JOINT INDUSTRY
OIL SPILL PREPAREDNESS AND RESPONSE
TASK FORCE

DRAFT INDUSTRY RECOMMENDATIONS to IMPROVE OIL SPILL PREPAREDNESS and RESPONSE

September 3, 2010

The Joint Industry Oil Spill Preparedness & Response Task Force (JITF) is comprised of member companies and affiliates of the American Petroleum Institute (API), International Association of Drilling Contractors, (IADC) Independent Petroleum Association of America (IPAA), National Ocean Industries Association (NOIA) and US Oil and Gas Association (USOGA).

The JITF is co-chaired by Keith Robson and Jay Collins.

The following companies and entities participated in the JITF:

American Petroleum Institute
Ampol
Anadarko
Apache Corp.
Aramco Services Co.
Baker Hughes
C&C Technologies
Chevron
ConocoPhillips
Dynamic Offshore
Ecosystem Mgmt. & Assoc.
ExxonMobil
GE Oil & Gas
Hess Corporation
Independent Petroleum Association of America
LOOP PLC
Marathon Oil
Marine Preservation Assoc.
Marine Spill Response Corp.
Natl. Ocean Industries Assoc.
Oceaneering
Oil Mop, LLC
Oil Spill Response, Ltd.
Petrobras America, Inc.
Polaris Applied Science
Research Planning
Seacor Holdings
Shell Exploration & Production Co.
Statoil
Tesoro
Tidewater
Wild Well Control

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EXECUTIVE SUMMARY

INTRODUCTION

With the emergency response phase of the Deepwater Horizon (DWH) incident nearly complete and preliminary findings and lessons learned becoming clearer, industry continues its assessment of what went well, what areas need improvement, and what areas need additional study. Experts from the industry have convened the Joint Industry Oil Spill Preparedness & Response Task Force (Oil Spill JITF), and are working cooperatively to address issues from the DWH. The Oil Spill JITF examined both the industry's ability to respond to a "Spill of National Significance (SONS)" and the actual response to the DWH subsea release based on information currently available.

Spill prevention remains a primary focus for the industry. Nonetheless, the current surface oil spill response system--as exhibited in the DWH Incident--continues to be effective. This system is specifically designed with the capability of contracting and expanding, depending upon the size and complexity of the required response. While there are many variables inherent in every spill response, the approach outlined below minimizes the likelihood of oil impacting sensitive shorelines while maintaining responder safety:

- The primary strategy should be to address the spill as close to the source (and as far offshore) as possible first controlling the subsea spill, then, applying appropriate quantities of dispersants.
- Oil that surfaces nearest the wellhead should be addressed through surface application of dispersants and, when conditions allow, mechanical recovery and/or in situ burning. Near the wellhead, these response activities need to be coordinated closely with other spill response and well containment activities.
- Beyond the immediate vicinity of the well head, aerial dispersant application should be used to treat oil that escaped the near-field mechanical recovery and in situ burn efforts.
- Further from the wellhead both dispersant application and mechanical recovery using vessels of opportunity should be deployed to combat floating oil. Accurate targeting of oil through visual observation and remote sensing from manned and unmanned aircraft, satellites, and other platforms should form a key part of the response.
- Finally, protective booming of priority areas should be conducted as identified through shoreline assessments and cleanup teams.

The scale of utilization of response tools used in the DWH Incident was unprecedented in the history of oil spill response, and despite the large amount of oil that was released over approximately 100 days, only a small fraction of that reached the shoreline. Examples from this response include:

- An Area Command was stood up and provided strategic input while still allowing the flexibility for the Incident Command Structure to implement tactical planning and direction.
- Over 400 controlled burns were conducted resulting in removal of between 220,000 and 310,000 barrels of oil from the environment.
- The application of dispersants was safely conducted in conjunction with approximately 1,400 total aircraft flights and treated significant quantities of oil.

- Subsea dispersant application significantly reduced the size of the surface slick and consequently reduced the shoreline impact. This is the only response tool that can effectively operate 24/7 and is not limited by weather conditions, except during strong tropical storms or hurricanes.
- In demonstrating the global logistical and mutual aid capability, over 40,000 responders and equipment were mobilized to respond including: GOM based oil spill contractors; cascaded equipment and personnel from other US and international locations; federal state and local agencies; and volunteers.
- Numerous technologies were employed to assist sensing and tracking the oil, including optical and infrared imaging. In addition, satellite imagery was used in tracking the surface spill and Remotely Operated Vehicles (ROV) assisted in monitoring for oil plumes in deepwater.

Nonetheless, the Oil Spill JITF members in this preliminary assessment believe that there exist a number of potential opportunities for improvement to the oil spill response system in the areas of planning and coordination, optimization of each response tool, research and development (R&D), and training/education of all parties preparing for or responding to an oil spill.

SUMMARY OF FINDINGS

The Oil Spill JITF was divided into subgroups that prepared detailed findings to support its recommendations. These findings, detailed in the main body of the document, are summarized as follows:

Oil spill response plans for each industry sector (storage facilities, marine transfer facilities and vessels, pipelines, and offshore facilities) are intentionally as standardized as possible. This improves the ability of government, industry and responders to prepare for events and implement an effective response. However, areas for improvement were apparent. Specific suggestions are made to improve 1) the speed with which the response can be "ramped up," including modular response strategies in areas such as Area Contingency Plans and Vessels of Opportunity 2) spill response plan content and structure, 3) the role of regulatory agencies, and 4) training and exercises for large spill events.

Oil sensing and tracking was a critical element in the DWH response. A variety of methods for the remote sensing of surface oil were successful at the DWH incident, but there are still opportunities for improvement. A methodology for subsurface remote sensing does not exist and is needed. In addition, improvements are needed in the connectivity between remote sensing data and trajectory modeling, with the goal of developing standardized protocols.

Dispersant application, both surface and subsurface, was a critical element in preventing significant oiling of sensitive shoreline habitats during the DWH response. However, misperceptions and knowledge gaps led to unanticipated restrictions on dispersant use. Industry and government both need to communicate the risks and benefits of dispersant use, as well as the safety and effectiveness of dispersant products. Furthermore, additional research should focus on the behavior and long term fate of dispersed oil in the water column when dispersants are applied near the sea floor.

***In situ* burning** was a highly valuable component of the DWH response that would not have been possible without the research and regulatory changes of the past 20 years. However, *in situ* burn technology remains limited by the performance parameters and similar to dispersant use, misperceptions and knowledge gaps led to delays in utilizing *in situ* burning and resulted in missed opportunities to remove more oil from the water.

The basics of **mechanical recovery** systems have not changed appreciably over the years, but incremental improvements continue to be made. While containment and removal is the preferred option, when possible, the practical limitations of such equipment need to be recognized and improvements to function in high sea states and currents are needed. Large skimmer systems also performed well in general, and there was no shortage of local storage capacity. Areas for improvement include continued incremental improvement in boom and skimmer design and a revisiting of the Effective Daily Recovery Capacity (EDRC) calculation for skimmers.

Shoreline protection and cleanup prevents or reduces the environmental effects of spilled oil once it reaches the shoreline. The basics of shoreline protection and cleanup have changed little over the past 20 years, but the knowledge of how and when to effectively collect oil has greatly increased. Some individual state and local actions, which were well-intentioned but in some cases potentially damaging to the environment (such as unnecessary and ineffective booming), need to be avoided through education, strengthened command and control protocols, and local involvement in planning efforts to ensure a cooperative joint response effort. In addition, the lack of trained and experienced individuals available to lead shoreline cleanup activities during the DWH Incident also demonstrates an area that needs addressing.

While the DWH response relied on proven technologies, the potential for new, or innovative **alternative response technologies** was a key consideration. Early in the response, an active program solicited and field tested technologies that demonstrated promise. This was later supplemented by a federal initiative, the Interagency Technology Assessment Program (IATAP), coordinated by the USCG R&D Center. Proven technologies specific to the DWH incident included the subsea injection of dispersants, the use of dispersants to dissipate concentrations of volatile organic compounds, and high capacity skimmers. Clearly, continued support of innovation in oil spill response is in the best interest of all stakeholders, but there must be a clear process and responsible organization to manage ideas.

CONCLUSION

The preliminary ideas presented in this report by industry are offered as a first step in the process of conducting a critical assessment of the current oil spill program. Most of these recommendations require the active participation and support of stakeholders other than industry. Moving forward, the members of the Oil Spill JITF believe that coordination between the private and public sectors is essential. For areas where improvements can be made, all stakeholders must agree on priorities and develop the cooperative mechanisms necessary if they are to be successfully implemented. Education, communication, and cooperation are the key to any future improvements.

RECOMMENDATIONS

Tables 1 and 2 list all of the Oil Spill JITF's near-term and long-term recommendations. The data in each table is organized by subgroup and includes both specific recommendations as well as who is responsible. The rest of the paper is supporting documentation for these tables and provides details and explanations around each category.

All actions are predicated on the availability of the appropriate federal and state agencies.

NEAR-TERM ACTIONS (INITIATED ON OR BEFORE APRIL 1, 2011)

Table 1. Near-Term Actions (Initiated on or Before April 1, 2011)

Item	*Description*	*Lead*
	GENERAL	
Lessons Learned Application	• Within one month of publication of the official lessons learned from the DWH Incident, the JITF will review those learning's and develop additional recommendations if warranted. • In addition, if the official Lessons Learned package from the DWH Incident contains information contrary to information contained in this Task Force's report, the Task Force will reconcile the report.	Oil & Gas Industry
	PLANNING	
Recommended Practice	The API will initiate the development of an API Recommended Practice on Oil Spill Response Planning.	Oil & Gas Industry
Source Control Branch in Incident Command Structure	Industry will have in place a Source Control Branch identified in their Oil Spill Response Plans (OSRP).	Oil & Gas Industry
Major-scale Response Support from Industry and OSROs	• Industry will convene a meeting among industry partners to consider the development of an agreement for providing trained company personnel with expertise in specific areas of oil spill response to a Responsible Party in the event of a federally declared SONS incident. • Industry will meet with major response co-ops to initiate the development of a pre-approval agreement or process that facilitates identification, availability, and commitment without delay of necessary resources to be made available to any Responsible Party in the event of a federally declared SONS incident.	Oil & Gas Industry
Well Control and WCD	Industry will continue to support the on-going efforts by the American Petroleum Institute (API) and the Society of Petroleum Engineers (SPE) in the development of a standard or recommended practice for calculating worst case and/or most likely discharge (WCD) rates for loss of well control incidents.	Oil & Gas Industry
Cascading of Resources	Industry will meet with appropriate federal and state agencies to initiate the development of a policy statement and possible Memorandum of Understanding to facilitate the cascading of resources and establish an alternative means of compliance for the "donor" areas including waiving US oil spill liability exposure and pre-emption of state requirements in the event of a SONS level incident. A description of this policy (and any MOU that may be developed) should be included in the applicable ACPs and individual OSRPs provided all federal agencies (USCG, USEPA, BOEM, and PHMSA) are in agreement with such a policy.	Oil & Gas Industry, Federal & State Gov. Agencies

Item	*Description*	*Lead*
	PLANNING (CONTINUED)	
GOM Planning Requirements and Response Capability	Industry will work with federal agencies to improve oil spill response capability and planning in GOM: • Pursue opportunities for improvements to OSRPs for initial response, ramp-up, facilities, support organizations and linkages to agency/public resources. • Industry will work with the major equipment manufacturers, OSROs, the USCG, and BOEM to assess any new technology or the use of technology used during the DWH Incident (to include evaluation of potential increases in skimming capacity via methods such as, but not limited to: increased EDRC skimmers and use of new boom technology including “ocean busters”). • Examine EDRC planning requirements for response to a Worst Case Discharge to determine applicability of volume reduction allowances for evaporation, borehole bridging, sub-sea dispersant application; in situ burn capacity; and surface dispersant capability, based on available data and the recent experience of the DWH response. • Develop protocol for systematic gathering and archiving of post-incident or post-exercise lessons learned.	Oil & Gas Industry, Gov., Contract-ors
Volunteer Program	Industry will initiate communication with the National Response Team (NRT) to encourage publication of the Federal Volunteer Guidelines as soon as possible.	To Be Determin-ed
	DISPERSANTS	
Communi-cation Tools	To improve understanding regarding dispersants, develop a series of simple fact sheets and/or other communication tools addressing various aspects of dispersants (effectiveness, tradeoffs, safety & health aspects, applicability in low wave environments and near-shore). These will be reviewed with appropriate government agencies for concurrence.	Oil & Gas Industry
Panel to Assess Research Efforts/Needs	An expert panel should be chartered to review data collection efforts for spill impact assessment and evaluation of ecological recovery rates for offshore, near-shore, coastal and estuarine areas impacted by spills. This can be modeled after the expert panels convened to review multi-year impacts and recovery in the U.K. after the *Braer* and *Sea Empress* spills; and in France and Spain after the Prestige spill.	Gov., Oil & Gas Industry, Academia, Contrac-tors
Review of Subsea Application	• Develop a summary of how subsea injection was utilized during the DWH response. • Develop a program for modeling and scaled testing of subsea dispersant injection to develop implementation criteria. • Investigate whether non-solvent based dispersants can be used effectively with this application mode due to rapid and uniform testing. • Work in conjunction with the Marine Well Containment Task Force to develop more efficient methods of applying the dispersants.	Oil & Gas Industry, Gov.
Review of Surface Application Techniques	• Review techniques and protocols to validate safeguards for response personnel while preserving operational efficiency. • Capture learning’s from the operational teams of DWH incident and sustain and enhance targeting and application capabilities learned.	Oil & Gas Industry, Gov., OSROs

Item	*Description*	*Lead*
	SHORELINE PROTECTION AND CLEANUP	
Crew Safety	The API will begin development of an API Recommended Practice on Personal Protection Equipment (PPE) for Oil Spill Response Workers.	Gov. (OSHA), Oil & Gas Industry, OSROs
Alternative Strategies	Thoroughly research the suitability of constructing tidal barriers and berms to determine whether these provide a positive net benefit, and can be demonstrated to be scientifically effective as a response strategy.	Oil & Gas Industry, Gov., Academia
R&D	Research should be conducted focused on the following items related to Shoreline Protection and Cleanup: • Enhancement of nutrient enrichment knowledge. • Exploring microbe usage in bioremediation. • Development of tidal and current flow baselines and scientific based strategies focused on determining shallow water inlet flow characteristics. • Development of technologies to improve "sandy" beach mechanized, mechanical cleanup.	Oil & Gas Industry

LONG-TERM ACTIONS (INITIATED ON OR BEFORE OCTOBER 1, 2011)

Table 2. Long-Term Actions (Initiated on or Before October 1, 2011)

Item	*Description*	*Lead*
	PLANNING	
Training and Drills/Exercises Program	Industry will initiate communication with the appropriate federal agencies to discuss potential enhancements in the training and drills/exercises programs.	Oil & Gas Industry, Gov., OSROs
Area Contingency Plans	The Area Committees should re-convene to address any recommended enhancements in the Area Contingency Plans. These would include, but are not limited to, the following: • Appropriate shoreline protection strategies and priorities based on Net Environmental Benefit Analysis. • Inclusion of local governments' concerns and participation in the Area Contingency Planning process. • Establish clear, well-understood protocols to discourage shoreline protection and cleanup response operations outside scope of ICS/UCS planning, review, and direction. • Identification, pre-determined use, and location of resources matched to the intended purpose. • Development of strategies and tactical approaches to support and expedite the cross-region transfer of resources to address the needs of a response to a federally declared SONS level incident. • A rededication to the principles of Incident Command Structure (ICS) and Unified Command Structure (UCS).	Gov.

Item	*Description*	*Lead*
	OIL SENSING AND TRACKING	

General	Industry and government should conduct a workshop focused on developing a path forward on evaluating and developing current or new technology related to Oil Sensing & Tracking. Areas of focus in this workshop will include, but are not limited to, the following:
	• Sensing & Tracking Recommendations
	  ○ Remote Sensing – Surface and Subsea
	  ○ Tracking – Surface and Subsea
	  ○ Improved mapping/graphic tools to portray oil plume locations and trajectories
	  ○ Science & Technology Recommendations
	• Satellite Use – including suitability for response direction at tactical level
	  ○ Use of various image analysis tools singly or in combination
	    - Infrared Cameras
	    - Underwater Acoustics
	    - Hyperspectral satellite-based imagery
	    - Others
	  ○ Applicability of fluorometric water sampling to determine dispersant effectiveness
	  ○ Improvements in logistical and operational management of aircraft platforms for sensing, tracking and control
	  ○ Buoy mounted oil sensing equipment
		Oil & Gas Industry
		Gov.

	DISPERSANTS	
Workshop to Improve Decision Making and Use Process	Industry will sponsor an industry-government (USEPA; USCG; NOAA; etc) workshop to discuss ways to improve dispersant decision making and use, including: • Area Contingency Plan process for tiered thresholds/approvals for dispersant use. • Review and discuss the rationale for stockpiling certain approved dispersants and consider adjusting the make-up of future to stockpiles as appropriate. • Review potential options to change regulatory procedures to allow a process for interim EPA approval for, under emergency situations, the use of dispersants that are stockpiled by response agencies outside of the US • Effectiveness monitoring protocols for surface (i.e. SMART) and subsurface application.	Oil & Gas Industry, Gov.
R&D	To the extent they are not adequately addressed through BP's $500M GOM research commitment, sponsor selected research projects in the following areas: • Technology for Oil and Dispersant Detection in the Water Column and on the Seafloor • Oil and Dispersant Fate and Behavior from Deepwater Releases • Dispersants – Subsea Application & Calm sea surface application • Ecotoxicity and Biodegradation • Next Generation of Dispersants	Oil & Gas Industry
	***IN SITU* BURN**	
R&D	Research should be conducted to identify fire boom that is more efficient in higher sea states and faster advancing speeds than currently available.	Oil & Gas Industry
Crew Safety	Industry to develop guidelines for selection of ISB safety officers prioritized on experience with marine vessel operations, and for training in IH and air hazards exposure	Oil & Gas Industry

Item	*Description*	*Lead*
	***IN SITU* BURN (CONTINUED)**	
Pre-Approval Process	A pre-approval process for in situ burning should be developed and implemented to remove procedural obstacles to in situ burning that could compromise the rapidity and efficiency of an integrated response effort. This should include: • Development and adoption of a common form for in situ burning preapprovals in conjunction with USCG, EPA, NOAA and industry. • Workshops and other learning opportunities for both regulatory agencies and communities to understand extensive scientific data (both lab and field based) as well as the value and net environmental benefit tradeoffs between oil spill and air quality consequences inherent in the use of in situ burning as a response tool. • Routine practice in the preparation and approval processes as part of drills and exercises. These should include scenarios involving open water offshore, near-shore/inshore, and on-land burns. • Development of training program for responders.	Gov., Oil & Gas Industry, OSROs
Guidance Document	The API will initiated a revision of the API Guidance document on *in situ* burning	Oil & Gas Industry
	MECHANICAL RECOVERY	
R&D	Continue Development and Research work on the following areas: • Large volume skimming platforms • Increasing encounter rate • Review R & D efforts on-going in international locations	Oil & Gas Industry, OSROs
Item	*Description*	*Lead*
	MECHANICAL RECOVERY	
Skimming Capacity Re-assessment	Federal agencies should re-assess the use of existing Estimated Daily Recovery Capacity (EDRC) calculation for defining skimmer capacity. The federal agencies should create a requirement that is based on realistic expectations and equipment capabilities.	Gov., OSROs, Oil & Gas Industry
Vessels of Opportunity Program	Following review of the lessons learned from the DWH Incident, a working group comprised of industry, USCG, local/regional port and harbor safety officials, and commercial fishing interests shall meet to develop a model Vessel of Opportunity agreement and Vessel Administration program.	Oil & Gas Industry, OSROs, Gov.
	SHORELINE PROTECTION AND CLEANUP	
Gulf Coast Environmental Sensitivity Mapping Index	Appropriate agencies and academia should begin the process to update these to quantify habitation categories and determine the overall ecological risk.	Gov.
	ALTERNATIVE TECHNOLOGIES	
Concurrent Incident Evaluation	Industry and the appropriate federal agencies should meet to discuss the functionality of the existing process for evaluating alternative technologies during an incident.	Oil & Gas Industry Gov.
Non-Incident Evaluation	Industry, the government, and appropriate organizations should meet to begin to develop a process that addresses the following: • A "Clearinghouse" for sharing of new information and technology. • Potential incentives that could be provided to facilitate the development of new technology.	Oil & Gas Industry, Gov., OSROs

FINDINGS OF THE SUBGROUPS OF THE JOINT INDUSTRY OIL SPILL PREPAREDNESS & RESPONSE TASK FORCE

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LIST OF ACRONYMS

µm	micrometer
ACP	Area Contingency Plan
ACS	Alaska Clean Seas
ALOFT	Airborne Light Optical Flight Technology
API	American Petroleum Institute
bbl	barrels
BOEMRE	Bureau of Ocean Energy Management, Regulation, and Enforcement (formerly the Minerals Management Service [MMS])
BOP	Blowout Preventer
CA OSPR	California Office of Oil Spill Prevention and Response
CEDRE	Centre de documentation, de recherché et d'expérimentations sur les pollutions accidentelles des eaux
CFR	Code of Federal Regulations
CIRCAC	Alaska Cook Inlet Regional Citizens' Advisory Council
COOGER	Centre for Offshore Oil, Gas and Energy Research
CRRC	Coastal Response Research Center
DO	Dissolved Oxygen
DOD	Department of Defense
DOR	dispersant-to-oil ratio, or dispersant application rate
DWH	Deepwater Horizon
EDRC	Effective Daily Recovery Capacity
EPA	United States Environmental Protection Agency
ESI	Environmental Sensitivity Mapping Index
ESRF	Environmental Studies Research Funds
FAA	Federal Aviation Administration
FLIR	Forward Looking Infrared Camera
FOB	Forward Operating Base
FOSC	Federal On-Scene Coordinator
ft	foot (feet)
GOM	Gulf of Mexico
gpm	gallon(s) per minute
IATAP	Interagency Technology Assessment Program
ICP	Incident Command Post
ICS	Incident Command System
IMT	Incident Management Team
IPIECA	global oil and gas industry association for environmental and social issues
IR	Infrared
JAG	Joint Analysis Group
JIP	joint industry projects
JITF	Joint Industry Oil Spill Response Task Force

km	Kilometer
LOA	Letters of Agreement
LOSCO	Louisiana Oil Spill Coordinator's Office
m	meter(s)
mm	milimeter(s)
MOU	Memorandum of Understanding
MSRC	Marine Spill Response Corporation
NASA	National Aeronautics and Space Administration
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NIMS	National Incident Management System
NOAA	National Oceanographic and Atmospheric Administration
NOFI	a maritime technology corporation
NOFO	Norwegian Clean Seas Association for Operating Companies
NTL	Notice to Lessees
OGP	International Association of Oil & Gas Producers
OMA	oil-mineral aggregates
OPA 90	Oil Pollution Act of 1990
OSR	Oil Spill Response
OSRL	Oil Spill Response Limited
OSRO	Oil Spill Removal Organization
OSRP	Oil Spill Response Plan
PAH	Polycyclic Aromatic Hydrocarbon
PERF	Petroleum Environmental Research Forum
ppm	parts per million
PWS OSRI	Prince William Sound Oil Spill Recovery Institute
PWSRCAC	Prince William Sound Regional Citizens' Advisory Council
R&D	research and development
RCP	Regional Contingency Plan
ROV	Remotely Operated Vehicles
RP	Responsible Party
RRT	Regional Response Team
SAR	Synthetic Aperture Radar
SCAT	Shoreline Cleanup Assessment Technique
SINTEF	independent research organization in Scandinavia
SLAR	Side Looking Airborne Radar
SMART	Special Monitoring of Applied Response Technologies
SMT	Spill Management Team
SONS	Spill of National Significance
SPE	Society for Petroleum Engineers
TGLO	Texas General Land Office
TPH	Total Petroleum Hydrocarbon
UAV	Unmanned aircraft or Unmanned autonomous vehicles
UC	Unified Command

US	United States
USCG	United States Coast Guard
UV	Ultraviolet
VMP	Volunteer Management Program
VOC	volatile organic compounds
VOO	Vessels of Opportunity
WCD	Worst Case Discharge

I. OIL SPILL RESPONSE PLANNING SUBGROUP FINDINGS

INTRODUCTION

Following the Deepwater Horizon (DWH) incident, the adequacy of BP's oil spill response plan (OSRP) for the Macondo exploration well, as well as those for other operators in the Gulf of Mexico (GOM), were called into question by a variety of sources. More specifically, industry was criticized for utilizing similarly formatted plans, with overlap in content. Concern about poor quality control was also expressed, with specific examples of what appeared to be inappropriate or outdated information.

