIZ). Primary interest appeared to be in evaluating alternative oil spill response options and in supplying data strengthened model simulations of oil-ice interactions. The purpose of this project was to conduct a workshop to assemble potentially interested organizations capable of funding such an experiment and establish an information base upon which to make decisions regarding a full-scale experimental oil release in the Arctic MIZ. Potential partners were identified and invited to participate in a Sponsorship Development meeting. The meeting was conducted October 15-16, 2001 at the Minerals Management Service, Alaska Regional Office in Anchorage, AK. TAR Project 453 http://www.mms.gov/tarprojects/453.htm

11.3. Partnering in a Workshop to Determine the Scope of an Experimental Oil Spill in Pack Ice in Canada

The objective of this jointly funded project with the DFO-Canada was to conduct a planning workshop for an experimental oil spill in pack ice offshore Canada. The workshop was successfully conducted November 1-2, 2005 at the Bedford Institute of Oceanography, Halifax, Nova Scotia. Some 30 scientists from nine countries participated in the workshop. A Steering Committee was formed to proceed with planning of the experimental oil spill. The MMS and DFO-Canada worked to conduct this research project under the auspices of the International Polar Year. A small experimental spill was conducted in the Gulf of St. Lawrence in January 2008. TAR Project 555
http://www.mms.gov/tarprojects/555.htm.

11.4. International Oil in Ice Workshop 2007

In 2006, the MMS initiated a JIP to organize and conduct an international workshop on recent advances in cleanup of oil spills in ice and cold climates. The workshop objective was to provide an international forum for presentation and discussion of key research, and operational and logistical issues associated with the response to accidental spills from exploration and development projects in ice-affected environments. The Oil in Ice workshop was successfully conducted October 10-11, 2007 at the Marriott hotel, Anchorage, AK. There were 276 registered attendees from nine countries (Canada, Finland, France, Germany, Norway, Russia, Sweden, United Kingdom and United States). Throughout the workshop, the general public, private industry and academic institutions were made aware that the Minerals Management Service through the Technology Assessment and Research program is actively funding and conducting research to improve the knowledge, technologies, and methodologies used to detect, contain, and clean up of oil spills that may occur in the worlds Arctic regions. TAR Project 587 http://www.mms.gov/tarprojects/587.htm.