The structure of all existing GOM OSRP's comply with Bureau of Ocean Energy Management, Regulation and Enforcement's (BOEMRE)[1] Notice to Lessees (NTL) 2006-G21 and Code of Federal Regulations (CFR) 30 CFR 254, the purpose of which is to strive for consistency of format, allowing for a rapid and effective response and to facilitate training and cooperative efforts. Nevertheless, in light of the issues that were raised and the magnitude of the DWH response, improvements to the OSRPs, to incident management, and to the planning process itself should be evaluated and implemented where appropriate.

The primary focus of this chapter is to improve the framework and written content of GOM offshore and other OSRPs and to make recommendations for improving the effectiveness of the response planning process. It is the Joint Industry Oil Spill Response Task Force (JITF)'s intent to capitalize on the lessons learned during the DWH incident and to incorporate these, where appropriate, in future spill response planning efforts. This chapter will explore the issues related to oil spill response planning, including 1) a brief background on the history of oil spill response planning; 2) the status of current response plans; 3) successes from the DWH response relating to response planning, and 4) specific recommendations for improvements.

HISTORY AND CURRENT STATE OF RESPONSE PLANNING

Regulations addressing oil spill response planning date back to the Clean Water Act of 1972 although historically, specific requirements for plan content have been limited. A paradigm shift occurred following the passage of the Oil Pollution Act of 1990 (OPA 90). The ensuing regulations required the development of comprehensive oil spill response plans for all industry sectors including exploration and production, marine transportation, refining, and distribution. Spill planning regulations promulgated by some states were even more comprehensive than the federal standards. In all cases, the regulations were intended to ensure the plan holders had adequate resources and processes in place to manage, to the maximum extent practical, up to a Worst Case Discharge (WCD) as defined in the regulations. Facilities or operations with the potential to cause significant and substantial environmental harm were (and are) required to submit their response plans to the appropriate regulatory agency for review and approval prior to initiating operations.

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[1] Formerly the Minerals Management Service

The adequacy of OSRPs and the actions prescribed therein are tested routinely through drills and exercises. Lessons learned from these drills and exercises are incorporated by the plan holders into the OSRPs and have become the primary means through which incremental plan and response process improvements are made. These lessons learned are also integrated into agency planning requirements or guidance documents. Furthermore, the experience of plan holder and agency personnel in executing strategies and tactics and adapting to various scenarios during drills or exercises has improved the functionality of plans across the response community.

Planning for an effective spill response encompasses a variety of aspects including, but not limited to:

- Spill detection and source control;
- Initial actions and assessment;
- Internal and external notification requirements;
- Incident management team(s) and processes;
- Response techniques including dispersants and *in situ* burning;
- Sensitive areas and protection measures;
- Response equipment and other resources;
- Wildlife rescue and rehabilitation; and
- Technological aspects of response communication and information exchange.

As per BOEMRE guidance via NTLs, existing plan structure is designed to focus on the initial stages of responses with less detailed guidance for supplemental stages of larger, extended duration incidents as with a WCD scenario. Although envisioned by both regulators and industry to be adequate for an offshore well blowout, OSRPs for the GOM have stood essentially untested for this type of response, a SONS, until the DWH incident. Each incident can present unique characteristics, so the plans must be broad and focus on initial response actions and activations while allowing the Incident Command System (ICS) organization to expand as needed.

Response plans are developed based on regulatory requirements that prescribe a specific format and content. Consequently, many plans have very similar content and format and in certain operating regions, contain some of the same reference information. To a large extent this is a desirable attribute that will assure, for example, that different plan holders will notify the same agencies, implement similar response tactics or prioritize the same sensitive resources for protection. The regulations do allow for alternative structures/formats but regulators often discourage deviations.[2] All plans are reviewed and approved by the governing agencies prior to initiating operations and contain all the information required by regulation. Additionally, plans must be consistent with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) and applicable Regional and Area Contingency Plans (RCPs and ACPs). All OSRPs must be reviewed and updated every few years depending on the applicable

[2] NTL 2006-G21/30CFR254.

regulatory requirements (2 years for GOM plans) with any significant changes submitted to the regulator for approval within 15 days for GOM plans.

SUCCESS STORIES FROM THE DWH RESPONSE

Current response plans contain or reference, in ACPs or RCPs, a substantial amount of information that is critical in a response. These plans have been used effectively for minor to major spills prior to the DWH event. The plans are very valuable for quickly identifying the initial actions to be taken to assess the incident and protect the health and safety of responders and the public. They also contain contact information and inventories of equipment, supplies, and services for local, regional and national response organizations to avoid delays identifying and mobilizing those resources. Additionally, they contain information on sensitive environmental, cultural, and socio-economic areas and often include tactical plans for protecting each area that are critical to minimizing the impact of the spill.

Specifically, the successes and benefits of spill response plans as demonstrated in the DWH incident include:

INCIDENT COMMAND SYSTEM

All plans, including BP's, incorporate the proven ICS model that uses common terminology, Incident Management Team (IMT) organization, roles and responsibilities, and a structured planning process to maximize efficiency, effectiveness and accountability. It also enables seamless integration of personnel from disparate organizations and backgrounds into a single IMT as evidenced by the rapid formation of an integrated IMT during the DWH incident. One of the components of the ICS model that worked well was the UC system.

TRAINING AND DRILL PROGRAMS

Through the program described in their response plans, BP provided several hundred trained personnel from their local and regional response teams to quickly begin managing the incident from their Emergency Operations Center in Houston, two Incident Command Posts (ICP) in Houma, LA and Mobile, AL and an Area Command Post in Robert, LA.

INNOVATIVE TECHNOLOGIES

Technologies such as dispersants and *in situ* burning are critical response tools, as evidenced by their successful use in the DWH response, and are most effective in the early hours or days of a spill. Consequently, most plans, including BP's, describe their use and reference dispersant pre-approvals in the NCP, ACPs and RCPs, which led to the approval to use dispersants in the early days of the DWH incident.

REGULATORY INTERFACE

Prompt notification of a spill to regulatory agencies as well as rapid coordination of response activities is crucial to an effective response. Contact information and roles, responsibilities, and reporting requirements of various agencies are often contained in response plans to facilitate this process.

Formal investigations and analyses of the response to the DWH incident by all private and governmental entities are anticipated to identify the strengths and weaknesses of the BP oil spill response plan. The JITF anticipates the BP plan and other plans using a similar format and content will be found to possess both strengths and opportunities for improvement. BP's OSRP has very detailed internal and external notification guidance including several decisions guides and tables with key contact information enabling them to rapidly contact the appropriate governmental agencies as well as to activate BP's IMT.

RESPONSE RESOURCES

While all Oil Spill Removal Organizations (OSRO) and resources utilized during the DWH were not listed in BP's plan, those that were served as a basis for identifying other resources. The ability of those organizations to identify and cascade equipment from around the world demonstrates the willingness of industry, the OSRO community, and suppliers to provide resources and spill response products and services in an expedited manner and should be recognized.

AREAS FOR IMPROVEMENT AND PRELIMINARY RECOMMENDATIONS

One of the primary areas for improvement identified by the JITF is the comprehensive ramping up of the level of response effort for a Spill of National Significance (SONS). This includes initially utilizing resources from the region, then cascading in additional resources from elsewhere in the US and finally from international sources. It should also include supplementing the plan holder's Spill Management Team (SMT) with additional trained personnel from other corporate and contract entities. A variety of additional response plan content and structure improvement opportunities have been identified along with training and drills, further utilization of the Unified Command (UC) concept, and the Regional Response Teams (RRT). Key improvement opportunities identified by this group for inclusion in OSRPs are briefly described.

The majority of the recommendations included herein can be implemented best by first convening a work group of key regulatory agency, industry, and OSRP consultants to determine the plan revisions necessary to make the improvements recommended. The work group would also ensure that other subgroup recommendations (e.g. dispersants, *in situ* burning, and mechanical recovery) are included in OSRPs.

RAMPING UP PERSONNEL, EQUIPMENT, AND LOCATIONS

Most plans only identify internal local and regional SMT personnel for initiation and longer term management of a response, respectively. This may not be adequate to manage very large incidents, such as a SONS. During the DWH response, industry provided experts to BP in many areas and although most operators have access to corporate Tier III and international responders, finding additional qualified personnel in the region in a timely manner should be examined. The JITF recommends that <u>an inter-industry Memorandum of Understanding (MOU) be considered to provide supplemental personnel trained in spill response management</u> and the ICS. It is recognized that this method would need a letter of interpretation from all regulating agencies regarding responder immunity to apply to all industry SMT members.

Different operators have access to different OSROs, oil spill co-operatives, private resources and response networks which, in some cases, have the potential to limit access to sufficient resources. Therefore, plan holders should assess alternatives for providing greater access to all resources within the US and internationally. Firstly, the National Strike Force Coordination Committee maintains the Response Resource Inventory (RRI), a national database of OSRO response resources. In a SONS event, this information should be made available to the UC as soon as possible. A description of, and link to, the RRI webpage should be added to the Logistics or Resource section of all OSRPs with similar information provided in each ACP.

Secondly, to ensure adequate response strategies and resources are available to manage a WCD to the maximum extent practical, planning requirements should include a process for identifying and cascading in resources from out of the region/US including obtaining waivers and approvals, addressing Jones Act issues for international resources, maintaining inventory lists in the plan (reference contractor web sites), and others. The cascading process should leverage all available response tools and supporting expertise such as dispersants, both subsea and aerial, mechanical recovery, *in situ* burning and shoreline protection to minimize impacts to sensitive environments.

Thirdly, not all plans include locations and sources of support services and if they do, they are often limited to local companies and may overlook the importance of key services such as catering, occupational or industrial hygiene expertise, or transport and warehousing services to the efficient functioning of a response effort. Plans should identify service providers capable of supporting an extended response for a SONS event. Furthermore, consideration should be given to pre-identifying ICPs and Forward Operating Bases (FOBs) with an infrastructure (food service, internet connectivity, sewage, etc.) that can accommodate large numbers of personnel and resources and obtaining concurrence on these sites from the regulators. This may be accomplished most effectively through the ACPs and consideration should also be given to pre-identifying existing industry infrastructure that can be made available via MOUs among operators.

Utilization of Vessels of Opportunity (VOO) was integral to providing additional skimming, *in situ* burning, shoreline booming, wildlife recovery and many other tactical operations during the DWH response. A program to manage such vessels can, however, be problematic if not well designed. A VOO program framework, based on lessons learned from the DWH incident and possibly including technical advisors to initially train and manage each group of vessels, should be developed and described in OSRPs inclusive of an example or template contract to expedite program implementation. The program could be managed by OSROs to ensure consistency and sustainability. Inclusion of the VOO program framework in the ACPs should be considered as a more viable alternative to inclusion in the OSRPs.

PLAN ADEQUACY, CONTENT, AND STRUCTURE

Based on the magnitude of the response required for the DWH incident, industry recognizes that existing OSRPs may need to be improved to effectively manage a WCD to the maximum extent practical, such as in the area of a subsea containment and ramping up to more effectively manage an incident. To improve plan adequacy, the DWH response should be reviewed to determine any opportunities for improvement to the OSRP as well as key response processes, facilities, support organizations, linkages to, and integration with, regulatory agencies, etc. This review could be conducted jointly by the United

States Coast Guard (USCG) and industry and should consider State and coastal Parish/County needs. <u>Guidance should then be developed for OSRP revisions to include the identified improvements</u>. Consideration should be given to ensuring the tiered approach takes into account operational requirements and associated oil spill risks wherein operations such as those with higher WCD and further distance offshore potentially could require different response measures and associated available resources. Finally, industry should commit to a thorough OSRP review by both operations and management representatives prior to agency submittals to ensure the plan content is complete and accurate.

Area and regional contingency planning should incorporate the involvement of local communities where appropriate. Experience shows that communities affected by an incident provide on the ground, local capacity needed in a cascading implementation plan. Where needed, branch offices should be activated to provide necessary response tools, from equipment to manpower and to assist in local response coordination. Local implementation will include a vessel of opportunity program that feeds into and coordinates with the area incident command. Branches offices can facilitate local outreach on response activities and work cooperatively with local officials as coordination is needed to communicate ongoing initiatives. Overall, local communities in close proximity to drilling and production operations will train and prepare according to contingency plans for the unlikely event of an incident so that local offices can implement action as needed.

Plan structure and format often is designed to ensure regulatory compliance at the potential expense of functionality. NTLs, CFRs, and other plan guidance should be revised to provide greater flexibility in using alternative plan structures/formats to enhance plan usefulness such as meeting organizational or operational risk requirements while still meeting regulatory requirements. Alternatively, <u>consideration should be given to a joint industry-agency effort to evaluate existing plans</u> in particular regions and explore the suitability of development of industry-wide plans that would encompass desired common plan elements across the spectrum of operations. Those plan elements that are operation- or receiving environment-specific would be left to the individual plan holders to develop.

Typically, industry OSRPs do not include a source control branch in the SMT organization although many offshore operators prepare a separate source control plan. <u>It is recommended that a source control component be added to the SMT organization in the OSRPs</u>. Inclusion of a procedure for accessing and activating additional SMT personnel as well as for identifying other sources of trained personnel is also recommended, via the aforementioned industry MOU. A list of experts in source control who could serve as technical advisors in a major incident should be identified and maintained in the OSRPs

For BOEMRE plans, a Quick Response Guide is optional and there is minimal guidance on content. However, such guides are very useful tools that provide rapid access to key information in the initial stages of a response. It is recommended that a best practice for content should be developed.

It is understood that, although BOEMRE provides some guidance, the process for calculating worst case scenario discharges is not consistent within industry. The American Petroleum Institute (API) is developing plans to work with other organizations such as the Society for Petroleum Engineers (SPE) to develop a standard or recommended practice for calculating worst case and/or most likely discharge rates for loss of well control incidents. This process is vital in moving the industry toward a consistent approach in evaluating WCD and the corresponding level of response capability. Industry experts are also looking to model effects of subsurface natural dispersion and dissolution of the oil into the water column to more effectively characterize the resulting WCD volume at the surface. This will allow operators to more accurately plan for the “effective surface WCD” and design a more fit-for-purpose surface response program taking into account reduction allowances as a percentage of the WCD such as in the areas of natural dispersion, evaporation, sub-sea dispersant application and *in situ* burning.

REGULATORY SUPPORT AND AGENCY ROLES

Cascading resources from out of the region/US during the DWH incident encountered many regulatory hurdles. A federal policy should be established for cascading resources and establishing alternative means of compliance waiving US oil spill liability exposure and preemption of state requirements, all of which limit the amount of assets capable of being cascaded to a SONS event. The policy should be supplemented by a MOU among responsible agencies for coastal states to assure appropriate regulatory approvals. A description of the policy should be included in the ACPs/RCPs, as well as individual OSROs, provided all federal agencies are in agreement with such a policy. Additionally, the agencies should address State planning standards, alternative means of compliance with those standards as appropriate, and plan holder liabilities for cascading resources to other areas.

Many regulations/guidelines are fairly prescriptive and should be revised to allow more flexibility to meet plan holder response needs and better reflect their response programs. However, since plan reviews generally focus on regulatory compliance and can vary depending on the agency reviewer, guidelines should be developed that not only evaluate regulatory compliance but also plan adequacy, while allowing for flexibility. The USCG and United States Environmental Protection Agency (EPA) have created consistent response planning requirements for Facilities and Tank Vessels as mandated by OPA 90. Development of similarly consistent requirements by BOEMRE for offshore operators should be considered and BOEMRE should establish a mechanism for recognizing and incorporating new breakthrough technology and response processes along with periodically updating allowed technologies. Finally, third party review in lieu of a regulatory review should be considered as a means of enhancing plan consistency, content and adequacy.

The Cosco Busan and (to a lesser extent) the DWH spills highlighted the need for a Volunteer Management Program (VMP) that is not generally addressed in OSRPs. Misunderstandings over what volunteers may and may not be allowed to do, and differences between agencies and RPs have created operational confusion in the field that led to negative media coverage, which adversely affected the credibility of the responses. Efforts have been made to develop guidance on volunteers but a definitive plan is still lacking. Federal Volunteer Guidelines being developed by the National Response Team should be published as soon as possible. These Federal guidelines should include the development of a process and identification of responsible organizations for 1) volunteer intake, 2) health and safety training 3) task specific training, and 4) volunteer management in the field. The guidance should also allow for responsible party (RP) involvement and consideration of the RP's contractors. Existing VMPs, such as those developed by California and included in the Northwest ACP, could be considered to form the development of a similar national VMP. Once finalized, the VMP should be included in all ACPs and referenced in individual OSRPs.

TRAINING AND DRILLS/EXERCISES

While existing training programs are generally acceptable, they should be enhanced as required to include 1) oil spill response information relevant to individuals with a role in response, such as field operations, IMT, senior management, 2) understanding of the applicable OSRP, ACP, and tactical shoreline protection plans including key interfaces and deployment strategies such as modular response for ACPs and VOOs, 3) dispersants and *in situ* burning for SMT and contractor personnel, and 4) training on the ICS system and Planning Cycle Process particularly for SMT personnel that would or could respond to spills including a SONS level incident.

The current requirements for drills/exercises are generally adequate but consideration should be given to enhancing WCD or SONS drill requirements to include simulated mobilization and/or actual identification of out-of-region resources and additional in-region plans and resources such as ACPs and activation of mutual aid SMT personnel. Consideration also should be given to holding a GOM SONS-type exercise on a periodic time frame allowing rotating operators to take the lead with participation from multiple other operators. This SONS exercise should be independent of exercises implemented by DHS in other geographic locations and should count as the regulatory-required exercise for each participating company.

There is no consistently established process for incorporating external lessons learned from training, drills/exercises and actual responses into OSRPs. Consideration should be given to using the Marine Well Containment System as a vehicle for large scale drills and developing a mechanism for industry and/or the regulators to collect and share lessons learned after major incidents or exercises.

UNIFIED COMMAND AND REGIONAL RESPONSE TEAM CONCEPTS

Both the UC and RRT concepts and functions, as stated in the NCP and the National Incident Management System (NIMS) were modified during the event. Some confusion and changes were only natural, since this was the first actual SONS event, but now we need to clarify the roles and responsibilities of the various agencies and the Executive Branch in managing a SONS event and make revisions to the NCP and ACPs to reflect any changes to the associated policies and procedures.

Once any necessary changes are implemented, the NCP and ACPs must emphasize the importance of well-understood lines of authority for response to major spills and pollution events, and the importance of supporting and validating the ultimate authority of the Federal On-Scene Coordinator (FOSC). Just as in a national security or natural disaster response, clear and uncompromised lines of authority are essential for public safety, mission clarity and execution of an effective and credible response effort.

Other improvement opportunities also include: 1) involving the Executive Branch in future SONS exercises, 2) encouraging Executive Branch members to participate in NIMS ICS including Planning Cycle Process and Joint Information Center training, and 3) developing guidelines for effective communication with and between the public, local governments, state government, the Executive Branch and local, state and federal agencies. Better communication will minimize the potential for differences in perceptions of success between the field and ICP level and at higher levels.

II. OIL SENSING AND TRACKING SUBGROUP FINDINGS

INTRODUCTION

A variety of oil spill sensing and tracking mechanisms have and are being developed from many divergent technologies. Most of these technologies can either detect hydrocarbons directly or indirectly or are related to environmental data recorders that are needed to model and predict spill trajectories. They include, but are not limited to, satellite imagery/Doppler radar, X-band radar, high frequency radio waves (CODAR), Forward Looking Infra Red camera and Side Looking Airborne Radar (FLIR and SLAR), optical and infrared cameras on airborne or undersea vehicles (manned or unmanned), underwater acoustics, fluorometry, stationary oil sensing equipment (e.g. buoy mounted) and the marine environmental data sensing systems used to aid in tracking released oil.

There are clusters of remote sensing technologies found throughout industry, but not well-defined standards for their use. Each technology has associated benefits and limitations and all have a fit-for-purpose design. There are gaps in oil sensing and tracking technologies that could be closed by additional research. Because of its limitations, remote sensing cannot be used to estimate spill volume, but can be used to monitor the location of oil and to identify the thickest areas of the slick.

Other obstacles are regulatory. For example, the FAA continues to oppose the use of Unmanned Aerial Vehicles (UAV) during spill response operations. Industry has on numerous occasions requested to test this platform for its viability in spill responses and tracking but has been denied airspace, even in open water trials away from any airport. For current response operations the most effective way to direct resources in the field (command & control) remains aerial observation. This potentially could be done more safely, at higher frequency, and in a more cost effective manner with UAVs.

During a response, the immediate deployment of resources is required for maintaining, gathering and relaying sensing information to end users. Remote sensing equipment can easily be deployed by vessels, buoys, and manmade structures, in so far as they do not impede response operations; the same holds true with airborne and/or subsea (manned and/or unmanned) remote sensing.

This chapter will explore the issues related to oil sensing and tracking technology including 1) a brief background on the history and current state of oil sensing and tracking technologies; 2) a discussion of areas for improvement of these technologies, and 3) specific recommendations for improvements.

HISTORY AND CURRENT STATE OF OIL SENSING

Most sensing and tracking systems from the past were compiled from existing similar technologies as a response to an oil spill incident. The National Oceanographic and Atmospheric Administration (NOAA) has typically taken the lead in the United States on developing oil spill-related sensing, tracking and monitoring systems and protocol. In 1976 when the tanker *Argo Merchant* ran aground on Nantucket

Shoals, NOAA began to standardize methods for assessing oil spills and a series of trajectory and fate modeling programs were created to provide the USCG with spill movement predictions.

Over time, the responsibility to assess, track, and monitor oil spill incidents has become a more collaborative effort between governmental agencies and industry. New sensing and tracking technologies slowly evolved over the decades, again primarily out of necessity. As computing speed and capacity grew, trajectory modeling became more reliable. The latest technology was utilized in the DWH response. The National Aeronautics and Space Administration (NASA) is using satellite technology to track the GOM loop current. Specifically, the Jason 1 satellite – a joint effort between NASA and the French Space Agency – and the Ocean Surface Topography Mission/Jason 2 satellites are taking loop current measurements. This information can be used to create sea surface maps to aid in trajectory modeling. Additionally, Acoustic Doppler Current Profiler technology is being utilized to understand subsea hydrology and oil plume[3] tracking. Finally, the response utilized Synthetic Aperture Radar (SAR; Canadian Space Agency RADAR SAT-2) and airborne-mounted multi-spectral color and thermal IR platform from Ocean Imaging Inc.

There have been advances in remote sensing, tracking and trajectory modeling, but technology at a whole has been advancing slowly, especially with respect to subsea plume modeling. Some outstanding advances have occurred, such as the use of synthetic aperture radar and Doppler shift radar in detecting and tracking oil. Most of these advances are driven by particular incidents or programs. Their use remains proprietary and not always available as a response option. Furthermore, the government and its contractors have sensing technology that remains classified and therefore unavailable to oil spill response workers. In trajectory modeling, the extrapolation of currents, weather, tides, time and visual data are used to predict tracking. Much of the environmental source data is published forecasting and not real-time information. Depending on the location of the spill, this information is either lacking or out-dated and a best-fit solution is utilized.

Some real time information can be uploaded remotely, but systems and technological variations create barriers. For example, remote tracking devices have difficulty distinguishing oil thickness and the most accurate information gathering device remains a well-trained visual observer. Aerial observation operations are used to update trajectories and oil slick maps two to three times per day, typically. Tracking buoys have been used in limited applications.

While few subsea plume models exist (CDOG for example), an improvement of subsurface oil modeling, sampling, and monitoring are required. A report was completed by PCCI Marine and Environmental Engineering for BOEMRE in 1999 that addresses this issue[4]. Since then, little publically-available research has been conducted on subsea oil plume tracking and modeling. Currently a mixed bag of technologies is being used at the DWH response, including Acoustic Doppler Current Profilers. The use of *in situ* fluorometers has been used successfully to identify the presence of hydrocarbons, but real-time measurement of hydrocarbon concentrations has been more problematic.

[3] For purposes of this report the word "plume" refers to concentrations of oil in water above background levels.
[4] *Oil Spill Containment, Remote Sensing and Tracking For Deepwater Blowouts: Status of Existing and Emerging Technologies*

SUCCESS STORIES FROM THE DWH RESPONSE

The most reliable source of information for the oil spill sensing and tracking program continues to be the highly skilled aerial observer. With properly trained operators, optical and infrared imaging and SLAR have proven reliable and successful during the response. Additionally, satellite imagery using various programs was extremely useful in tracking a spill covering this large of a geographic area and an ocean imaging system developed by BOEMRE and CA OSPR specifically for spill response was used successfully.[5] Finally, Remotely Operated Vehicles (ROV) successfully monitored plumes in deep waters.

AREAS FOR IMPROVEMENT AND PRELIMINARY RECOMMENDATION

Most areas suggested for improvement require increased research and development for advancing technologies in surface and subsurface oil sensing and tracking, as well as a standard for deployment. Both federal and state governmental support for advancing this technology is required, especially in the areas of permitting and regulatory oversight.

The most important recommendation is to investigate opportunities to further develop appropriate oil sensing and tracking emergent technologies. Industry needs to develop an industry-wide standard for these technologies' parameters and a protocol for their deployment. Also, the JITF recommends an interagency effort to garner support for these technologies, especially establishing a streamlined permitting process and availability of more governmental resources. Besides the general call for the research, development and standardization of promising oil sensing and tracking technologies, the JITF provides the following recommendations on specific technologies.

TECHNOLOGICAL ADVANCES

There is a need for improvement in accuracy, standardization in protocols, updated environmental data, and a way to input real-time information directly into trajectory modeling programs of surface sensing & tracking technologies. Real-time turn-around is not adequate to direct offshore resources using surface remote sensing technology and a stand-alone methodology for subsurface remote sensing & tracking is non-existent. Cloud-cover, night-time, and false positives restrict remote sensing usefulness. More effective autonomous methods are required, as well as improvements with detection technology and processing software that could facilitate data turn-around and reduce false positives. Developing technologies specifically related to hydrocarbon detection in deep waters is recommended, as responders need a clear understanding of the oil's fate and transport from deep and ultra-deep releases. The JITF recommends investigating available surface remote sensing capabilities and undersea remote sensing devices that provide oil concentration and fate information in order to identify cost effective, safe and effective technologies.

The JITF recommends evaluating processes or methodologies of compiling data that create an efficient and effective standardized surface tracking system. The goal is to have the ability to link needed

[5] http://www.mms.gov/tarprojects/544.htm; http://www.mms.gov/tarprojects/594.htm; http://www.mms.gov/tarprojects/658.htm; http://gos2.geodata.gov/E-FW/DiscoveryServlet?uuid=%7B12B11544-8411-242A-9D9C-025254AB7B47%7D&xmltransform=metadata_to_html_full.xsl

environmental monitoring information (e.g. buoys, satellites, remote sensors), trajectory modeling, and tracking systems. It is also essential to identify systems that have the potential to provide accurate tide and current information for near-shore, bays and estuaries and to incorporate aerial and remote-sensing imagery in high-resolution maps which can direct off-shore skimming and dispersant application. As a constituent of surface tracking, the JITF recommends considering the further application of CODAR to determine its feasibility as a system that can be used by various marine related end users.

Additionally, the JITF recommends evaluating existing capabilities for subsurface tracking, and investigating the need for and ability to create high-resolution 3D maps of subsurface plumes and currents. The JITF will analyze information from the DWH incident relating to the fate and transport of deep-water released oil to determine the benefits of improving industry's understanding of subsurface oil concentrations, movement and fate. The JITF also recommends assessing AUV deployment for subsurface plume tracking. There has been no focused research to develop those types of technologies. As a result, responders are left with no accurate subsea current information. Acoustic (sonar) approaches could cover more area than the current scope of their approach but translating acoustic data to oil concentration and/or presence is currently unreliable.

The JITF recommends implementation of a program to adopt private, public, and especially Department of Defense (DOD) satellite systems. Older technologies such as SAR have good capabilities to detect differences in the capillary action at the surface that is dampened by oil. These systems are viable at night and are not affected by cloud cover. Unfortunately, dampened capillary action is not necessarily indicative of oil on the water so on-site or other more discriminating remote verification is necessary to determine whether oil is actually present.

In order for satellite technology to be viable in emergency response, it must be accessible at least once daily. Current capabilities that meet the minimum of daily accessibility are the new high resolution optical satellites. However, the timing with the area of interest must coincide with daylight and cloudless skies. Conversely, improvements with current detection technology and processing software could improve data turn-around and reduce false positives. Use of satellite imaging to supplement visual observations will require improvements in real-time processing and communication of remote sensing data. Cost effective tracking buoys with real-time transmission capability could augment other observation techniques (e.g., provide night-time data). High-resolution mapping and imaging capabilities to accurately reflect oil slick distribution (patchiness, windrows, streamers, etc.) should be developed. The JITF recommends investigating whether existing satellite imagery can be made accurate and responsive enough to direct offshore operational resources (e.g., skimmers) or must remain a large scale mapping tool.

Ultraviolet and infrared sensing is a far better mechanism to identify oil at the surface of the water but these are also the most sensitive to the affects of cloud cover, rain, and wave action at the water surface. Furthermore, it has not been demonstrated that they are commercially viable or flexible enough to provide the anytime- anywhere coverage that would be desired in a large, fast paced event. The military may have this technology, but it is not available to the general spill response community. The JITF recommends exploring the possibility of combining Hyperspectral (UV to IR) image analysis with radar, SAR, or LiDAR. Some companies offer hardware and software to both capture and integrate LiDAR and hyperspectral images.[6]

[6] SpecTIR, 9390 Gateway Drive., Ste 100, Reno, NV, 89521

High Frequency Radio Wave - surface current monitoring (CODAR) monitoring provides a high resolution view of the currents in locations where these systems have been established; however, CODAR monitors are still very limited in coverage. They are also only valuable in determining what has happened and what is happening at present. In order to utilize this information in a predictive mode, the wind effects must be removed from the signal in order to determine what the water movement related to tides and background currents would be without winds.

Then, in order to determine a trajectory prediction, the movement of the water must be matched to future lunar and seasonal conditions and again combined with a wind forecast. This appears to be a reasonable alternative when responding to a spill away from shore and where other data (e.g. buoy data) is unavailable. These systems were not available widely enough geographically and have not been around long enough to be considered a reliable tool.

Underwater acoustics and sonar technology was not originally developed for the purpose of tracking oil. However, if the DWH response is any indication, there likely will be development of a system or platform designed specifically for subsea oil tracking using this instrumentation. Currently, ad hoc systems are being deployed with some success. Yet, even if it can be proven highly effective, using sonar in the oceans is known to disrupt and injure marine mammals making it a less attractive choice.

SMART laser fluorosensor and fluorometry technology had limited effectiveness in the DWH response due to the limited number of SMART-trained professionals available. Oil spill responders were contracted from the UK, Canada, and Norway because of the inadequate resources available in the US to run SMART monitoring efforts. Safety precautions also limited SMART usefulness in measuring dispersant effectiveness from aerial platforms (vessels needed to be two miles from application and often could not find the dispersed oil). Fluorometry did work well for monitoring sub-surface “plumes”; however, it required dedicated deep-ocean vessels with trained crews. Furthermore, fluormeters are very limited in the volume of samples they inspect and the distance over which they are sensitive. They also have no ability to change the focus of the optics to look further nor do they have any ability to change filters/wavelengths once deployed. The light sources have also been bulbs, which complicate achieving higher illumination levels at any distance from the light source.

This fundamentally provides a yes or no response – is there dispersed oil or not – and while a fluorometer can be fairly sensitive, it is not enough information to be particularly valuable. Furthermore, if the intent is to find dispersed oil, the dispersed plume separates from the surface slick very quickly and then moves with subsurface currents only. The surface slick continues to move with currents in combination with the wind. This produces a situation where sub-slick readings continue to be zero and, unless care is taken to sample the actual plumes, leads to the impression the dispersion is not working effectively.

Although fluorometry and fluorometers themselves are now much improved over the first bulky units, the technology still requires dropping highly trained technical teams near spill sites to handle the instruments. As such, trained manpower and vessel limitations (i.e. logistics) may always limit the effectiveness of flourometry during a response. Consequently, this sensing technique may only have usefulness for pilot studies on dispersant effectiveness and not for routine dispersant application during the response.

Laser fluorosensors are based on the same fluorosence phenomena used in fluorometry except that the light source is a UV laser typically airborne along with the detector. This technology may be the only reliable approach for discriminating between oiled and unoiled vegetation and capable of detecting oil on different types of beaches as well as snow and ice[7]. Laser fluorosensors can also be used to estimate slick depth and can be used with other sensors such as ultraviolet (UV), infrared (IR), SLAR, and microwave to improve performance[8]. The JITF recommends studying the potential modifications to fluorometers that would extend the range and volume of water that could be sampled.

The ability to detect oil on the water surface from a vessel requires that the viewing point is very high above the water. A vessel that is low to the water has very limited ability to see oil far into the distance. This is often evidenced very clearly by spray vessels and skimmers that can't stay in line with oil slicks. All marine platforms are affected by sunlight, darkness, sea state, and rain/fog. Subsurface ROVs are limited by their sensing technologies and visibility.

Aerial platforms provide a better vantage point than vessel-based marine platforms, but the observers must be trained in both the approach to observation and understand what local biogenic or organic factors might interfere with their observations of surface oil.

Certain optical and instrument sensors can improve and complement aerial tracking capabilities. Some of these (IR) are capable at night but the area must then be open for instrument flight rules rather than visual flight only. UV monitoring will continue to be affected by rain, fog, and clouds and most technologies will be affected by sea state. Additionally, aerial tracking works well during the day only.

A multispectral color and thermal IR instrument platform from Ocean Imaging was flown daily (sometimes twice-daily) to map the oil's extents, weathering state and thickness during the DWH response. This data was used to: 1) provide input and validation data for NOAA's oil spill trajectory forecast models; 2) document the effects of surface and subsurface dispersant applications; 3) recognize and document the existence and thickness of oil at the far boundaries of the spill; and 4) map oil reaching the shoreline. Image data could be processed while still airborne, although data could not be transmitted to the command post until the plane landed. Fully processed oil state/thickness maps were disseminated to multiple Command Centers within two to three hours after the flight mission. This technology offers the opportunity to provide high resolution oil thickness mapping which is not obtainable from satellite images.

The use of unmanned aircraft (UAV) in oil spill response is new. UAVs do work well, but have not been traditionally utilized in spill response. Even when responders wanted to deploy them as part of a sensing program, the reluctance of the FAA to permit their use has been a major obstacle. The JITF recommends continuing to refine the logistical and operational management of aircraft platforms in sensing and tracking services by providing standardized R&D parameters, deployment protocols and training. It also suggests allowing industry to evaluate the feasibility of utilizing UAV as sensing, tracking, and command and control platforms.

Buoys have a capability to measure in only the location where they are moored. This is a limitation as oil does not remain in place as a result of both physics and chemistry. It is still unknown how well stationary sensing equipment might work on a buoy, although early indications suggest that it is effective.

REGULATORY ISSUES

[7] M.F. Fingas and C.E. Brown.: "Review of Oil Spill Remote Sensors", presented at the Seventh International Conference on Remote Sensing for Marine and Coastal Environments, Miami, Florida, 20-22 May, 2002.

[8] M.N. Jha, J. Levy and Y. Gao.: "Advances in Remote Sensing for Oil Spill Disaster Management: State-of-the-Art Sensors Technology for Oil Spill Surveillance", *Sensors*, Vol. 8, pp. 236-255, 2008.

Regulatory issues tend to be centered on the development and deployment of any new technologies. The lack of interest in development, and the complexity of permitting technologies seem to be prevalent at both the state and federal level. It sometimes takes an event like the DWH incident to refocus priorities on the importance of research on new technologies. The DOD has many very useful systems and platforms that can be and are currently being used in the GOM. The issue arises with availability and then interoperability. Having a more streamlined requesting mechanism, along with developing a wide-spread repository of resources available to response personnel would be a great benefit.

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III. DISPERSANTS SUBGROUP FINDINGS

INTRODUCTION

Based on extensive research and applications to oil spills over the past 40 years, chemical dispersants are considered by industry experts and environmental stewards to be an acceptable, and often preferred, means of minimizing the environmental impact of oil spills. Although they are one of several tools available to combat oil spills, dispersants are a necessary component of an effective response to large volume offshore spills. The DWH incident response was no exception: application of dispersants (both surface and subsea) played a key role in the effectiveness of the response. However, better communication is needed to promote understanding of the benefits and limitations of the technology. Additionally, more work is needed to refine the technology to improve dispersant effectiveness and more fully evaluate the potential for environmental harm; to improve the regulatory approval processes for dispersant types and use during a response; and to study potential long-term impacts of dispersants and of dispersed oil on the GOM environment.

This chapter will explore the issues related to dispersant use, including 1) a brief background on the efficacy and safety of dispersants, 2) successes from the DWH response relating to dispersant application, and 3) specific recommendations for improvements.

THE EFFICACY AND SAFETY OF DISPERSANTS

Dispersants convert surface oil slicks into tiny droplets (<100 microns in diameter) that mix into the water column. When properly executed, waves and other mixing energy distribute dispersed oil droplets in the water column, where the oil undergoes natural biodegradation. The principal ecological benefit of this dispersion is to keep oil from entering near-shore bays and estuaries, or stranding on shorelines, thereby protecting sensitive coastal habitats and the species that inhabit them. Dispersant use minimizes the likelihood of oil contacting marine mammals, birds, and turtles. However, dispersing oil into the water column presents a trade-off: mitigating damage to the shoreline and to organisms that may encounter surface slicks means exposing the water column temporarily to elevated concentrations of dispersed oil.

Dispersant ingredients in formulations like Corexit EC9500A are found in common household products such as food, packaging, cosmetics, and household cleaners[9]. They are non-carcinogenic and do not bioaccumulate. Further, dispersants and dispersant ingredients do not pose a health risk to spill response workers provided they follow sound operating procedures and wear appropriate personal protective equipment.

Industry, government, and academia have conducted many studies evaluating the efficiency, and aquatic marine toxicity, and biodegradation rates of dispersants and dispersed oil. We know that

[9] http://www.nalco.com/

dispersants and dispersed oil rapidly biodegrade in an offshore environment.[10] Taken together, these data suggest that concentrations acutely toxic to marine organisms are likely to persist in only a relatively small region, in the case of subsea injection of dispersants, and for both a small region and short period of time, in the case of surface application of dispersants, as long as sufficient dilution can occur. When that is the case, there is no scientific evidence to date to suggest that significant long-term impacts on the offshore ecosystem have resulted from the use of modern dispersants in response to an oil spill. By contrast, impacts to wildlife, coastal habitats, recreation, commercial fishing, etc., from floating oil that is not dispersed can be severe and long-lasting.

Given this benefit weighed against the risk, world-wide regulatory approval of dispersant use has continued to expand and even consideration of dispersant application closer to shore has gained a level of acceptance in some locales. Furthermore, dispersants are favored over other options like mechanical recovery for large volume offshore spills due to the fact that they allow for rapid treatment of large surface areas even in poor weather conditions where mechanical recovery and *in situ* burns are ineffective (i.e. generally at sea states of 6 feet and above and winds of greater than 15 knots). In fact, the effective dispersion of oil droplets increases with physical mixing produced in these scenarios.

SUCCESS STORIES FROM THE DWH RESPONSE

MOBILIZATION EFFICIENCY

Dispersants were on scene, and provided the initial capability to respond to the oil spill, while other mechanical means were still being mobilized and deployed. Response organizations were able to quickly amass a comprehensive array of large and small aircraft from North America and Europe for dispersant operations, mobilize stockpiles from around the globe, and coordinate with dispersant suppliers for re-supply rates that did not limit dispersant operations. Multi-layered, Tier 1, 2, and 3 dispersant capabilities were immediately available in the GOM, while stockpiles of dispersants were cascaded into the GOM, and the manufacturing stream was opened to meet the demands of the spill.

There were approximately 1,431 total flights (application, spotter, reconnaissance) safely conducted during the response. Approximately 976,000 gallons (23,200 barrels) of dispersant were applied by aircraft, potentially treating between 500,000 and 1.5 million barrels of oil, depending on the effectiveness and rate of application. The diversity of airborne dispersant platforms provided broad coverage (six C-130 Hercules), intermediate coverage (BT-67 and DC-3), and more precise spray capability (King Air BE-90 and also, Air Tractor) (Table 1).

- Aerial application system technology was effective at meeting droplet size requirements and desired deposition patterns. The various aircraft systems/flow meters were calibrated for 5 gallons per acre application, thus carefully regulating the amount of dispersant applied to a given area.

[10] The National Academy of Science publication – "Oil spill dispersants: Efficacy and effects" summarizes the discussion about fate and impacts of dispersed oil. http://www.nap.edu/catalog.php?record_id=11283 This publication references many studies that were undertaken to study efficiency and potential impacts of dispersants and dispersed oil.

- Targeting and minimization of airborne dispersant was achieved by an integrated system of spotter aircraft, aerial photography, and feedback from the UC.

Table 3. DWH Response Surface Dispersant Application Systems

MC 252 - Deepwater Horizon Response
DISPERSANT APPLICATION SYSTEMS (Subsea Systems Not Evaluated)

Type	System	Volume	Equipment	PROS	CONS	Number	Owner/Operator
Aerial	ADDS	5000	C-130	Large Payload, Extended Flight time	Availability of aircraft, crew requirements (6)	3	CCA/Lynden (1), Alyeska/Lynden (1), OSR/Air Contractors (1)
	Fixed	3200	C-130	Medium Payload, Extended Flight time, Dedicated, smaller crew requirements then ADDS-equipped C-130s		1	MSRC/International Air Response
	Fixed	2000	C-130	Medium Payload, Extended Flight Time	Military Asset	2	USAF
	Fixed	2000	BT-67 (Turbo DC-3)	High Maneuverability, Medium Payload		1	Airborne Support Inc.
	Fixed	1000	DC-3	High Maneuverability	Small Payload	2	Airborne Support Inc.
	Fixed	240	King Air (BE-90)	Spot Treatment, minimal crew (2)	Small Payload	2	Dynamic Aviation
	Fixed	800	AT-802	Precision Spraying, minimal crew (1)	Single pilot/engine, limited distance from shore to operate due to single-engine layout	3	Lane Aviation
Surface	Boatspray	Per Cargo		Versatility to be mounted on different vessels of opportunity	Difficulty in finding targets without aerial observers	2	MSRC, CCA. One system used for scientific missions

MINIMIZING OIL STRANDING ON SHORES

Given the large volume of oil spilled, the lack of significant shoreline oiling can be attributed in large part to the use of dispersants on the surface and subsea. During the first 3 weeks of the spill, reports of oil impacts on the coastal habitats were limited. After implementation of the subsurface injection and because of concerns about the volumes of dispersants being used, surface application of dispersants was significantly curtailed because of concerns raised by regulators.

Despite imposing restrictions, as more information was provided, government officials often described the use of dispersants during the DWH response as highly effective. As the EPA noted on its website on May 27, "toxicity data does not indicate any significant effects on aquatic life. Moreover, decreased size of the oil droplets is a good indication that, so far, the dispersant is effective" in the DWH response. (The EPA analysis came as a result of aggressive monitoring conducted by BP in the GOM.) Other indications of government support for dispersant use are summarized below.

- In a May 24, 2010 press conference, EPA Administrator Jackson stated, "Our tracking indicates that the dispersants are breaking up the oil and speeding its biodegradation, with limited environment impact."

- USCG Rear Admiral Mary Landry echoed Administrator Jackson's statement by saying Corexit has prevented "much more" highly toxic oil from reaching US shorelines.

- Other quotes from EPA Administrator Lisa Jackson

  - "...dispersants continue to be the best of two very difficult choices."
  - "We know that dispersants are less toxic than oil."
  - "We know that surface use of dispersants decreases the risks to shorelines and organisms at the surface."
  - "We know that dispersants breakdown over weeks rather than remaining for several years as untreated oil might."
  - Regarding dispersant use at the well head - "Our tracking indicates that the dispersants are breaking up the oil and speeding its biodegradation, with limited environmental impact at this time."

- Paul Anastas, who heads EPA's Office of Research and Development, said the decision to allow dispersant use was sound given the dangers posed by the oil. He called the oil "enemy No. 1," and said that test results show the dispersant use "seems to be a wise decision and the oil itself is the hazard that we are concerned about." He also said "We do believe that use of dispersants was one important tool in the overall response to this tragic oil spill," but he and other EPA officials also acknowledge "tradeoffs" and say continued monitoring is needed.

- Head of NOAA, Jane Lubchenco - (speech on May 18th) - "As the oil reaches the shoreline, cleanup efforts become more intrusive and oil recovery rates decline."

Members of Government agencies, academia, and industry that convened during the spill for a workshop at LSU concluded that the use of dispersants to disperse the oil into the water column was less environmentally harmful than allowing surface oil to migrate into sensitive wetlands and near-shore coastal habitats

- University of New Hampshire co-director of CRRC, Nancy Kinner, indicated it is the consensus of the group that up to this point, "use of dispersants and the effects of dispersing oil into the water column has generally been less environmentally harmful than allowing the oil to migrate on the surface into the sensitive wetlands and near-shore coastal habitats".[11]

SUBSEA INJECTION

Injection of dispersant at the source of the subsea release was approved by the EPA on May 14 and remained operational for the entire spill except for limited periods where containment operations interfered (e.g., when the riser was intentionally severed). Injection rates were based on a chosen dispersant application rate (DOR) of 1:20 and best estimates of oil escaping at the time of initial implementation. The maximum rate of injection of dispersants was 20 gallons per minute (gpm), which assumes 13,700 barrels (bbl) per day of oil to be treated whereas typical injection rates were 8-10 gpm, which assumes 5,500-6,900 bbl/day oil to be treated. Given the much higher official estimated discharge rates (i.e. 50,000 – 60,000 bbl/day, or 10 x the original estimate), it is clear that the DOR was much

[11] www.crrc.unh.edu/dwg/dwh_dispersants_use_meeting_report.pdf

lower than the target of 1:20. The total volume of dispersant injected subsea was approximately 771,000 gallons.

Despite the extremely low DOR, all evidence concerning the effectiveness of subsea injection of dispersants is positive and suggests effective dispersion of the oil. Furthermore, both NOAA and EPA reported less oil on the surface after the implementation of subsea injection. The operation was therefore judged to be effective, even with inefficient injection methods and a DOR that would likely have been less efficient for surface application techniques. Application was achieved with coiled tubing pushed into the plume by an ROV; future systems could be much improved.

While clearly more study is needed, subsea injection can be viewed as a proven contributor to addressing spills from offshore wells because applying dispersants at the wellhead has the following advantages over applying dispersants at the surface and other response options:

- Safety: subsea injection reduces the amount of oil coming to the surface and this in turn (a) reduces exposure of surface vessels and personnel to volatile components of the oil and (b) reduces the need for surface recovery, *in situ* burn, and surface dispersant operations; thereby reducing exposure of response personnel to accidents during these operations.

- Requires much less dispersant: dispersants work best on fresh oil. Testing has shown that fresh oils with high API gravity readily disperse at dispersant to oil ratios below 1:100 and even lower when the dispersant is mixing well with the oil.

- More precise: application of dispersants into the blowout is more precise and can be better controlled than surface application of dispersants. Subsurface application is preferred as it ensures that all dispersant is mixed with oil in one manageable location before it spreads.

- Proceeds 24/7: subsea injection proceeds day and night whereas all other response operations are limited to daytime and subsea injection is not limited by weather conditions, except strong tropical storms or hurricanes. All other response options have weather limitations.

- All oil is treated: an efficient subsea dispersant delivery system could potentially treat all oil escaping from a single release point.

Members of the public, media, and regulatory agencies expressed concern over the long-term fate and effects of dispersants, dispersed oil, and the possibility of persistent subsea plumes of dispersed oil. Biodegradation of oil and dispersed oil is a natural process accelerated by the warm GOM surface water and also occurs at depth in colder temperatures but at slower rates. Dispersed oil biodegradation should occur without nutrient or oxygen limitations because of dilution from this highly active environment being fed by the Mississippi River system.

Ongoing research indicates that an oil plume was found 1200 – 1400 m below surface. There were very low concentrations of oil in the identified plume, measuring 1-3 parts per million (ppm) approximately 500 – 1000 m from source, with measurements returning to background levels at greater than six miles from the source. Field samples indicate dispersed oil droplets from the plume measured 2.5 – 60 microns, as expected for a light oil. Dissolved oxygen (DO) concentrations within the dispersed oil measured either within normal levels or slightly lower; no evidence of anoxia could be detected.

DILUTION AND DISSOLVED OXYGEN

Government data on the presence of subsea oil (see NOAA website) showed dispersed oil concentrations quickly diluted to very low concentrations consistent with model predictions. The Government Joint Analysis Group (JAG) issued a peer reviewed study on June 23, 2010 indicating that, among other things, DO and Total Petroleum Hydrocarbon (TPH) levels from dispersed oil plumes were not present at toxic levels or levels of concern. Also beyond 6 miles, the concentration of the subsea plume dropped to levels that were not detectable.

Measurements and observations conducted by BP, as well as NOAA, and other agencies during the DWH response supports the rapid dilution of dispersed oil plumes. As reported on June 23, 2010 by NOAA,[12] the dispersed oil plume associated with the subsea injection of dispersant dilutes to only 1-2 parts per million (ppm) within 1 to 5 kilometer (km) of the discharge point. Most studies of dispersant and dispersed oil toxicity find that acutely toxic concentrations are well above 2 ppm. Sensitive organisms could be affected by dispersed oil at these levels, but considering that standard acute toxicity tests expose organisms to a constant concentration of either dispersant or dispersed oil for 48-96 hours, only a limited number of organisms would contact dispersed oil in concentrations that would cause an acutely toxic response.

A second report from JAG released on July 23, 2010 confirmed that the circumstances characterized in the first report were essentially unchanged, i.e. that TPH and DO levels away from the immediate vicinity of the spill site remained at non-toxic levels.

While there is evidence of slightly reduced DO levels in the area affected by the subsurface oil, it was minor compared to the annual decrease in other near-by areas of the Gulf attributable to well-documented algal blooms from nutrient loading caused by agricultural runoff from Mississippi River. Runoff and air deposition of reactive nitrogen and terrestrial phosphorus have been identified as the primary causes of the yearly hypoxic zones found along the US Gulf Coast.

Dr. Nancy Rabalais has been monitoring the hypoxic zones in the GOM since 1985. “It would be difficult to link conditions seen this summer with oil from the BP spill,” said Rabalais, “in either a positive or negative way.” The slicks were not continuous over large areas for extended periods of time, which would be necessary to see the localized effects of toxicity or oxygen drawdown. “The Mississippi River nutrient-enhanced growth of phytoplankton is what fuels the hypoxic zone, and has for many years,” she said.

Studies supported by BP as well as those by EPA (June 30, 2010) suggest that eight listed EPA dispersants did not pose concerns from a toxicity standpoint. A second round of studies by EPA released on August 2, 2010 on dispersed oil show mixtures of dispersants and oil are generally no more toxic to two aquatic species than oil alone. Paul Anastas, who heads EPA's Office of Research and Development said, "For all eight dispersants in both test species, the dispersants alone were less toxic than the dispersant-oil mixture." EPA found Corexit "is no more or less toxic than the other available alternatives."

Industry is not aware of any evidence showing that significant long-term impacts to the offshore ecosystem have resulted from the use of dispersants in response to an oil spill. For example, during the

[12] http://www.noaanews.noaa.gov/stories2010/20100623_brooks.html

response to the 1979 Ixtoc blowout, dispersants were aerially used in Mexico's waters. Approximately 2 M gallons were applied. While scientific studies on this spill were limited, there were some measurable short-term impacts on phytoplankton and zooplankton populations but both populations recovered in a short time (Soto et. al. 2004). In a report to Congress in 1990, Mielke indicated that shrimp landings in the years following the spill were "unchanged or increased from previous yearly catches." The shrimp fishery included areas in the vicinity of the blowout. Note that data and studies from this spill are limited.

Industry, government, and academia have conducted many studies evaluating the efficiency and marine toxicity of dispersants and dispersed oil. These studies combined with our knowledge of the rapid dilution of dispersants and dispersed oil in an offshore environment show that concentrations acutely toxic to marine organisms persist in only a relatively small region in the case of subsea injection of dispersants and for both a small region and short period of time in the case of surface application of dispersants. The National Academy of Science publication – "Oil spill dispersants: Efficacy and effects" summarizes the discussion about fate and impacts of dispersed oil.[13] This publication references many studies that were undertaken to study efficiency and potential impacts of dispersants and dispersed oil. Localized impacts caused by the use of these dispersants are transient, as oil concentrations in the water column decrease rapidly, given the high dilution potential.

AREAS FOR IMPROVEMENT AND PRELIMINARY RECOMMENDATIONS

COMMUNICATIONS AND STREAMLINED APPROVAL PROCESSES

There were misperceptions and knowledge gaps regarding dispersants that lead to unnecessary restrictions on dispersant use. During the first 3 weeks of the spill, reports of oil impacts on the coastal habitats were limited. After implementation of the subsurface injection and because of concerns about the volumes of dispersants being used, surface application of dispersants was significantly curtailed. Subsequently, even though less oil was likely reaching the sea surface, more oil was reported to reach shorelines. More detailed analysis is needed, but there is a potential cause and effect relationship between the reduced use of dispersants and oil washing up on shorelines and impacting birds.

<u>The JITF recommends reviewing barriers to dispersant use as identified in DWH spill, and developing improved communications, as well as working with the government to streamline approval processes.</u> This would include reviewing environmental conditions and dispersant approval processes as applied during the DWH spill and determining if restrictions on dispersant use did in fact lead to increased shoreline impacts. Reviewers should consider improvements to communication/understanding regarding dispersants. The JITF also recommends developing fact sheets and/or other communication tools (for posting online, and for media and government access) addressing effectiveness of dispersant use during DWH spill, trade-offs (short term water column impacts vs. shoreline oiling) associated with dispersant use, human health and safety concerns associated with dispersant use, and the merits of applying dispersants in low wave heights, on surface emulsions, and near-shore environments.

<u>The JITF recommends sponsoring an industry-government (EPA, USCG, etc.) workshop to discuss ways to improve dispersant decision making and use</u>, including developing a system in the ACP for tiered thresholds/approvals for dispersant use that exceed Tier 1, 2, and 3 regulatory requirements as specified

[13] http://www.nap.edu/catalog.php?record_id=11283

in USCG regulations (February 2011); and reviewing and discussing the rationale for stockpiling certain approved dispersants. Furthermore, the workshop should consider adjusting the make-up of future stockpiles as appropriate. Listing on various country approval lists (US, UK, Australia, etc) increases the opportunity to comply immediately or help make the case that other countries see value in a given product, so it should be considered for use in the country of concern on an emergency basis.

Concerning dispersant effectiveness, emphasis should be placed on peer reviewed/independent sources beyond test data in marketing brochures or done for country registrations. Placing emphasis on effectiveness shown in a diverse set of lab tests and in actual responses and for a diverse range of oils (light to heavy oils, crude oils to refined products) and oils that are weathered or emulsified gives heavier weight to these considerations. The same is true of data concerning toxicity to marine life and response personnel: emphasis should be placed on peer reviewed/independent sources beyond test data in marketing brochures. Finally, shelf life should be a factor of consideration since the longer the material can be held without loss of effectiveness the better since materials may be stored for years. Given that dispersant availability was an issue limiting dispersant product choices during the DWH response, ability to produce needed quantities should also be considered.

The workshop should guide efforts to develop better tools to monitor dispersant effectiveness in surface applications in order to overcome the limitations of current USCG Special Monitoring of Applied Response Technologies (SMART) protocols. New approaches would remove bias currently focused on immediate, high efficiency measures of dispersant effectiveness and allow new ways to quantify the delayed effectiveness or slower rates of slick spreading and dispersion seen in calm waters or with heavier/emulsified oils. Furthermore, these efforts should result in tools/protocols for monitoring the effectiveness of subsea dispersant injection.

The workshop would also review potential options to change regulatory procedures to allow a process for interim EPA approval for, under emergency situations, use of dispersants that are stockpiled by response agencies outside of the US, and have been approved for use in countries such as UK, France, Norway, Australia, etc. that have rigorous screening criteria, and for such products that have demonstrated effectiveness on similar oil types.

APPLICATION TECHNIQUES

Lessons learned from operational teams of DWH incident regarding targeting and application capabilities suggest that there were many complications to dispersant use that surrounded application. There were reports of response personnel being negatively impacted by dispersants; yet the capability to specifically monitor for the presence of dispersants in the air is limited. The amount of dispersant sprayed exceeded the amounts envisioned by several stakeholders. While aerial application technology was adequate and effective, protocols for targeting were evolving and cumbersome and delays often resulted in a less than optimal use of dispersant assets. Finally, vessel spray systems were not utilized, except by "Source Control" to suppress VOCs, and for limited test applications of different dispersants for effectiveness and research purposes. As such, the JITF recommends <u>reviewing dispersant surface application techniques and processes to validate safety margins and promote the use of as little dispersant as necessary to disperse the oil.</u>

Efforts should review techniques and protocols (e.g. drift modeling, air monitoring) to validate safeguards for response personnel while allowing for operational efficiency, and should also capture lessons learned, including an assessment of the following aerial surveillance, remote sensing, communications and information sharing, and operational and tactical spray/no spray decisions. Regular targeting training should be conducted with industry and government representatives and efforts should be made to assess the need for new application equipment.

Subsea injection is a proven new approach that could benefit from further refinement. Additional efforts concerning subsea injection should involve developing a summary of how subsea injection was utilized during the DWH response including evidence of efficiency and effectiveness. Researchers should model and scale test of subsea dispersant injection to develop implementation criteria (DOR limits, oil type limits, temperature limits). In conjunction with the Marine Well Containment Company initiative, researchers should develop more efficient methods of applying the dispersants. They should also investigate whether non-solvent based dispersants can be used effectively with this application due to rapid and uniform mixing.

FATE AND EFFECTS OF DISPERSANT USE

Although initial studies/data indicate that impacts of dispersant and dispersed oil are expected to be minimal and short lived, more research is necessary.

The JAG has released two peer-reviewed reports on subsea monitoring data and plan more analysis/reports with data/conclusions regarding both DOR and potential toxicity. Additionally, BP has committed to a $500 million research program to look at the fate and effects of the DWH incident. Aspects of this long term research program will address fate/effects of dispersed oil (chemically dispersed and naturally dispersed).

The JITF recommends that a panel of experts be chartered to review data collection efforts as part of spill impact assessment and evaluation of ecological recovery rates for offshore, near-shore, coastal and estuarine areas impacted by spills. This can be modeled after the expert panels convened in the UK after the *Braer* and *Sea Empress* spills, and in France and Spain after the *Prestige* spill that looked at multi-year impacts and recovery. The panel would draw on data collection and research reports affiliated with the DWH incident, and look for supplemental sources of information to support their mission. They can be specifically chartered to address the unique aspects of the DWH incident, such as the significant depths of the oil release, prolonged and high volume use of dispersants, impacts of pre-existing low dissolved oxygen concerns for portions of the Gulf, potential mitigating or exacerbating aspects of hurricane events, etc. In addition to interpreting data and applying the results, the panel will also consider funding other research.

In addition, to the extent they are not adequately addressed elsewhere, industry will consider sponsoring selected research projects in the following potential areas of study:

<u>Technology for Oil and Dispersant Detection in the Water Column and on the Seafloor</u>

The foundation for work on this topic is the DeepSpill (SINTEF 2001) experiment and the ongoing DWH incident response, where many techniques are being used but details are not yet publicly known. It will be important to find out what has already worked during the DWH response.

- Development of remote “survey” technologies for rapid and accurate detection of oil and plumes in deep- and mid-water over larger distances; acoustic survey techniques (multibeam echosounders and chirp sonar) are promising. Work should go to validating and standardizing the "fine-tuning" of instruments to detect different sized oil aggregates in the water column, and ability to differentiate oil dispersions from other types of particles in the water. This technology will be very useful for proving the effectiveness of dispersants applied at depth. Technology may also be developed for ecological assessments and natural resource damage assessments of baseline/impacted planktonic communities, since it may also be used to semi-quantitatively determine organism distributions and densities.

- Development of fine-scale plume sampling and analytical methodologies that accurately characterize the plume, e.g. Polycyclic Aromatic Hydrocarbon (PAH), TPH, water-accommodated fraction, with respect to chemical constituents of concern that are directly relevant for ecological risk assessments.

- Current *in situ* methods (CDOM fluorometry, normal light transmissometry, and laser light backscatter) need further refinement to be more than semi-quantitative for oil/gas and constituents of concern. They also require sample water to pass directly though the instrument, so they are inefficient for large-scale survey work, such as to determine the extent of a subsurface plume. Can we develop technologies for *in situ*, quick differentiation of potential sources, such as spills from natural seepage?

- Development of ROVs and UAVs to deliver analytical packages autonomously and/or remotely when surface conditions may be unsuitable for a surface-support vessel. Underwater vehicles and gliders, for example, can be standardized for quantifying oil and gas in the water column. Support continued refinement of the realistic use of the SMART Protocol from USCG/NOAA based on lessons learned with regard to protocol limitations during the DWH spill.

<u>Oil and Dispersant Fate and Behavior from Deepwater Releases</u>

As the DWH incident demonstrated, there is a continuing need to understand how oil behaves and disperses (both naturally and after application of dispersants) within the water column when released at significant depth, temperature, and pressure. Field studies (e.g. DeepSpill) must be performed to improve the development of predictive models and be expanded to investigate a wider variety of variables such as:

- greater water depth, the role of temperature, pressure, volume, and rate of release

- the role that initial mixing and well-head dynamics played with respect to the flow from the well head, the size of the droplets in the water column particularly after subsea injection of dispersants, and the emulsification rate.

- Variable crude properties and varied gas-oil ratios

- Composition changes (solubilization, dispersion, emulsification) with distance and time from the point of release - at depth and on surface, enhanced accounting for different components of the release (gas, oil, PAH, water accommodated fraction and particle fraction, etc.) with the intent to relate fate and weathering to mass balance

- Quantification of horizontal and vertical diffusion of treated oil. Knowledge of vertical and horizontal diffusion of dispersed oil in water is still very limited. We need better understanding of dispersed oil diffusion in seawater below and above the pycnocline to enable better model development of dispersed oil plumes in deep sea.

- Support continued refinement of blowout model with results of field study for a wider variety of crudes with potential hydrate-formation[14]

    - Incorporate into 3D trajectory model to be coupled into surface trajectory models.

    - Address long-term releases lasting weeks to months.

    - Include a particle size prediction algorithm for dispersant-treated oil.

- Validate and standardize methodologies to determine rate of release from deep water source

Dispersants

- Effectiveness of deep water application, determine optimal rate and method of deepwater application. Is spill more dispersable at well head where temperatures are higher than surrounding seawater? Differences from surface application, such as the fate of the solvent (which evaporates to some extent under surface conditions). Consider developing dispersants specifically for deepwater injection. A deepwater dispersant may not need any solvent or very little solvent.

- Evaluate effectiveness of subsea application of dispersants using the injection technique, conditions, and oil type of the DWH incident. Show whether or not the process was effective even when injection methods and rates weren't optimal.

- Natural conditions controlling effectiveness of dispersants - These factors include temperature, mixing energy (but little is known about deep sea injection into rapidly moving oil from a blowout); salinity, time till dispersant application, sub-sea conditions (dissolved oxygen; hydrostatic pressure; water solubility and composition of dispersants and their constituents).

- Communicate findings of multiple studies that dispersants stay with oil under calm conditions for periods of up to and exceeding 2 weeks and still allow oil slicks to disperse when mixing conditions increase. Consider doing additional research proving the dispersants can work in calm seas. For example, dispersant-treated slicks spread very thin in calm seas allowing them to disperse at much lower energy than thick slicks.

- Enhance protocols for monitoring of dispersant application efficiency. Better version of SMART.

- Summarize previous research and conduct new research showing the emulsions of light crude oil (and maybe even medium to heavy crudes) can be effectively treated with dispersants and disperse. The difference is that emulsions will take longer for dispersion to happen.

[14] http://www.cdogmodel.com

- Research applicability of various "green chemistry" formulations to identify dispersant formulations and manufacturing approaches that could reduce the potential human and environmental toxic impacts. Focus areas would beformulations that reduce the use of chemical solvents while also maintaining broad dispersant effectiveness over range of oil types and weathered states:

    - Water based formulations with greater effectiveness than those currently on the market

    - Dispersants with concentrated surfactant packages that reduce need for solvents and also lower overall application rates while maintaining effectiveness (DOR of 1:100 or less) -- dispersant gels and concentrated formulations

    - Use of clay particles to stimulate slick breakup and form Oil-Mineral Aggregates (OMA's), initial research underway by Canadian Department of Fisheries and Oceans

- Replace current surfactant packages with new generation chemicals that are more biodegradable

- Identify potential combinations of spreading agents and surfactants that work to enhance dispersant effectiveness under low mixing energy situations (less than 1 foot seas)

<u>Ecotoxicity and Biodegradation</u>

- Toxicity of dispersant and oil-dispersant mixtures to sensitive life history stages of pelagic deepwater and mid-water organisms (little work has been done with such animals due to the difficulty of maintaining appropriate environmental conditions). Testing should address acute impact thresholds as well as chronic exposure concerns for organisms that may travel with the plume rather than be able to swim independently (follow through time). Deepwater species testing has been done by some research institutions (Harbor Branch Oceanographic Institution and Monterey Bay Research Institute) that may be useful in development of methods for keeping those animals alive for realistic testing.

- Biodegradation of dispersant and oil-dispersant mixtures on the deep- and mid-water by microbial respiration has not been well studied. How long does it take? What are the important environmental variables? Can we confirm that dispersants have net-positive effect within these communities,

- Verification of dispersion models that spatial effects on seafloor organisms is limited to the immediate proximity of the release, even for a long-term event. This can be addressed via studies of DWH incident impact (seafloor transects around the wellhead). This is important to verify as deep water corals and chemosynthetic communities (animal communities living in the deep sea on dissolved gases and benthic habitats) are sensitive habitats that can have protected status. Additional data supporting lack of deepwater benthic impacts will be TPH analysis of sediments and near benthic water column.

- Model and verify predicted impacts of dispersants and dispersed oil to higher trophic levels including marine mammals, turtles, and fishes. With injection at depth, the potential interaction of a marine mammal with dispersed oil is significantly different than exposure to floating oil at the surface. Have marine biologists develop the food chain pathways between deepwater ecosystems, mid-water ecosystems, and near-surface ecosystems.

- Development of a standard mammal survey and necropsy procedure

Surface Observations and Trajectory Models

- Real-time data on currents, tides, and winds as well as sustained observations of physical and chemical parameters of the whole water column are important in driving the models that inform the trajectory forecast for the spilled oil.

- High Frequency radar derives fields of surface currents, which are the most useful predictor of the surface trajectory; these observations feed into trajectory models in real-time. Coverage along the Gulf Coast is coastal and not financially supported as well as it once was, additional capacity further offshore would help. This item is a project identified in the Shell-NOAA collaboration on Hurricane Observations in the Gulf of Mexico, but has not been undertaken due to lack of funds. Most of the rest of the world has little to no coverage.

- Conduct a mass balance of the DWH incident to compare with the NOAA "oil budget."

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IV. *IN SITU* BURNING SUBGROUP FINDINGS

INTRODUCTION

In situ means "in place." *In situ* burning refers to the controlled burning of oil spilled from a vessel, facility, pipeline, or tank truck close to where the spill occurred (ASTM, 2003a). For spills on open water, responders usually have to collect and contain the oil using fire-resistant booms, because the oil has to be a minimum thickness to be ignited and sustain burning. This boom needs to withstand the combined forces of heat exceeding 2,000°F, wave action, and towing. Typically, the oil contained within a fire-resistant boom is ignited using a hand-held igniter or an igniter suspended from a helicopter. When conducted properly, *in situ* burning significantly reduces the amount of oil on the water and minimizes the adverse effect of the oil on the environment.

In situ burning has been used effectively in the DWH Incident and has demonstrated its effectiveness in responding to a deep water blowout. The volume of oil burned in this response has been between 220,000 and 310,000 barrels. This was accomplished in 411 controlled burns over the course of the response to date. While conducting these burns various types of fire boom were utilized. *In situ* burning operations in the DWH response highlighted the need for two items: continued research and development of fire boom; and more importantly, training and development of improved decision processes for execution of *in situ* burning operations.

BACKGROUND ON THE EFFICACY OF *IN SITU* BURNING

Burning oil *in situ* allows for the rapid removal of oil that has been collected and contained on the water surface. An *in situ* burn converts the liquid oil into its primary gaseous combustion products - water and carbon dioxide, plus a smaller percentage of other unburned or residual byproducts, including soot and gases. *In situ* burning does not completely remove spilled oil from the environment; the burned oil is primarily converted to airborne residues (gases and large quantities of black smoke or soot) and burn residue (incomplete combustion byproducts). However, when conducted properly, *in situ* burning significantly reduces the amount of spilled oil on the water, thereby, preventing that oil from remaining in the water or moving and affecting other resources and habitats.

REQUIREMENTS FOR IGNITION

In order to burn oil spilled on water, three elements must be present: fuel, oxygen and a source of ignition. The oil must be heated to a temperature at which sufficient hydrocarbons are vaporized to support combustion in the air above the slick. It is the hydrocarbon vapors above the slick that burn, not the liquid itself.

Heat transfer back to slick: Most heat from a burning oil slick is carried away by the rising column of combustion gases, but a small percentage (about 1% to 3%) radiates from the flame back to the surface of the slick. This heat is partially used to vaporize the liquid hydrocarbons which rise to mix with the air above the slick and burn; a small amount transfers into the slick and eventually to the underlying water.

Once ignited, a burning thick oil slick reaches a steady-state where the vaporization rate sustains the combustion reaction, which radiates the necessary heat back to the slick surface to continue the vaporization.

Flame temperatures: Flame temperatures for crude oil burns on water are about 900 °C to 1200 °C. But the temperature at the oil slick/water interface is never more than the boiling point of the water and is usually around ambient temperatures. There is a steep temperature gradient across the thickness of the slick; the slick surface is very hot (350 °C to 500 °C) but the oil just beneath it is near ambient temperatures.

Oil burning rates: The rate at which *in situ* burning consumes oil is generally reported in units of thickness per unit time (mm/min is the most commonly used unit). The removal rate for *in situ* oil fires is a function of fire size (or diameter), slick thickness, oil type and ambient environmental conditions. For most large (> 3 m diameter) fires of unemulsified crude oil on water, the "rule-of-thumb" is that the burning rate is 3-3.5 mm/min. Automotive diesel and jet fuel fires on water burn at a slightly higher rate of about 4 mm/min. In other words, relatively fresh oil can be eliminated at the rate of about 0.07 gallons/minute/square foot.

Factors affecting burn efficiency: For efficient burns, removal efficiencies are expected to exceed 90% of the collected and ignited oil. Factors affecting burn efficiency include original slick thickness, degree of emulsification and weathering, area coverage of the flame, wind speed, current, and wave choppiness.

Slick thickness: Extensive experimentation on crude and fuel oils with a variety of igniters in a range of environmental conditions has confirmed the following "rules-of-thumb" for relatively calm, quiescent conditions:

- the minimum ignitable thickness for fresh, volatile crude oil on water is about 1 mm;
- the minimum ignitable thickness for aged, unemulsifed crude oil and diesel fuels is about 2 mm to 5 mm;
- the minimum ignitable thickness for residual fuel oils, such as Bunker "C" or No. 6 fuel oil, is about 10 mm; and,
- once 1 m^2 of burning slick has been established, ignition can be considered accomplished.

The key oil slick parameter that determines whether or not the oil will burn is slick thickness. If the oil is thick enough, it acts as insulation and keeps the burning slick surface at a high temperature by reducing heat loss to the underlying water. Very thin slicks are rapidly cooled by loss of heat to the under lying water. As a result vapors are not formed and eventually enough heat is transferred through the slick to allow the temperature of the surface oil to drop below its fire point, at which time the burning stops.

IN SITU BURNING AND IGNITION PARAMETERS

When oil is spilled at sea, it is subject to a variety of transport and weathering processes. Of the eight major weathering and behavior processes, the following can directly influence slick ignition and burning:

Wind, wave, and current action: Experiments have shown that *in situ* burning is possible only under relatively calm conditions. When winds are stronger than approximately 20 knots and waves are higher than 3 feet, burning becomes increasingly difficult because the oil cannot be contained in a boom and because it would rapidly emulsify due to wave action.

As with wind and wave action, the effects of current that can limit the effectiveness and performance of ordinary containment booms apply to fire-proof booms as well. When the current is stronger than about one knot the boom cannot contain the oil, which splashes above the boom or escapes beneath it.

Advection: Advection or drifting only occurs for spills on water. It is the process of surface slicks being transported away from the site of a spill by water currents. Advection is usually a combination of residual current movement and wind-induced surface movements. Other causes of movement may occur from tidal currents, river outflows, and longshore currents. The advection process influences the location of slicks and thus determines whether the oil can be burned from a safe distance from the spill source or from land where people, property or other resources can be at risk. Advection can move the oil away from land, sensitive resources, or population centers; it can also move the oil toward these resources of concern.

Spreading: Spreading is a key process for *in situ* burning on land and on water because the thickness of an oil slick is determined by the spreading rate of the oil spill. The ignitability and burnability of an oil spill is strongly dependent on the thickness of the slick. Another element influencing the spreading factor on water is the specific gravity of the spilled oil. The oil's specific gravity will determine where in the water column the oil will float. If the oil does not float, it is not a candidate for *in situ* burning.

Evaporation: Evaporation is one of the most important processes that affect the properties and behavior of any spilled oil. Highly evaporated oils are difficult to ignite and burn because the remaining heavier weight components don't readily sustain burning. Therefore, it is important to understand evaporation rates for various oil types and how evaporation affects the properties of the oil remaining on the surface.

Formation of water-in-oil emulsion: When crude oils and heavy refined oils are spilled at sea, they often form water-in-oil emulsions, which occur in the presence of mixing energy usually from wave action. During emulsification, water is incorporated into the oil in the form of microscopic droplets. When water content of a slick reaches 50% - 85% (depending on oil type), ignition and burning become very difficult, if not impossible, without the use of special additives. The oil in the emulsion cannot reach a temperature higher than 100 °C until the water is either boiled off or removed. The heat from the igniter or from the adjacent burning oil is used first mostly to boil the water rather than heat the oil to its fire point.

A two-step process is likely involved in emulsion burning: "breaking" of the emulsion, or possibly boiling off the water, to form a layer of unemulsified oil floating on top of the emulsion slick; and subsequent combustion of this oil layer. High temperatures are known to break emulsions. Chemicals called "emulsion breakers", which are common in the oil industry, also may be used. For stable emulsions the burn rate declines significantly with increasing water content. The reduction in burning rate with increasing water content is decreased further by evaporation of the oil. The effect of water content on the removal efficiency of weathered crude emulsions can be summarized by the following rules-of-thumb:

- little effect on oil removal efficiency for low water contents up to about 12.5% by volume;
- a noticeable decrease in burn efficiency with water contents of 12.5-25%, the decrease being more pronounced with weathered oils; and
- low burn efficiency for stable emulsion slicks having water contents of 25% or more.

Some crudes form meso-stable emulsions that can be burn efficiently at higher than usual water contents. Paraffinic crudes appear to fall into this category.

Dispersion and dissolution: Dispersion and dissolution are physical processes that move the oil and the more soluble lower molecular weight hydrocarbons from the slick into the water-column. Dispersion may occur from natural processes as well as a result of dispersant use. For *in situ* burning, dispersion and dissolution effects will remove oil from the slick into the water column that could otherwise be burned. Under moderate to high turbulence or wave action, 'temporary dispersion' may occur. This is where relatively large oil droplets may break from the slick causing them to be temporarily submerged and when they resurface, they can be outside the burn area and may remain unburned in the environment.

OPERATIONAL ISSUES AND GUIDELINES

In situ burning on water requires more extensive logistics than burns on land. The oil has to be contained to a minimum thickness to start and maintain the fire. Fire resistant boom and vessels for towing the boom are required unless there is natural containment (e.g., in ice, trapped in debris). Spotters in aircraft usually direct the boat crews to the oil. Once the oil is contained in a safe place, an ignition source is needed. Generally, fire-fighting equipment is not required because the fire can be put out by letting one side of the boom go so that the oil becomes too thin to sustain the fire. Dip nets and other hand tools will be needed to recover any floating burn residue. Depending on how far offshore the burn is located, there may be a need for support vessels.

Skilled boat operators are needed to tow the boom in a 'U' configuration at speeds that concentrate, but do not lose the oil by going too fast. After ignition, the burn can be controlled by towing the boom at the speed needed to keep it at the maximum thickness (typically about 0.5 knots). For spills that are naturally contained on water (e.g., on or between ice floes), an ignition source may be used to start the burn once the spill has been located and approvals obtained. Due to access issues in ice-covered waters, the Helitorch may be the preferred ignition source under these conditions.

For spills on open water, *in situ* burning is ideally accomplished in the following steps (Buist, 1998):

1. Two vessels collect a patch of oil in fire-resistant boom that is towed until the oil fills about one-third of the area inside the boom.
2. The boom is towed a safe distance from other patches of oil.
3. The oil inside the boom is ignited (see section above on ignition sources). The boom is slowly towed into the wind, to keep the oil toward the back of the boom and so that the smoke will go behind it.

4. The oil burns until the fire goes out. If there is a problem, it is possible to let one end of the boom go, allowing the oil to spread into a thin slick and the fire goes out quickly.

5. Whenever possible, floating oil residue is collected, and the boom is inspected for damage.

6. The boom is towed to pick up the next batch of oil. If the oil is continually leaking from a source, such as a well blowout, the fire-resistant boom can be positioned to capture the oil a safe distance from the source. The oil is burned as it accumulates inside the boom.

IGNITION PROCESS

A fire can be started with a range of ignition sources, from a simple match to more sophisticated equipment. The ignition source is used to provide enough heat for a long enough period so that some of the oil vaporizes and the vapors ignite. Heavy oils require longer heating time and a hotter flame to ignite, compared to lighter oils. A key goal during an on-water burn is to ignite as much of the oil surface as possible, so that the oil is heated enough to form vapors and sustain the burn. Specialized ignition sources include the 'Helitorch,' an incendiary device that hangs from a helicopter and drops a burning substance such as gelled gasoline onto the area to be burned. The Helitorch requires a highly trained flight crew to operate the equipment effectively. The gelled gasoline is loaded into a 55-gallon tank on the Helitorch. The fuel is pumped through a nozzle and ignited with propane jets. The falling stream of burning fuel separates into individual globules that burn for 4 - 6 minutes, igniting the oil or other combustible material. Its success rate is high, and it has ignited crude oil in winds up to 16 knots (30 km/hr). Helitorches are commercially available, being first developed for fire-fighting and forestry management. They are safe because they allow ignition from a distance, thus keeping people removed from the open fire.

In situ burning is conducted differently for spills on water versus land. On water, spilled oil rapidly (within hours) spreads into very thin slicks that are too thin to burn. Therefore, unless the response is very rapid, the oil has to be collected and concentrated into thicker slicks. The oil may also emulsify and evaporation may remove most of the burnable components, making burning of collected oil difficult or unachievable beyond the first 12 - 24 hours after it is spilled. Thus, on water *in situ* burning is primarily considered an option for incidents with a continuous release source (e.g., a well blow-out) or when oil is trapped in ice.

SAFETY ISSUES

Safety hazards for *in situ* burning operations are similar to those of ordinary skimming at sea, with the added hazards related to the combustion process. Several points are especially useful to keep in mind:

- A specific burn plan should be prepared in order to methodically address safety hazards, protection measures, training requirements, communication, and other operational elements that have to be considered for a successful and safe burning operation. A burn site safety plan should be included in the general burn plan.

- The burning should be controlled, and flashback to the source prevented. Great care must be taken so that the fire is controlled at all times.

- Ignition of the oil slick, especially by aerial ignition methods (such as the Helitorch), must be well coordinated with neighboring vessels and be carefully executed. Proper safety distances should be kept at all times.

- *In situ* burning at sea will involve several vessels working relatively close to each other, perhaps at night or in other poor-visibility conditions. Such conditions are hazardous by nature and require a great degree of practice, competence, and coordination.

- Response personnel must receive the appropriate safety training. Training should include proper use of personal protective equipment, respirator training and fit-testing, heat stress considerations, first aid, small boat safety, and any training required to better prepare them to perform their job safely. Safety hazards are substantial and should be given due attention. Usually they pose a much greater risk to the responders than chemical exposure.

A sample site safety plan for marine *in situ* burning operations can be found here http://response.restoration.noaa.gov/book_shelf/656_NAVY_SSP.pdf

HUMAN HEALTH CONSIDERATIONS

Levels of concern for public health associated with burning spilled oil *in situ* should be assessed in the context of the effect of oil spills in general and the risk the spill poses to people and the environment. The impact of a temporary reduction in air quality from particulates due to burning should be weighed against the impact of an untreated spill on the environment. A large percentage (20%-50%) of the spilled oil may evaporate and cause a temporary reduction in air quality from volatile organic compounds. In other words, whether the oil is burned or allowed to evaporate, air quality will be compromised. The decision whether to burn, or to continue to burn, must be made in consideration of all of the risks and tradeoffs posed to human health and the environment by the spill and the available countermeasures. These issues should be discussed and resolved during the planning process.

In situ burning generates mostly carbon dioxide and water, particulates, and small quantities of nitrogen oxides, sulfur dioxide, ketones, aldehyde, and other minor combustion gases. PAHs, some of which are suspected human carcinogens, are found in minute concentrations, adsorbed to the soot particulates. Studies on *in situ* burning smoke components indicate that particulates in the smoke plume remain the only agent of concern more than a mile or two downwind. The gases created in the burn dissipate to background levels a short distance downwind, and the level of PAHs attached to the particulates is much below the level of concern. Public exposure to smoke particulates from the burn is not expected unless the smoke plume sinks to ground level. However, since the general public may include individuals sensitive to air pollutants their tolerance to particulates may be significantly lower than that of the responders.

Particulate size: Since 10 micrometers (µm) in diameter is the size below which particulates may be inhaled and become a burden on the respiratory system, scientists divide the particulate mass into “total” particulates, which include any size measurable, and “PM-10,” which is the fraction of particulates smaller than 10 µm in diameter.

Particulate size also plays a crucial role in determining how long they will be suspended in the air. Larger particulates (tens of µm in diameter) would precipitate rather quickly close to the burning site. Smaller particulates (ranging from a fraction of a µm to several µm in diameter) would stay suspended in the air for a long time and be carried over long distances by the prevailing winds. Particulates small enough to be inhaled (PM-10) are also the ones to remain suspended. If those particulates do not descend to ground level (where people are), they will not threaten the population downwind.

Particulate level of concern: The general public may be protected by minimizing exposure and conducting the burn only when conditions are favorable and exposure to particulates from the burn is below the level of concern. The National Response Team recommended level of concern for the general public is 150 micrograms of particulates per one cubic meter of air, over a one hour period. This level is much more conservative than the present legal requirement set at 150 microgram of particulates in a cubic meter of air, but averaged over 24 hours. In the process of adopting *in situ* burning, the different regions around the country adopted the NRT's recommendation for a health-protective particulate level of concern.

ENVIRONMENTAL CONSIDERATIONS

Burn residue: Generally, burn residues are less toxic than the original oil and have less volatile hydrocarbons with low boiling points. They are denser and more viscous than unburned oil. Chemical analyses of burn residues show relative enrichment in metals and the higher-molecular weight PAHs, which have high chronic toxicity but are thought to have low bioavailability in the residue matrix. Bioassays with water from laboratory- and field-generated burn residues of Alberta Sweet Mix Blend showed little or no acute toxicity to sand dollars (sperm cell fertilization, larvae, and cytogenetics), oyster larvae, and inland silversides. Bioassays using field-generated burn residues showed no acute aquatic toxicity to fish (rainbow trout and three-spine stickleback) and sea urchin fertilization. Bioassays using laboratory-generated Bass Strait crude burn residue showed no acute toxicity to amphipods and very low sublethal toxicity (burying behavior) to marine snails.

Localized smothering of benthic habitats and fouling of fish nets and pens may be the most significant concern when semi-solid or semi-liquid residues sink. At the Honan Jade spill, burn residue sank in 2 hours and adversely affected nearby crab pens. Residues, whether they float or sink, can be ingested by fish, birds, mammals, and other organisms, and may also be a source for fouling of gills, feathers, fur, or baleen. However, these impacts would be expected to be much less severe than those manifested through exposure to a large, uncontained oil spill.

Direct temperature effect: Burning oil on the surface of the water could adversely affect those organisms at or near the interface between oil and water, although the area affected would presumably be relatively small. Observations during large-scale burns using towed containment boom did not indicate a temperature impact on surface waters. Thermocouple probes in the water during the Newfoundland test burn showed no increase in water temperatures during the burn. It appears that the burning layer may not remain over a given water surface long enough to change the temperature because the ambient temperature seawater is continually being supplied below the oil layer as the boom is towed.

Water-column toxicity: Results from the laboratory and field studies indicated that, although toxicity increased in water samples collected beneath oil burning on water, this increase was generally no greater than that caused by the presence of an unburned oil slick on water. Chemical analyses performed along with the biological tests reflected low hydrocarbon levels in the water samples.

Effect on surface microlayer: The surface of the water represents a unique ecological niche called the "surface microlayer," which has been the subject of many recent biological and chemical studies. There is little doubt that *in situ* burning would kill the organism in the area of the burn. However, when considering the small area affected by *in situ* burning, the rare nature of this event, and the rapid renewal of the surface microlayer from adjacent areas, the long-term biomass loss is negligible.

Birds and mammals: In the wake of a major oil spill, any spill response method that would prevent the oil from spreading and impacting larger areas is clearly advantageous for birds and mammals. Based upon our limited experience, birds and mammals are more capable of handling the risk of a local fire and temporary smoke plume than of handling the risk posed by a spreading oil slick. Birds flying in the plume can become disoriented and could suffer toxic effects. This risk, however, is minimal when compared to oil coating and ingestion, the result of birds' exposure to the oil slick.

It is not likely that sea mammals will be attracted to the fire, and the effect of smoke on marine mammals is likely to be minimal. Mammals, on the other hand, are adversely affected by oil ingestion and oil coating of their fur. Therefore, reducing the spill size by burning the spilled oil can reduce the overall hazard to mammals.

Waste generation: Review of the environmental impacts would not be complete without considering the waste an oil spill can potentially generate. It was estimated that 350 miles of sorbent boom was used during the first summer of the *Exxon Valdez* cleanup, more than 25,000 tons of sorbent material of all kinds was sent to landfills, and oily water twice the volume of the oil spilled (from skimming a fraction of the oil) had to be treated. Enough energy was used that summer to support the energy needs of 11,000 people, power 1,300 boats of all sizes, and provide hot water equal to the needs of a city of 500,000 people.

In situ burning of oil will generate waste. Even the most efficient burning will leave a taffy-like residue that will have to be collected and treated or disposed of. Burning the oil at sea will not be as efficient as burning it in engines, furnaces, or power plants, and will generate a substantial amount of particulates. However, by minimizing the solid and liquid waste generated by beach cleanup, and by reducing the energy required to support the response operation, burning even some of the oil at sea is likely to reduce the overall waste generation of a spill.

MONITORING AND MODELING THE SMOKE PLUME

SMART is a cooperatively designed monitoring program for in situ burning and dispersants. In general, SMART is conducted when there is a concern that the general public may be exposed to smoke from the burning oil. It follows that monitoring should be conducted when the predicted trajectory of the smoke plume indicates that the smoke may reach population centers, and the concentrations of smoke particulates at ground level may exceed safe levels. Monitoring is not required, however, when impacts are not anticipated.

Monitoring operations deploy one or more monitoring teams. SMART recommends at least three monitoring teams for large-scale burning operations. Each team uses a real-time particulate monitor capable of detecting the small particulates emitted by the burn (ten microns in diameter or smaller), a global positioning system, and other equipment required for collecting and documenting the data. Each monitoring instrument provides an instantaneous particulate concentration as well as the time-weighted average over the duration of the data collection. The monitoring teams are deployed at designated areas of concern to determine ambient concentrations of particulates before the burn starts. During the burn, sampling continues and readings are recorded both in the data logger of the instrument and manually in the recorder data log. After the burn has ended and the smoke plume has dissipated, the teams remain in place for 15-30 minutes and again sample for and record ambient particulate concentrations. Data are then channeled to the UC to assist the with decision-making, including whether particulates concentration trends at sensitive locations exceed the level of concern..

The easiest and simplest way to monitor the smoke plume is by visual observation, which provides useful information on the plume direction and behavior. However, to try and assess the smoke component in the plume, instruments tethered from a blimp collected data on gases and particulate composition and concentration, while remote controlled helicopters took samples in the smoke, and a LIDAR instrument, which uses laser beams to detect particulate concentration in the plume was used from an aircraft in several test burns. These methods were very useful in providing information on the smoke composition and component concentrations, but they cannot be used on a real time basis to provide immediate feedback during the burn itself. Real-time aerosol monitors are now available. They are small and portable, may be carried by hand and in a helicopter, and are easy to operate. Since they count particles by light scattering, their output is not as accurate as more traditional methods that weigh the particulates as they accumulate on a filter media. However, these instruments may provide useful real-time feedback during *in situ* burning operations if population exposure to the smoke plume becomes an issue.

Modeling is another approach to estimating the concentration of particulates in the plume. Several models were developed, including a relatively simple model developed by NOAA, and Airborne Light Optical Flight Technology (ALOFT), a complicated model developed by the National Institute of Standards and Technology. Using information available on atmospheric conditions, burn parameters, and even terrain characteristics, this model, which is now available for use on a powerful PC, can predict the plume behavior and both ground and plume particulate concentrations over distance. The model has been used for several test burns, and was found to be reasonably accurate. Models are particularly useful for planning purposes and for situations in which direct air sampling is not possible.[15]

WHY USE *IN SITU* BURNING?

The priorities for any oil spill response are to protect health and safety of the public and responders, secure the source and stabilize the situation, and begin containment and removal actions. To address these objectives, decision-makers work to remove the threat of spilled oil and reduce the environmental impacts from the spill. The main advantage of using *in situ* burning is that large volumes of oil (which are physically contained to the required slick thickness) can be removed rapidly from the surface of the land or water under ideal conditions This transference of the oil from the water or land surface into the atmosphere also reduces the need for temporary storage for recovered oil. As an example, fresh oil can burn at a rate of 3 milimeters (mm) per minute, meaning that a pool of oil 300 feet (ft; 91 meters [m]) in diameter could theoretically burn at the rate of over 400,000 gallons per hour. However, most oil spill slicks are thin so the fire burns through a patch of oil in minutes.

[15] Additional information on trajectories of smoke plumes from *in situ* burn can be found at http://fire.nist.gov/bfrlpubs/fire03/PDF/f03160.pdf.

There are operational constraints that affect the oil removal efficiency of *in situ* burning. For open water spills, it takes time to corral a patch of oil to the required thickness in a safe area, burn it, recover the residue, inspect the boom, and return to the oil collection area to start the *in situ* burn process again.

In situ burning can be more efficient than mechanical recovery under similar spill conditions because recovery devices, e.g., skimmers and temporary storage for skimmed oil, are not necessary with *in situ* burning. With *in situ* burning, there is no need for handling and disposal of the oil. However, *in situ* burning has its own logistical tradeoffs to be considered, particularly, having enough fire boom available in the first 24 hours of the spill to conduct the number of burns necessary to remove all the oil that can be contained.

A second advantage of *in situ* burning is its relatively high burn efficiency. Studies have shown that as much as 90% - 99% of the oil volume, boomed and maintained at the required thickness, can be removed by burning under normal conditions. Case studies of actual burns, in particular on land, support this high efficiency. Burning is often considered on water and on land because responders need to prevent the oil from spreading into more sensitive areas or over larger areas and it offers the possibility of relatively complete removal of the liquid product if the logistics can be arranged. In several cases, an oil spill was burned on land because it was thought that the forecast for heavy rains would result in oil being flushed into sensitive areas. Burning in the early phase of the spill removes most of the oil before it can cause further damage on the water or on land.

A third advantage is that burning reduces the amount of oily wastes for collection and disposal. This factor will have a significant weight in the decision to conduct an *in situ* burning for remote or difficult to access areas. Limited access might make mechanical or manual recovery impractical (or even harmful to the environment) to implement. Thus, *in situ* burning provides an option for oil removal where traditional response countermeasures are impossible to implement or would cause environmental damage (as with spills on ice or near marshlands). When a situation presents ideal conditions, *in situ* burning can significantly reduce the environmental impact of the spill as well as the spill response.

PRE-BURN PLANNING

The first two steps toward using *in situ* burning at an oil spill are obtaining approval to conduct the burn and developing a burn plan. Checklists have been developed to provide an easy way to compile the information needed by decision-makers. The checklist documents should contain the incident-specific information that support the decision whether *in situ* burning should be approved, including, but not limited to:

- Nature, size, and type of product spilled,
- Weather: current and forecasted,
- Oil trajectories for on-water spills,
- Evaluation of other response options,
- Feasibility of using *in situ* burning (wind speed, sea state, oil type, weathering, thickness, visibility, use of dispersants),
- Potential impacts to habitats and wildlife: consultations with natural resource agencies on potential impacts and tradeoffs,
- Equipment and personnel requirements and availability,
- Detailed burn plan,

- Health and safety plan (including public notifications, site security, and fire-fighting capabilities), and
- Monitoring plans, as needed (air, water, sediments, vegetation, wildlife).

The burn plan should include information on:

- Amount of oil to be burned,
- Area to be burned,
- Ignition methods,
- Estimated duration of the burn,
- Tactical assignments of resources (for specific personnel and equipment),
- Results of smoke plume trajectory modeling, if available,
- Plan for additional burns,
- Methods for terminating the burn,
- An air sampling and data capturing sub-plan,
- Specified monitoring endpoints and conditions that will be measured to determine the need for burn termination, and
- Methods for collecting burn residues.

SUCCESS STORIES

LOGISTICS, SUPPLY AND DELIVERY OF EQUIPMENT

DWH *in situ* burn operations began work with the fire boom inventories of Marine Spill Response Corporation, Clean Gulf, and US-based supplier Elastec/American Marine. In the early days of the blowout and response effort, members of the response team recognized that arrangements would need to be made rapidly with OSROs and potential equipment suppliers outside the GOM region to supply amounts of fire boom that would be adequate to meet the needs of a large and potentially long term response. The bulk of the fire boom employed in the DWH response came from non-US sources. The relatively limited size of fire boom inventories among US OSROs at the time of the incident reflects the fact that *in situ* burn operations are discouraged in a number of jurisdictions or viewed only as a secondary response technique to mechanical recovery. Fire boom inventories among US OSROs also reflect the fact that in virtually all jurisdictions *in situ* burning capability is not counted toward applicable response planning standards. As a result there is diminished incentive to allocate OSRO capital and expense budgets to acquisition of large inventories of fire boom.

The relatively specialized needs of the *in situ* burning operations for DWH, and the incident's demands on the Operations and Logistics Sections of the SRT dictated that the *in situ* burning operations team took responsibility for its own equipment acquisition. This turned out to be beneficial, since among the tasks confronting the operations team was testing different types of boom available for their suitability and performance. The relatively small size of the OSRO community, the willingness across industry sectors to provide support for the DWH response, and the interest of vendors in seeing their products used combined to enable the *in situ* burning operations team to secure lines of supply for fire boom from around the world (e.g. Clean Caribbean, Angola, and Brazil). Once shipments of fire boom were arranged, the Logistics Section within the DWH SRT worked effectively to move the boom through the supply chain to forward staging areas for deployment.

The global support for the supply of fire boom to the DWH response, and the ability to cascade boom and other equipment from other regions to meet the needs of DWH represents a success story that should be reviewed for its applicability to future events. The chief impediment to the movement of boom from out of region to the DWH response was the restrictions a number of state regulatory agencies place on OSROs within their jurisdictions for equipment transfers out-of-region. Even with the unprecedented scale of the DWH incident and the response needs it generated, mechanisms wer inadequate to overcome these problems. This contrasts with the readiness of non-U.S. jurisdictions to allow transfers of equipment such as fire boom to the U.S. Gulf Coast and with the principles and expectations of mutual aid that have characterized other forms of disaster response. Provisions for federal, USCG-supervised direction for out-of-region support for major-scale responses, or development of an MOU among states to establish expedited decision making for such support, should be priorities for study and action going forward.

HAND IGNITERS AND VESSEL SUPPORT

The bulk of on-water *in situ* burn operations for the DWH response were carried out in the general vicinity of the Macondo well location at distances ranging from 40 to 50 miles offshore. This distance made it impractical to rely on Helitorch ignition of scheduled burns. The *in situ* burning operations team determined at the outset that ignition of burns would need to be accomplished from boats. Hand igniter products were identified that allowed ignition of burn operations to be carried out safely and effectively.

In situ burning operations had ready access to vessels required for deployment and towing of fire boom, ignition of burns, and monitoring. Strong and effective operational support was provided by the VOO program. Coordination of vessel operations generally from the perspective of the *in situ* burning operations unit was viewed as a success. The principal challenge arose from the recruitment and coordination of fishing vessels. Partly this was due to the competing needs of the shoreline protection and near-shore response operations, a probably inevitable consequence of a response of the magnitude of DWH, with its diversity of operations. The distance from shore at which the majority of *in situ* burning operations were conducted required that only the relatively larger VOOs be assigned for support of *in situ* burning, and finding fishing or shrimping vessels of sufficient size and seaworthiness was an issue in the early days of the response effort. The Fishing Vessel Coordination Unit worked effectively to vet vessels offered and to address issues of adequacy of safety and communications equipment, crew safety training, etc.

AERIAL OBSERVATION

The scale of the DWH response presented challenges of an historic magnitude in terms of organization of the multitude of vessels operating offshore in support of various facets of the response. Air support and observation was indispensable for guidance and direction of on-water *in situ* burning operations, for avoidance of conflict with other on-water response operations, and for monitoring of the effectiveness of burns being conducted. The RP's Aviation Section, and the cooperation and common effort of USCG and FAA personnel assured that aircraft were available, scheduled, and that the airspace above the operating sector was safely managed. Again because of the distance of the initial DWH spill location from shore, fixed wing aircraft were used in lieu of rotary aircraft, because of the quicker time-to-station, and the superior cruising range offered by these aircraft. The overall aviation effort, along with air-to-sea communications, represents a success for the response.

MONITORING OF BURN EFFECTIVENESS

The *in situ* burning operations section relied upon the ASTM standard (F1788-97(2003)) and a straightforward method of assessment of burn effectiveness developed by S. L. Ross Environmental Research Ltd., and widely recognized across the response community. This method relied upon estimates of aerial extent of the oil slicks identified for burning, conservative assumptions as to slick dimensions, and time required for the burning to take place. This methodology was accepted by FOSC and supporting regulatory agencies. Efficiencies for the DWH operations were consistent with results from experimental burns, demonstrating the effectiveness of this important response alternative.

AREAS FOR IMPROVEMENT AND PRELIMINARY RECOMMENDATIONS

FIRE BOOM DESIGN AND OTHER ANCILLIARY TECHNOLOGIES

Even the most effective fire boom products utilized in the DWH response were at their operational margin in sea states of 3 feet, which were relatively common at the response locations. <u>Improvement in the ability of fire boom to contain and concentrate oil in an effective manner in higher sea states and at a higher advancing speed</u> would significantly assist the efficiency of *in situ* burning operations. This could be accomplished by adapting the NOFI corporation's "Ocean Buster" ™ containment boom design for fire boom.

The accompanying diagram shows how the NOFI Ocean Buster gathers and concentrates oil differently than a conventional 'U' configuration. High speed guide boom towed with an opening of approximately 50 m narrows to a sweep opening of 20 m, that in turn narrows to a roughly 'teardrop' shaped enclosure at the stem that is protected on nearly every side by boom. This design functions as a temporary storage unit that concentrates the oil and isolates it from wind and wave forces in a manner that is superior to "U' boom configuration. When used in connection with mechanical recovery operations, the Ocean Buster also includes a high capacity flexible separator. By means of the separation (settling) technique, the Ocean Buster design contains a thick layer of calm oil. This configuration provides a sheltered containment area of almost pure oil enabling excellent recovery rates for skimmer operation. Incorporated into fire boom design it would provide an optimum concentration and thickness of oil for both speedy ignition and efficient burning.

The Ocean Buster design/configuration offers two advantages over conventional containment boom or fire boom: the ability to operate in higher sea states; and the ability to contain oil at speed up to or greater than 3 knots. The advancing speed is very important in *in situ* burning operation because typical containment boom start to entrain oil at 0.75 knots, requiring a slow advancement through the water in order to contain oil thick enough for a burn.

The outcome would be a larger fire boom system able of containing oil while traveling at speeds up to 3 knots and work in higher sea states expanding the window of operations for *in situ* burning compared to current limitations. The advantages offered by a shift from 500 ft to 1000 ft sections of fire boom used in a single burn needs to be evaluated also since that would allow operators to have a wider swath width which in theory would also increase encounter rate.

Research and engineering of new fire boom design, and operational trials of any new boom design will be necessary to validate the capability of re-engineered fire boom. The ASTM F2152 Standard for fire boom identifies the following performance characteristics are among those that must be incorporated into any fire boom design:

- Minimum performance characteristics are grouped under three headings: Operability, Oil Containment; and Fire-Resistance. All minimum performance characteristics listed here shall be achieved before a boom is considered to meet the requirements of this guide.

- The fire-resistant boom shall withstand oil fires and contain oil in various conditions that include both calm water and waves with a significant wave height of up to 1 m and a period of 3 to 4 seconds.

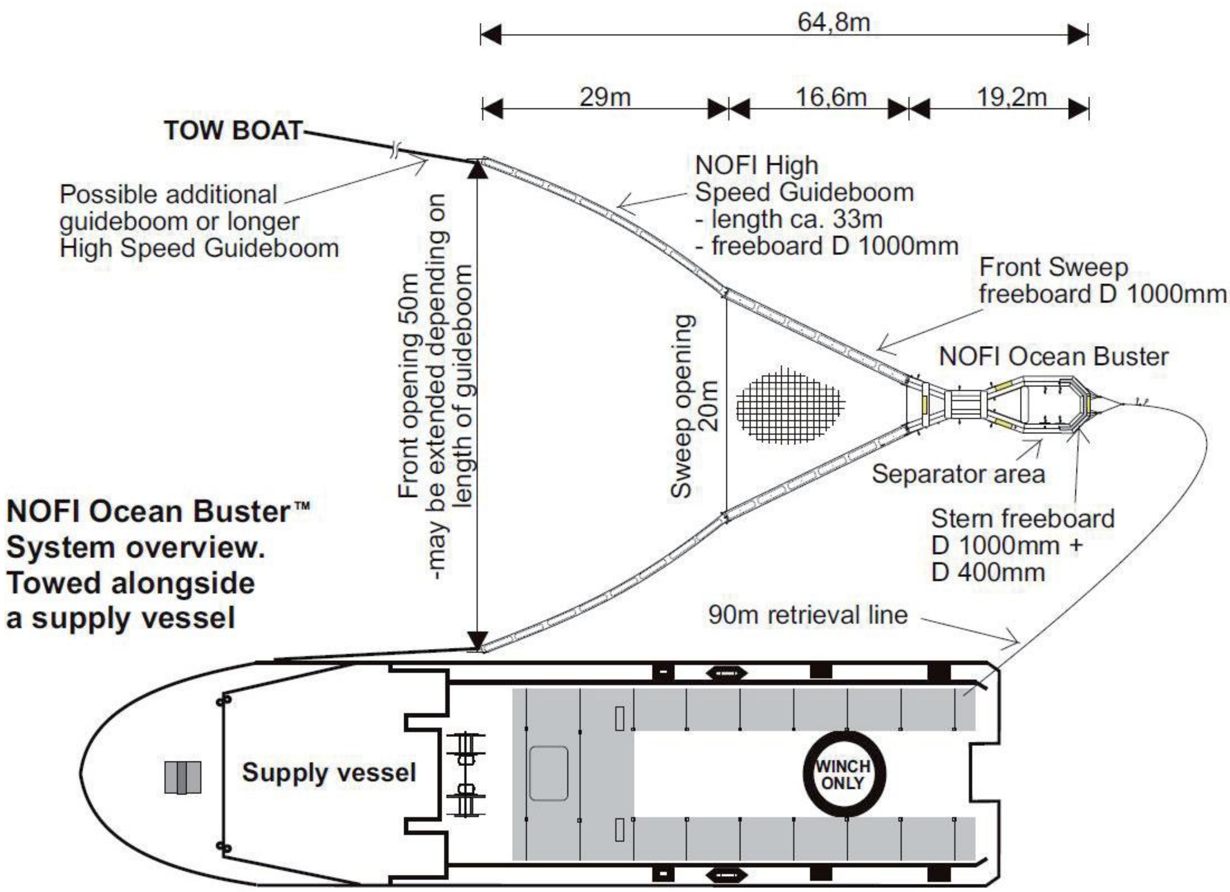

Figure 1. NOFI's Ocean Buster™ fire boom system

- Fire-resistant oil spill containment booms shall be manufactured of components that do not degrade significantly and that maintain fire resistance characteristics while exposed to typical marine environmental conditions.

- The fire-resistant boom and any ancillary equipment shall not be adversely affected by use or storage at temperatures within the range of -40 to 40°C.

- If the boom's materials of manufacture include any hazardous materials, the appropriate Material Safety Data Sheet and exposure limits shall be provided by the manufacturer. The fire-resistant boom system shall not create or add to the hazardous waste pollution, nor shall it have any special disposal requirements beyond that typically required of oil spill booms.

- Prior to exposure to an oil fire, the fire-resistant boom shall display similar oil containment characteristics expected of conventional oil spill containment booms.

Improvements in remote sensing techniques and technologies (discussed in the previous chapter on Oil Sensing and Tracking), and mechanical recovery technology (discussed in the subsequent chapter on Mechanical Recovery) would allow responders to locate thickest patches of oil and improve oil encounter rates, as well as herding oil more effectively to enhance *in situ* burning.

PRE-DEPLOYMENT AND STAGING OF FIRE BOOM

Pre-Deployment of fire boom for availability for response is an issue with both operational and regulatory/compliance implications. First, with respect to operational needs, the unprecedented size of the DWH blowout and spill resulted in over 400 different burns being conducted during the response. The magnitude of the response required an amount of fire boom beyond what could foreseeably be staged at Gulf Coast locations but, as noted, cooperation across many sectors of industry and the response community enabled supplies of fire boom to cascade to the response. While more fire boom could and should be staged in the Gulf region for future response needs, the focus of future regulatory and systems attention should be on streamlining decision processes to expedite cross region movement of fire boom and other critical supplies to response locations where they are needed.

The second factor influencing pre-deployment of fire boom involves regulatory requirements. The regulations developed to implement OPA 90 focused on port staging areas, identifying High Volume Ports by name and specifying requirements for OSROs that serve plan holders in High Volume Ports. This scheme did not address spill response requirements for offshore exploration and production of oil and natural gas because BOEMRE oversaw such operations. An approach similar to the USCG High Volume Ports concept that identifies OSRO requirements for the exploration and production sector with reference to level of activity and logistical and practical connection to shore bases is recommended. USCG already identifies as High Volume Ports the Mississippi River from Baton Rouge to Southwest Pass and vessel traffic to LOOP, Houston Ship Channel and Galveston Bay, Corpus Christi, Sabine-Neches River, Pascagoula, and Mobile Bay. These areas also support the offshore exploration and production sector in the Gulf. Pre-deployment requirements for fire boom could be identified for these areas, with the proviso that equal attention should be given to streamlining decision processes for expedited cross region movement of boom and other equipment.

REGULATORY MATTERS

In situ burning in the DWH response required an approval process that slowed the response time down for operations. The complications and delays in obtaining approvals derive from the fact that under federal law and under a number of state laws *in situ* burning is considered an 'alternative' response technology. Time was consumed in the decision process for proposals to burn offshore concentrations of oil that adversely affected deployment and logistical schedules, and that in some cases constrained weather and/or sea state windows that were optimum for burning operations. <u>A pre-approval process or an expedited approval process for *in situ* burning will be necessary to remove procedural obstacles to *in situ* burning that could compromise the rapidity and efficiency of an integrated response effort</u>.

Pre-approvals for *in situ* burning of oil spills have been widely adopted in RCPs and ACPs across the US. However, the exact details of where one can burn with pre-approval remain a patchwork due in large part to varying state and local requirements. Geographic differences, likely spill scenarios and potential impacts, as well as varying levels of familiarity at the RRT and ACP levels. The success demonstrated by *in situ* burning operations in the DWH response compel reconsideration of *in situ* burning as a suitable and advanced spill response technology, instead of an alternative response method that can or should only be considered as a supplement to mechanical recovery. The approval process for *in situ* burning operations was too often slowed by discussion on smoke trajectories and potential human impacts. These are valid considerations when *in situ* burning operations are proposed for near-shore or onshore locations in close proximity to human populations. However, they unreasonably limit operational flexibility in situations such as DWH where target locations have been many miles offshore and distant from coastal environments and sensitive populations.

The particulate emissions and dark smoke plume that dissipate within a few miles of the source are far less than the long term environmental impacts from unburned oil that can contact sensitive coastal, intertidal and shoreline environments, such as the Gulf Coast's marshes and barrier islands. An unreasonably slow decision process can place these environments at risk if delays result in lost opportunities to burn or to carry out burning operations with maximum effectiveness. The decision process for *in situ* burning approvals must take into account that the short term air impacts are far less detrimental than the long term impacts of oil in the marine environment.

Finally, if approval for permits for a response operation is to be tasked to an agency outside the current command structure, then it must be the responsibility of that agency to place an individual at the response center that possesses the authority to approve issuance of permits. In a number of cases, requests for approval to carry out specific *in situ* burning operations were delayed because of various considerations, among them the lack of burn plume observation capability. Requests for this approval were going outside the command center. As a result, discussion of needs, priorities, and alternatives for action – which in the case of so many other response issues could be carried out via face-to-face meetings in the command center – were subject to the inevitable delays and inefficiencies of relying upon people more distant from the response and from information about the priorities of the response effort.

True "pre-approval" where the responders, typically the FOSC, may unilaterally approve the use of *in situ* burning or other alternate response technologies is very limited. The allowable scenarios are exclusively open water and far offshore (Appendix A, Table 1). These pre-approvals often do not cover all Federal waters (i.e. those outside of the territorial 3-mile limit of State waters), but may be limited to areas much farther offshore. For example, some of New England and the Mid-Atlantic coast have extended limitations to 6 miles offshore, but Maine has a 12-mile restriction. California pre-approval starts at 35 miles offshore. The GOM states (FL, AL, MS, LA, TX) use the statutory territorial three-mile limits for FOSC approval. In most cases, these restrictions are defined under various MOU and Letters of Agreement (LOA) between the various trustee agencies (Appendix A, Table 2). These MOU/LOA are then referenced as part of both RRPs and individual ACPs.

Case-by-case approval exists in marine near-shore areas not covered by pre-approval. In some cases, marine near-shore areas may have an expedited approval process already defined that will increase the probability of obtaining approvals within the limited timeframe for successful spill ignition and burning. Pre-approvals are non-existent.

Further approvals are typically required for marshes, inland waterways, and on-shore burning. Particularly for dry land, burns often require consultation with local fire response officials who are often unfamiliar with the environmental trade-offs involved in oil spill response.

Given the responsibilities of individual state governments to their constituents, it is unlikely that a single uniform set of *in situ* burn policies and procedures can be adopted nationwide. Therefore, the focus for improved utilization of *in situ* burning as a response practice should focus on ensuring an efficient pre-approval and rapid case-by-case approval process through the RRTs and the states. This should include development and adoption of a common form for *in situ* burning preapprovals in conjunction with USCG, EPA, NOAA and industry.

While the dividing line between state and Federal waters for most purposes is most commonly defined as three miles seaward of the shore, that dividing line has not been uniformly adopted for the purposes of deciding when the FOSC has unilateral pre-approval for implementing *in situ* burning. Both EPA Region 1 and 2 states and Federal agencies have adopted a six-mile boundary for pre-approval. In the west, California has a 35-mile boundary.

One of the reasons for the extended boundaries is that one of the hazards of *in situ* burning is the potential human exposure to PM10 in the smoke plume. The East and West coasts predominantly have onshore breezes which push the plume towards the shore. Thus, the impacts and potential hazards from the burn can extend greater distances than would be implied by the localized area of the burn itself. In particular, this was a concern for California due to the potential impact on non-attainment status for PM10 and other pollutants. That issue has been mostly resolved with formal agreements from EPA that emergency actions such as *in situ* burning would not affect attainment status. Such agreements should be implemented uniformly across the United States to remove a potential conflict between emergency response needs and requirements for ambient air quality.

Another consideration is simply that the smoke plume, regardless of PM10 or other chemical constituents, is unsightly. It is pragmatically viewed as better to adopt less intrusive response measures in the areas readily visible to the public.

SAFETY ISSUES

Initial safety concerns in the planning and approval process for *in situ* burning operations focused on health impacts from smoke and soot emissions resulting from the burns. A workable plan was developed for personal protective equipment for response personnel, and for monitoring of smoke and particulate trajectories and concentrations, with competent Industrial Hygiene professionals with air quality backgrounds identified and placed in work crews to execute this plan and assure crew safety. One of the key lessons learned however was the importance of safety issues associated with the burn operations arising from the presence of personnel at sea, notably vessel to vessel transfers, and the slip, trip and fall and other hazards associated with working on vessel decks. From the experience of the DWH *in situ* burn operations, these safety issues present themselves with greater significance and frequency than do issues associated with potential inhalation exposure to smoke and ignition products. As a result it is recommended that selection of safety advisors who support on-water *in situ* burning operations be prioritized for experience with marine and vessel operations generally. Such individuals can be given training to enable them to perform any required air monitoring and oil vapor exposure tasks. However, it is less likely that Industrial Hygiene professionals with air monitoring experience will possess (or can quickly acquire) a robust understanding of the safety issues that present themselves with operations at sea.

Through the operations plan developed for *in situ* burning operations, measures were taken to assure that the vessels and crews assigned to these operations received safety preparedness fit for purpose. As mentioned, the response personnel assigned to the VOO program vetted vessels for suitability for operations at more distant offshore locations. The *in situ* burning operations section then organized and carried out a four hour tabletop training course for the vessel crews on the operational and safety concerns associated with *in situ* burning, followed by an 8 hour on water practice session prior to deployment to the field. In addition, vessels assigned to *in situ* burning groups were checked for fittings and equipment, with case-by-case decisions made to add or to remove vessel equipment based upon whether such equipment could present a hazard or interference with burn operations. This extra safety effort assisted the safety and efficiency of the *in situ* burning effort overall.

COMMUNICATION AND TRAINING

The JITF recommends that workshops and other learning opportunities for both regulatory agencies and communities be coordinated to facilitate sharing of the extensive scientific data (both lab and field based) as well as the value and tradeoffs inherent in the use of *in situ* burning as a response tool. These would be supplemented with routine practice in the preparation and approval processes as part of drills and exercises.

The JITF recommends developing training requirements and a training program for *in situ* burn responders and supervisors. Specific training sessions should include scenarios involving open water offshore, near-shore/inshore, and on-land burns. Furthermore, advanced personnel training opportunities for *in situ* burn operations should be organized. Few people in the US can conduct *in situ* burns. Many new crews had to be trained urgently during the DWH response. Development of a standard training course material may be desirable.

V. MECHANICAL RECOVERY SUBGROUP FINDINGS

INTRODUCTION

Mechanical recovery of oil spills has been the primary response tool in the US National NCP for over forty years. The basic premise involves containing the oil with boom, and/or recovering it with a skimming device or sorbent material, storing the recovered oil on board the skimming vessel, and then disposing or recycling the recovered material. External constraints on mechanical recovery techniques include poor weather, high winds, heavy sea conditions, and fast currents. Historically, mechanical recovery has not been an efficient response method in the open ocean.

The key for mechanical recovery to be effective and efficient is encounter rate, the amount of oil which comes into contact with the skimmers over a given time period. It is important to understand that encounter rate is negatively impacted through oil rapidly spreading on the water's surface under the effects of gravity, surface tension, current movement, and wind. Spilled oil will quickly spread out over the water surface to a thickness of about one millimeter. As a reference point, visible oil sheen is only 0.003 millimeters thick, and a cup of spilled oil can create a visible sheen over an area the size of a football field. Additionally, it does not take long for wind to further reduce the encounter rate by moving spilled oil into fragmented fingers or windrows of oil on the surface. As oil rapidly spreads and reduces in layer thickness and breaks into patches or windrows, the encounter rate and recovery efficiency of skimmers is significantly reduced. Containment boom can be towed by vessels in a "V" or catenary configuration with the skimmer placed at the boom's apex to enhance encounter rate or can be used independently to collect the oil and increase the thickness of the spilled oil to make skimming more effective. In open water responses, aircraft are often used to direct vessels to the thickest areas of recoverable oil to maximize encounter rate.

Although the basic concepts of booms and skimmers have not changed much in many years, the oil spill response industry is always trying to improve. Evidence of this includes forty years of research and development (R&D) and the worldwide sharing of lessons learned through various fora. Oil spill conferences have been conducted for many years and have been effective venues to demonstrate improvements in equipment, communicate results of many research projects, and share lessons learned from actual spill response experiences.

Improving mechanical recovery technology and increasing capability will be beneficial but will not be the final solution. We must continue to strive for improvements in all areas, and all response methods (mechanical recovery, dispersants and *in situ* burning) must be fully utilized to ensure the most effective response.

This chapter will explore the issues related to mechanical containment and recovery technology and techniques, including 1) a brief background on the history of mechanical recovery over the past forty years; 2) a discussion of equipment, constraints, and the systems approach; 3) successes from the DWH response relating to mechanical recovery, and 4) specific recommendations for improvements.

FORTY YEARS OF MECHANICAL RECOVERY

Modern research into oil spill containment and recovery equipment of the late 60s to the 80s had its genesis following the *Torrey Canyon* accident off the coast of the United Kingdom in 1967.

The response to this incident demonstrated:

- A lack of capacity to respond to a major crude oil spill;
- The need for low-toxicity dispersants;
- A dearth of oil spill containment and recovery equipment inventory; and
- That R&D was needed;

Even though industry has invested significant time, money and effort to develop better response tools, weather, wind, and currents are limiting factors in the effectiveness and efficiency of all spill response equipment.

Boom will broadly range in size from smaller “creek” boom of about 6-inches in height to heavy ocean boom of 6-feet, or greater. All oil boom (small or large) is constrained by the laws of hydrodynamics and physics and will entrain oil beneath the boom if subjected to a current greater than around 0.75 knots. Oil can also splash over the boom in higher sea states. The introduction of hydraulic reels with fleeting arms has allowed for safe deployment of larger boom.

Skimmer technology experienced a similar development profile. Early offshore skimmers were highly complex systems with rudimentary drive systems. Basic weir skimmers and mechanical skimmers were developed throughout the period of the ‘70s – ‘80s.

Key objectives in design of skimmers over this time period:

- Increase oil recovery rates;
- Reduce water collection; and
- Increase range of oil viscosities handled.

These developments were achieved by advances in pump technology and hydraulic system designs with significant performance improvements. Additional work was done in the early ‘80s to develop heavy oil recovery systems.

In the same way that the *Torrey Canyon* initiated spill response development, infrastructure and investment, the 1989 *Exxon Valdez* spill, and the subsequent passage of the OPA 90 influenced the present day development mechanical recovery systems for oil spill response from the 90s to today.

- Dedicated response vessels. The advent of the Oil Spill Response Vessel (OSRV) was a direct result of OPA 90. These special purpose vessels, which can range upwards in excess of 200’, and the OSROs who operate them, provide the key oil spill response sentinel responsibility in the US today.

- Development of Fast Response Vessels (FRV) using oleophilic/aquaphobic brush skimmers
- Incorporation of a systems approach to oil spill recovery: containment, recovery, and temporary storage.

The development work that commenced in the '70-'80's continued over the past two-decades. Continued advances in pump technology and hydraulic system design offered refinement in mechanical recovery technology, including:

- High viscosity belt skimmers
- Viscous oil pumping technology
- Remote control skimmers
- High capacity skimmers

Other developments included:

- Sorbents – Considerable research has been accomplished on sorbents over the past two-decades. While recap is outside the scope of this document, insight can be gained at http://www.boemre.gov/tarprojects/180.htm
- Water / oil processing / temporary storage efficiency
- Development of fast deployment inflatable ocean boom
- Increased encounter rate booms (harbor/ current / ocean buster)
- Improved coordination and control of offshore assets (radar/aerial observation techniques/communications)
- Research and continued development of fire boom.
- Significantly enhancing recovery rates for oleophillic disc and drum skimmer by coating the rotating surfaces with a fuzzy fabric material or by adding grooves to drum skimmers to increase surface area

MECHANICAL RECOVERY EQUIPMENT, USE AND LIMITATIONS

Boom design and construction have not significantly changed over the past twenty years. There are two basic types of boom: fence and curtain. Fence boom tends to be simple rigid construction suited more for sheltered waters. Curtain boom with tension members built-in at the bottom (and sometimes the top) of the boom are more suited to open water environments as they resist the tendency to topple under wind and wave conditions. Booms are constructed from a range of materials, but predominantly Poly Vinyl Chloride, Polyurethane, Polyurethane alloys, neoprene and rubber. Standards for construction exist under ASTM F20 but they are not universally applied. Boom size, reliability and integrity are important considerations when assessing applications for boom.

There is often a misconception that boom can be used to protect an entire shoreline. It is not feasible or effective to completely boom off a shoreline. This has failed on many spill responses, including the DWH response. Initially deploying boom may be difficult, but maintaining boom on station is sometimes even more difficult. The answer in most responses, including the DWH response, is not to deploy more boom but to use the boom as designed and provide education on its limitations and practical uses. It is important to set expectations at an appropriate level.

ENCOUNTER RATES

As noted earlier, an important aspect for responding to oil spilled in open water is the oil encounter rate. When oil is spilled, depending on its physical characteristics, it will tend to spread on the surface of the sea due to gravity. Typically oil with a higher API gravity (lower density) will spread more quickly (examples of API gravity: light crude oils – API gravity of 38-40; heavy crude oil – API gravity of 20 or less). This spreading effect is then exacerbated by the effect of wind and current breaking the oil into windrows. In order to effectively recover oil at sea, oil must be concentrated into thicker oil layers using oil booms to permit skimming operations, or large quantities of sea water with low oil concentrations must be recovered and processed in tanks to permit gravity separation to take place. The effectiveness of the recovery operations has a direct correlation to the level of oil encountered.

The length of open water containment boom usually deployed in an open-water tow, is typically limited to 1500 feet. Beyond 1500 ft, controlling the vessels becomes difficult and increased vessel size and horsepower become necessary. When using boom lengths of 1500 ft, the actual opening or swath width to encounter oil is limited to 300 to 500 ft. Current boom technology limits the speed of advance of any system to ensure that the current flow at the boom apex is kept below 0.7 knots. Speeds above this will lead to oil entraining under the boom. The combination of these factors means that any boom/recovery system will have its oil encounter rate limited.

Because of the ship handling limitations of long boom systems, equipment has been developed that is comprised of single or dual sweep arm systems. Vessels fitted with this equipment can operate autonomously and contain oil using shorter sweep arms and skim oil into internal tanks. Experience in DWH and other spills (*Erika, Prestige*) have shown that sweep arm systems are extremely effective and can cover large sea areas. Political obstacles may be encountered when using foreign flagged skimming vessels in the US because of the Jones Act, but it was reported by the US National Incident Commander that Jones Act restrictions did not inhibit any foreign flag skimming vessel during DWH because they were not involved in restricted activities.

The speed of advance of boom systems is a limiting factor in encounter rate. Systems such as the 'current buster' technology have demonstrated an ability to recover oil at a speed of up to 5 knots. These systems are capable of covering greater swaths of ocean, thus increasing encounter rate.

To maximize encounter rates, a number of advancements have been made for better management of response resources so that they can be directed to the heaviest concentrations of oil. As such, developments have occurred in a number of forms:

- Ship radar based systems
- Aerial observation systems ranging from aircraft / helicopters/unmanned air vehicles/ balloons

- Improving communication arrangements to ensure that surface vessels can be directed to oil concentrations

- Ensuring rapid down-linking of aerial observations or oil plots to vessels on scene.

OIL CHARACTERISTICS AND SPILL RELEASE PROFILE

The weathering and fate of oil and its impact on spills has been studied for many years. The characteristics of spilled oil play a major part in the effectiveness of oil recovery and containment operations. Low viscosity oils (light crude oil) tend to spread very quickly making containment and encountering oil more difficult. High viscosity oils (heavy crude oil and fuel oils) tend to have a reduced spreading rate. This helps improve the encounter rate but the recovery of these oils is much more difficult. After recovering highly viscous oil, pumping the oil into storage is often a limiting factor. These problems have been recognized in spills around the world. The cases involving high viscosity fuel oil seem to rank among the most difficult and complex spill responses to date. In certain cases, crude oil can exhibit high viscosity characteristics, in particular paraffinic oils with a high pour point and/or wax content. Oils with a high asphaltene content also pose a problem as they can rapidly form emulsions when released into turbulent sea conditions These oil types, or their weathered components, are highly persistent and are often resistant to dispersant application, leaving containment and recovery as one of the few viable response options. The DWH spill profile provided unique challenges to responders. The oil had to travel a mile to reach the surface, thus, the oil was already weathered to some degree. Also, the oil surfaced over a 25 square mile area which made containment and recovery very difficult.

RECOVERY MECHANISMS

There are currently four main types of skimmers that have been used to recover oil at sea: oleophilic, weir , vacuum, and mechanical. Although the principles behind skimming systems have not changed over the past thirty years or more, better design and engineering have led to improvements. Each of the systems has their advantages and disadvantages.

Oleophilic systems

Oleophilic systems rely on the property of oil adhering to a drum, belt, brush, disc or mop type arrangement. The oil is then scraped off into a chamber from where it is pumped to storage. These devices are efficient and it is common for them to have a high recovered oil to water ratio. The oil types most suited are the light to medium viscosity oils but very high viscosity oils are handled using the brush type fittings.

Weir skimmers

These systems rely on oil passing over a weir arrangement which is used to separate the oil and water phases. The units are less efficient than their oleophilic counterparts and often the recovered liquid has more water than oil. For this reason, they require large storage capacity. The range in the size of weir skimmers varies tremendously. Larger systems take in substantial quantities of oily water mix over a weir and then use high powered pumps to transfer the mixture into high capacity storage tanks where separation can take place. These systems are widely used across the European Union. They are used in conjunction with coastal tankers of about 300 ft long. One of the benefits of weir skimmers is their ability to handle both light and heavier products. The heavy products may require the introduction of water with the recovered product to assist in pumping the material into storage.

Vacuum skimmers

These units rely on the use of vacuum or air movement technology to lift oil from the surface of the sea or the shore. Vacuum systems are versatile and able to be used on a variety of oil types although refined volatile products must be avoided for safety reasons. The advantage of vacuum systems is that generally they include an integral storage container and, if mobile, may be used to transport oil to final storage. A disadvantage is that they can be inefficient by recovering more water than oil.

Mechanical skimmers

These systems rely on the physical collection of oil from the surface and include devices from conveyor belts to actual grab buckets. These types of skimmers are more suited to very viscous oils.

Positioning skimmer systems

Once oil is encountered in the boom, the next objective is to get the oil skimmer into the oil. This can be difficult as the boom configuration will keep the oil away from the vessel's side. Cranes on vessels must be capable of lifting the skimmer over the ship's rail and have sufficient reach to deliver the skimmer to the apex of the boom. The umbilical hoses must be long enough to reach the oil location, and also extend to the oil storage. They must be supported so as not to drag on the skimmer. Operators use remote controls to position the skimmer and ensure it is operating correctly. New wireless remote controls are now being fitted on modern skimmers.

Active boom systems

In the early 1980s work was carried out to develop skimming systems that had the oil recovery systems built into the boom. These systems were developed as a direct consequence of well blow outs in Mexico. Similar systems are the Ro Boom/Ro skim system and the Transrec system. These systems are operated by Norwegian Clean Seas Association for Operating Companies (NOFO) in Norway and a total of 14 systems are stored along the coast in response bases. Designated offshore vessels are pre-fitted with the facilities to receive this equipment and the crews trained in their use. Similar systems are available in the US.

Other technology developments

High capacity skimming devices have been developed to deal with high volume spills. One example is the new oleophilic skimmer recently tested in the BOEMRE Oil and Hazardous Material Spill Equipment Test Tank (OHMSETT), the 'Octopus' device. This unit uses brush devices to recover oil and has a capacity of 300 cubic meters per hour (2000 barrels/hr)[16] Other examples are the Boom Vane[17] and the Crucial skimmer.[18]

Skimmers have been developed over recent years to deal with high viscosity oils produced in Norway. The resultant hi wax skimmer has proved effective in a number of spills (*Erika, Prestige*).

Recognizing the need to move into deepwater off the coast of Norway, the Norwegian oil industry developed a technology challenge presented at the 2008 International Oil Spill Conference. This process is still underway and over 120 international companies signed agreements to fund four R&D projects: faster towing of boom; large floating work platform for sheltered waters; portable skimmers for sheltered waters; and ship-based solution for applying dispersants.

There have also been previous research projects to convert tankers into high volume recovery systems by modifying the tankage of the vessel and fitting it with dedicated sweep arms.

PUMPING AND PUMPING SYSTEMS: HOSES AND UMBILICAL HOSES

A key in all recovery devices is the capacity and type of the pumps fitted. They can either be on board or remote. On board pumps, while more effective as they can be used to discharge oil rather than relying on pump suction performance, tend to increase the weight of the device which reduces portability. The pump type is critical to ensure effective pumping of the recovered oil. More viscous oils require high powered positive displacement pumps while lighter oils can be handled by smaller centrifugal or diaphragm pumps. Much work has already been done by USCG in the Joint Viscous Oil Pumping System program to identify means of pumping viscous oils.

Another issue to consider is the umbilical hoses connected to skimmers operating beside a vessel. These hydraulic and discharge hoses create a 'drag' factor on skimmer systems when they are deployed over the side of a vessel. In some cases, the hoses are contained in a floating umbilical container which reduces this drag factor. Ideally the industry would adopt a single standard of hoses and coupling connections so equipment is fully compatible.

STORAGE ISSUES

A major limiting factor in effective containment and recovery operations is the availability of waste oil storage on the skimming vessel. The size of storage, in comparison to the recovery capability of some of the recovery systems, is a critical factor. Weir skimmers as noted previously are prone to high levels of water pick up which rapidly fills storage barges or tanks to capacity with large quantities of water. Gaining permission to pump water which separates from recovered oil while in an onboard storage tank into the apex of the collection system is critical to extending the operating capability of the system. The nature of the recovered product is also an important factor as heavy oils will be difficult to handle. Specialized pumps may be required and storage tanks may require heating coils to permit the recovered product to be removed.

[16] The recovery capacity of commonly used offshore skimmers is 200 – 1,000 bbl per hour. There are a small number of offshore skimmers with recovery capacities of 1,200 – 2,000 bbl per hour.
[17] http://www.allmaritim.com/english/products/orc-boom-vane/
[18] http://www.pws-osri.org/programs/projects/annual_reports/2008/08-10-12.pdf

OPERATIONAL ISSUES

Many VOOs were pressed into service during the DWH spill. VOOs are typically fishing and shrimping vessels, but may also be vessels which support the offshore oil industry. These vessels can be effective if deployed with equipment that is suitable to the vessel configuration and capability.

EFFICIENCY AND WEATHER

At sea containment and recovery is severely limited by weather. Once sea conditions go beyond winds of 20 knots and wave heights of 6-8 feet, the performance of oil containment booms and skimming systems is significantly reduced and the risk to the responder is increased. Similarly as noted previously, the efficiency of booms at relative current speeds of greater than 0.7 knots becomes an issue.

SUCCESS STORIES FROM THE DWH RESPONSE

While some suggested that assets ought to have been on-site sooner, they were available when called upon. Due to OPA 90, the US had access to more mechanical recovery equipment than any other location in the world. The concept of cascading out-of-area resources also worked very well. Vast quantities of response assets were brought to the scene from other parts of the US and around the world. Furthermore, various types of skimmers were needed during the life cycle of the oil and all types needed were brought to bear in sufficient quantities. Other oil companies assisted by providing personnel and equipment, and OSROs fully cooperated with each other.

The systems approach proved to be effective as well. Lack of local storage was not an issue. The combination of containment, skimmer, on board storage, local barge or ship for storage, and transport of recovered material to disposal facility was successfully implemented and larger skimming systems performed well and remained on station throughout, providing an excellent communications platform.

During the DWH response, existing equipment was used in an innovative manner, and new technology was developed. Firstly, Marflex arms for containment and skimming were strong and worked well in adverse sea conditions. However, in heavy seas, only the arm on the leeward side was effective. This reduced its overall effectiveness, but it was still skimming when other systems could not. Seaweed in the tanks was a problem until specialized pumps were added to take care of the debris. Seaweed and debris were issues with this skimmer and all other skimmers working in the debris-laden windrows of oil far away from the source. Hydrogen sulfide was a problem with this system, but this could have been remedied by offloading more often.

Recently developed skimmers also were effectively employed. These included crucial “fuzzy” oleophilic disc skimmers and HOSS barge (four belt) skimmers. Additionally, current buster technology worked at higher speeds through the water, increasing the encounter rate. The current buster technology may be the future for offshore skimming operations, and VOO skimming worked in some areas. The only issue limiting the effectiveness of available skimming resources was not having enough trained response operators to run the current buster systems which created situations where the advantages were not utilized. Finally, decanting of recovered water from the skimmer into the boom apex improved the efficiency of recovery operations.

AREAS FOR IMPROVEMENT AND PRELIMINARY RECOMMENDATIONS

The DWH incident presented challenges regarding encounter rate complicated both by inappropriate expectations for recovery systems, and by a continuous release of oil from a discharge one mile below the surface of the water. When the oil reached the surface, it covered an area of 25 square miles and was already a thin film and/or weathered oil. The ability of responders to encounter the spilled oil was further reduced by placing a five mile exclusion zone around the well area.

COMMUNICATION AND REGULATORY MATTERS

During DWH, the adequacy of the strategy of containment and recovery was called into question. Some suggested that the performance of containment and mechanical recovery lags behind other strategic response methods and falls short of expectations. Understanding the limitations of mechanical recovery and how performance might be improved in the future is important. For example, the skimmer quantity was sufficient but managing the public's and policy-makers' expectations regarding typical encounter rates was an issue.

The regulatory required Effective Daily Recovery Capacity (EDRC) calculation for skimmers provides a simple mathematical calculation for estimating (or de-rating) the capabilities of a skimmer based on its pump's capacity. However, a skimmer's EDRC calculation results in a recovery rate that is usually overstated. This approach is the result of the 1992 negotiated rulemaking process, and it is recommended that this approach be evaluated to determine if there is a more realistic way for determining skimmer capability required by the regulations. Although a new ASTM standard for testing skimmer capacity and recovery rates has been developed, the JITF recommends evaluating ASTM's minimum standards for skimmers and boom. Finally, more consistency is needed between standards for USCG, EPA, BOEMRE, and State regulations with respect to mechanical recovery requirements.

TECHNOLOGICAL IMPROVEMENTS

In containment operations, the encounter rate is a function of the boom length and shape, and the speed of advance. The combination of these two parameters helps determine the 'swath' width of a system. An improved encounter rate will always improve the effectiveness of mechanical recovery, including wider swath, skimming while moving through the water at higher speed, and skimming while working in higher seas.

Boom systems fail once the current speeds are in excess of 0.7 knots perpendicular to the boom. This parameter limits the ability of any booming array to cover the sea surface as the speed of advance must be limited to prevent oil from being lost under the boom. New technology has been developed to operate boom systems at higher speeds and some of this new technology was used in the DWH response. High speed booming/recovery systems may improve encounter rate, reliability, and sustainability.

Improvements in remote sensing and tracking techniques and technologies (discussed in the previous chapter on Oil Sensing and Tracking), would allow responders to locate thickest patches of oil and improve oil encounter rates.

"A Whale" is a large vessel using a weir skimmer with sufficient storage and oil water separation capability to handle large volumes of oil and water, and could be valuable if available. A disadvantage is that tankers or large barges create a large wake which pushes floating oil away from the weir skimmer. Additionally, large vessels that are not maneuverable will not be useful. Maneuverability is vital during offshore skimming operations. Industry should investigate the effectiveness of large volume skimming vessels in response scenarios.

The JITF recommends designing oil trawl nets for tar balls and patties, oiled debris and other oiled flotsam that vessels of opportunity could pull and recover. Furthermore, fishing vessel arms need to be redesigned to be strong enough to pull oil trawl nets and transfer capabilities of storage barges need to be improved. There is a need to improve handling systems for hydraulic and discharge hoses to reduce their drag effect on skimming systems. Additional consideration should be given to reviewing sweeping arm technology used on dedicated barges/vessels in open water. Finally, international standardization of couplings and fittings would facilitate exchange of system parts.

Improvements in technology used in other parts of the world (particularly Japan and Norway) should be considered, including at-sea oil containment and recovery systems, and work done on pumping systems in the Joint Viscous Oil Pumping System Workshop. The NOFO technology challenge is a global challenge was presented at the last International Oil Spill Conference for any manufacturer to offer solutions to improving oil recovery operations at sea. This was specifically aimed at open water environments in severe weather, which would effectively improve encounter rate. An initial entry was screened by specialists from the Norwegian sector and in the end some twenty projects were passed through to next stage which included R&D investment, prototyping and testing. The results of this work should be reviewed as it represents the latest in industry R&D, as projects include a number of recovery systems and operations enhancements. The JITF recommends continuing research and development of systems which can be used in more severe sea/weather conditions.

VESSELS OF OPPORTUNITY

The JITF recommends designing and developing a response package/system specifically for vessels of opportunity, staging these systems in strategic locations, and developing a training program for crews of vessels of opportunity. Efforts should be made to identify a suitable training program for vessel operators and crews of VOO because while the number of response personnel was not an issue during DWH, there was a shortage of trained operators for various skimming systems. There were examples of skimming systems not being used effectively due to inexperienced operators, and more skimming systems could have been mobilized if trained operators were available.

Additionally, although, there was no shortage of marine assets, there was an issue with offshore supply vessels (vessels of opportunity) being too big to tow ocean boom. Most of the bigger vessels of opportunity could not operate at the slower speeds necessary to tow ocean boom without destroying it. The large purpose-built oil spill response vessels did not have this problem because they were built to operate at the slow speeds needed for the job.

VI. SHORELINE PROTECTION AND CLEANUP SUBGROUP FINDINGS

INTRODUCTION

As discussed in the previous chapters, the fundamental objective of oil spill response and recovery is to protect the shoreline by removing floating oil before it impacts land and other surfaces. Tactics include ocean booming and skimming, *in situ* burning, and dispersant application.[19] Protective booming supports this shoreline protection strategy by keeping oil off the shore, thereby preventing or reducing the environmental effects to sensitive resources and wildlife habitats. The oil is then removed from the environment using skimmers and sorbents.

Pre-impact efforts involve conducting a pre-impact survey and cleaning up shoreline from debris, if possible. Once the oil has impacted the shoreline, SCAT teams are mobilized. Once the SCAT teams have characterized the shoreline, documented the degree and extent of stranded oil and recommended appropriate cleanup or treatment techniques for a particular shore segment, shoreline cleanup can begin. The planning section's environmental unit provides guidance and direction to the tactical teams.

Shoreline cleanup techniques can be labor intensive and often involve wiping, scrubbing, hot and cold water washing, manually and mechanically picking up oiled and contaminated sand, soil, and debris. Water streams may be used to flush or refloat oil in sensitive resource/habitat areas to a location where skimming and sorbents are used to recover oil. Oiled marshes and swamps are areas where this strategy would be appropriate. Man-made structures, such as pier faces, pilings, and vessels require pressure washing and/or more intensive cleaning to remove the oil from their surfaces. Staining is often a residual effect of the oil spill.

Given the level of intrusion required for shoreline cleanup, there are instances were oiled shoreline should be left to naturally biodegrade. Mechanical sediment or vegetation removal and human trampling associated with shoreline cleanup activities can cause more damage to biota than would the presence of stranded oil. Natural removal of residual oil by wave and tidal action along with biodegradation will generally restore sensitive shoreline ecosystems with a greater net environmental benefit than mechanical or manual techniques.

The DWH cleanup process generated tons of solid waste that required proper disposal in landfills or incineration. During the DWH response, 665 miles of shoreline were impacted. Some 40,000 responders were engaged to clean beaches; marshes; mangroves; and private, industrial and commercial

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[19] ASTM has standards for shoreline response, including ASTM F2464 - 05 Standard Guide for Cleaning of Various Oiled Shorelines and Habitats, ASTM F2204 - 09 Standard Guide for Describing Shoreline Response Techniques, and ASTM F1872 - 05 Standard Guide for Use of Chemical Shoreline Cleaning Agents: Environmental and Operational Considerations. NOAA has also published guides: http://response.restoration.noaa.gov/type_subtopic_entry.php?RECORD_KEY%28entry_subtopic_type%29=entry_id,subtopic_id,type_id&entry_id(entry_subtopic_type)=335&subtopic_id(entry_subtopic_type)=8&type_id(entry_subtopic_type)=2

waterfront. To date, 8.76 million feet of sorbent boom used during the DWH response have been collected and processed for disposal.

This chapter is divided into four sections: 1) a brief history of shoreline protection and cleanup techniques, 2) discussions of the equipment, constraints, and the systems approach, 3) successes from the DWH response relating to shore line cleanup, and 4) specific recommendations for improvements.

TWENTY-YEAR HISTORY

The basic concepts for shoreline protection and cleaning have changed very little over the last 20 years. Protection techniques include activities such as barriers, booming, herding oil with pumps and hoses for mechanical removal, collecting oil from the water with sorbents, using skimmers and vacuum trucks and manually removing oil from the environment.

OPA 90 directed Area Committees to be established to plan for a coordinated community response to an oil discharge. For areas under the USCG jurisdiction, Area Committees are designated for each coastal Captain of the Port zone. The EPA is in charge of inland Area Committee development and has designated each EPA region as an Area and the RRT as Area Committees.

ACPs have good information on environmental sensitivities and strategies to aid the response. The Area Committees are tasked to identify sensitive resource (primarily fish, wildlife, and human use) areas and develop plans and priorities for their protection. Maps are prepared to help identify these sensitive resource areas. Strategic and tactical shore line response objectives are prepared for each of the types of shoreline. The plans also describe the types of shoreline protection measures available to protect sensitive resources, emphasizing the limits of each protection measure. Where mechanical shoreline protection response actions are not feasible, area committees consider alternative measures. The plans also provide guidance on developing site-specific protection strategies, including equipment and logistical needs, operational constraints, and physical conditions for the area.

The GOM has individual USCG Captain of the Port ACPs as well as a One Gulf Plan.

Shoreline cleanup processes are now a familiar part of oil spill response in many countries. The response industry has considerable data on effectiveness of shoreline cleanup for major oil spills over the past 20 years. Major spills with shoreline cleanup components since OPA 90 include:

- *Prestige* carrying 70,000 tons of fuel oil broke up off the Spanish coast.
- The stern of the Maltese tanker *Erika* sank off the northwest of France after splitting in two. It was carrying 25,000 tons of viscous fuel oil. Shoreline cleanup was required to mitigate the effects of oil coming ashore.
- Ecuadorean-registered ship *Jessica* spilled 571 tons of diesel and bunker oil into the sea off the Galapagos Islands in what was seen as one of Galapagos' worst environmental disasters.
- Some 1,400 tons of heavy fuel oil leaked from the bulk carrier *Treasure* off Cape Town prompting rescue of the endangered Jackass penguin on Dassen and Robben Islands.
- A ruptured pipeline spewed 1,100 tons of heavy oil into Guanabara Bay, Rio de Janeiro, in Brazil.

- The Liberian-registered *Sea Empress* hit rocks near Milford Haven, Wales, and spilling 72,000 tons of oil.

- The *Haven* spilled more than 50,000 tons of oil off Genoa, Italy.

- After explosions and fire, the Iranian tanker *Kharg-5* spilled 70,000 tons of crude oil, endangering the coast and oyster beds at Oualidia.

- The *Exxon Valdez* grounded and spilled 38,800 tons of crude oil into Prince William Sound, Alaska; approximately 900 miles of shoreline was oiled.

SUCCESS STORIES FROM THE DWH RESPONSE

The GOM has an abundance of oil spill response contractors and equipment. Shoreline protection strategy with boom was deployed for sensitive areas before the oil reached land. This WCD spill did not stress the shoreline protection and cleanup resources of the response community to the point of failure. The extent of the spill could have been more challenging if dispersant had not been used at the spill source. However, the public perceived this was a worse case discharge and thought there was not enough equipment and personnel to protect their shores.

Responders utilized effective strategies and technology. Sandy beach cleanup achieved the overall goal of rapid cleanup. SCATs developed and guided effective, scientifically relevant strategies and tactics in a very complex shoreline and wetland environment. Resources were sufficient and adequate processes were in place to manage activities effectively. The Unified Command developed general treatment guidelines for operations and shoreline treatment recommendations on a segment-by-segment basis using net environmental benefit principal which meet the stakeholder’s needs.

Current technology was effective in accessible areas such as beaches and near-shore environments. Responders used best practices in which the actual tactics and technologies are very basic for beaches and non-intrusive for wetlands. Marsh washing equipment was tested by field trials prior to tactical application. Marsh cleaning operations were focused on the type of oil (floating light product to heavy weathered oil), specific staining issues were addressed and cleanup waste and debris was removed effectively.

The wildlife rescue and response was very efficient and effective. Activities by trained professionals supported by volunteers were well managed which resulted in minimal wildlife impacts.

AREAS FOR IMPROVEMENT AND PRELIMINARY RECOMMENDATIONS

APPROPRIATE TECHNIQUES, COMMUNICATION, AND COORDINATION

Given the wide-ranging impacts of the DWH oil spill, with over 600 miles of shoreline affected in four states, the response could not be fully supported by experienced, seasoned responders. Marsh and sensitive resource areas were damaged by inappropriate and improperly applied response tactics implemented by inexperienced responders; damages could have been avoided with experienced supervision. When a robust oil spill response industry becomes overburdened from a large scale incident, then trained and qualified government responders and experts from the USCG and NOAA should supplement the personnel response.

Some of the methods used for shoreline protection were seen to be ineffective, damaging and cost prohibitive. Offshore sand berms and barriers did not achieve a positive cost benefit and offered only short term protection. Building tidal barriers had a destructive net result and yielded increased erosion and impeded natural biodegradation. The use of barriers, berms and dams to block tidal inlets was physically destructive and caused negative environmental consequences such as increased erosion in other areas, impediment of natural biodegradation, reduced the natural recovery of biota, local salinity changes that were harmful to flora and fauna and reduced physical degradation by waves and tides. Virtually all coastal geologists agree the overall environmental effects of these techniques were negative. Therefore, the practice of employing barriers and berms should be thoroughly researched, shown to provide a positive net benefit, and demonstrated to be scientifically effective as a response strategy prior to implementation.

Some local governments developed and implemented their own strategies and tactics that were in contradiction to the efforts of the UC. In some cases, locally implemented tactics for shallow water recovery and sensitive area protection was ineffective and improperly maintained. Improperly anchored boom was carried well into the marshes by storms and retrieval was very damaging to the environment. It is in the best interest of all stakeholders that all response strategies be approved, implemented and managed by the UC, which has local government representation. A single entity acting alone should be discouraged from implementing shoreline protection and cleanup response tactics.

In some cases, booming was driven by public and private demand, often based on political and business considerations. This practice resulted in booming shortages that otherwise could have been used in locations predicted to be impacted by oil movement trajectories when many areas unnecessarily boomed never saw oil.

It is not feasible or effective to completely boom off a shoreline; the strategy will fail, and will often lead to more damage as boomed areas must be maintained and groomed. Limited deflective boom can be effective under the right conditions with good tactical planning. Additionally, adverse weather can break sections of boom away, causing physical damage to bird rookeries, sensitive wetlands, and other resources. There is a serious misconception as to the benefit of booms particularly in the inshore areas. This has occurred repeatedly on the DWH response and great efforts are being expended to safely recover stranded boom from sensitive areas, without inflicting environmental damage.

A core lesson of the DWH response is to educate stakeholders on boom limitations and practical use. There must be, however, an opportunity to improve booming plans at the community level. The JITF recommends setting expectations for limitations of boom performance. The JITF also recommends developing and publishing a scientifically based effort versus benefit analysis of all shoreline protection and clean up strategies deployed during DWH response, to be shared with state and local governments. This would help to alleviate some of the opinion differences in how best to protect and remove oil from coastal regions and best practice tactics implementation. Finally, preemptive coastal restoration should be considered and implemented by state governments to improve the integrity of the states' natural barriers and improve tidal flow based on hydrodynamic principals and the ESI Index should be updated to reflect current conditions.

TECHNOLOGICAL DEVELOPMENTS

The JITF recommends additional effort to research and develop shoreline protection and cleanup technology. First, efforts should be made to enhance nutrient enrichment and microbe application knowledge and processes to support consideration of shoreline treatment strategies involving bioremediation techniques. Secondly, researchers should strive to enhance oil cohesiveness characteristics knowledge and develop herding compounds to improve efficiencies in near-shore environments. Studies should be conducted on use of oil herding agents on marsh grass prior to impact to minimize coating of grass. Additionally, enhancements are possible in the area of floating plasma technologies to improve floating oil recovery efficiencies. These efforts also should result in technologies to improve sandy beach mechanical cleanup. It was clear during the DWH response that we need to develop mechanized efficiencies in tar ball removal to lessen high manual labor requirements.

Additionally, there is opportunity to conduct research and development to extend boom performance, investigate the development of high current booms, and improvement anchoring systems. Development of booms that are more robust and able to withstand or operate in higher sea conditions and current speeds is recommended. Finally, researchers should develop Gulf Coast tidal and current flow baselines and scientific based strategies for the implementation and use of sensors to determine shallow water inlet flow characteristics.

SAFETY PLANS

Safety plans and personal protective equipment requirements were not adjusted to reflect the responder's environment. Protective clothing was mandatory for beach workers such as the wearing of Tyvek® suits, long sleeve shirts and cover from the boots to the neck. Safety officials did not recognize the hazards of working in the hot summer Gulf coast climate until after several workers experienced heat exhaustion. Heat stress became a huge issue during the response. The lack of experienced safety officers may have been a factor in poorly-developed safety plans.

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VII. ALTERNATIVE RESPONSE TECHNOLOGIES SUBGROUP FINDINGS

INTRODUCTION

A perception exists that the oil spill response (OSR) community has not embraced many technological advances in the past thirty years, i.e., that the response to the DWH spill has been based on old and therefore, less effective techniques. In actuality, the OSR community, which encompasses a wide range of industrial, academic and governmental organizations, has been active with respect to identifying, evaluating and implementing spill response improvements as they have become available.

While the traditional approach to OSR consists of three main components, mechanical recovery, chemical dispersants and *in situ* burn, this does not preclude the consideration of other non-traditional approaches or improvements to current techniques. In fact, it is in the best interest of an effective oil spill response that that the most efficient response options be a part of the oil spill toolkit, regardless of where the ideas may have originated.

The following describes key focus areas that are at least partly engendered by scrutiny in light of the DWH spill.

- New response technologies should be identified, evaluated, and when feasible, incorporated into the oil spill response toolbox.
- Efficient processes for the evaluation of new technology ideas should be developed and sustained.
- Responsibility for the encouragement of new, innovative technologies should be defined.

This chapter will explore the issues related to the identification and evaluation of alternative technologies and innovative techniques, including 1) a brief background on evaluation procedures during and before the DWH incident; 2) a summary of typical technology areas that have been considered; 3) successes from the DWH response relating to alternative technologies, and 4) specific recommendations for improvements.

ALTERNATIVE TECHNOLOGY DEVELOPMENT & EVALUATION

EVALUATING ALTERNATIVE TECHNOLOGIES DURING THE DWH INCIDENT RESPONSE

Processes have been in place to evaluate and develop new oil spill response technologies for some time. However, it is generally the case that during oil spills, numerous unsolicited ideas intended to provide for enhanced spill response are received and expected to be acted upon even though the spill response is in full force and resources are not freely available. The advent of electronic communication has facilitated the ability of the public to provide even more suggestions. As quickly as ideas can be submitted, there is an expectation that responses will be provided equally rapidly.

In the case of the DWH incident in the GOM, vast numbers of unsolicited ideas were submitted by the public to BP. The number of submissions rapidly exceeded 100,000 at a time when the response was still in the early stages. Nevertheless, there was a process in place to receive and evaluate submissions (Figure 2).

The BP DWH incident alternative response technology evaluation process provided that submissions were first categorized as either Source Control or Oil Spill Response. Under Oil Spill Response, there were then 4 stages for the evaluation of submissions: preliminary evaluation, classify, technical review/prioritize and finally field test. Submissions entering the prioritization stage were then subjected to a specific ranking methodology, with 13 categories. A numerical value was assigned to each category, ranging from -1 to 3 (depending on the category); then each submission received a score between 0 and 28. The process schematic is depicted below.

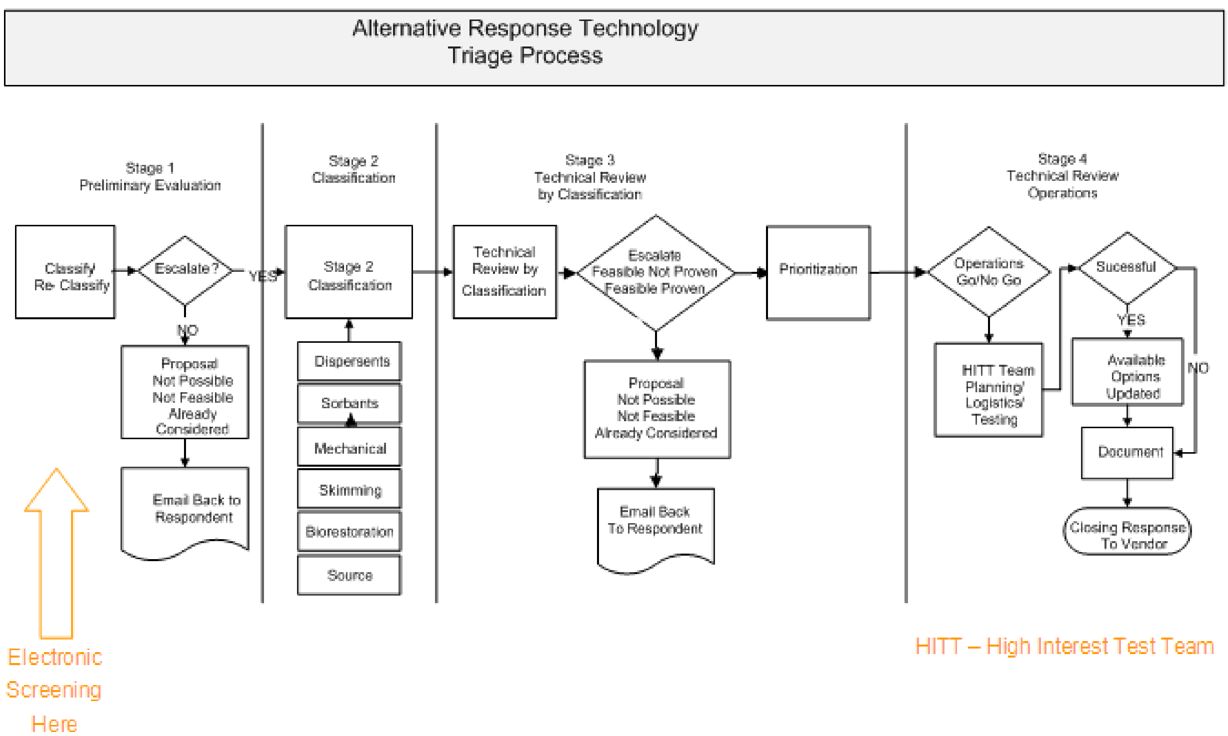

Figure 2. Alternative Response Technology Triage Process

- Many suggestions were received for "improved" spill response, e.g., 130,000 suggestions by mid-July for DWH (1/3 on oil spill response & clean up, 2/3 focused on subsea efforts)
- The bulk of response suggestions did not proceed beyond the initial evaluation stage
- Suggestions fell into several categories: already done/considered, worth further consideration, not feasible

- An efficient mechanism for dealing with suggestions is of value with respect to public relations, i.e., a timely response to the submitter is important
- It was felt by many in the public and government that BP was not responsive enough with respect to considering outside suggestions
- The SONS designation added a heightened level of awareness and expectation to the spill response.

Although there was a process for collecting and considering unsolicited suggestions relating to the DWH incident, it was felt by many in the public and within government agencies that BP had not been responsive enough with respect to timely evaluation of a large volume of often disparate suggestions. The perception by government and the public was that BP was not giving the ideas enough attention, and that as a result, the spill response was not as effective as it could be.

As a result, the federal government created a process coordinated by the USCG to supplement BP's efforts. In May, then-commandant and FOSC Admiral Thad Allen asked the Coast Guard Research and Development Center in New London, CT to coordinate a group that became the idea clearinghouse: the Interagency Technology Assessment Program (IATAP). The IATAP is responsible for collecting and coordinating the evaluation of DWH-related suggestions. The IATAP team of technical experts includes representatives from EPA Agency, Fish and Wildlife Service, Maritime Administration, BOEMRE, NOAA, the Department of Agriculture and US Army Corps of Engineers.

The following excerpt highlights the IATAP process:

Alternative Oil Spill Response Technologies

> *White Papers shall provide technology ideas/solutions to support the five technology gap areas identified above. Offerors are hereby notified that it is highly likely that White Papers may be shared with several different Government agencies and other interested parties (which may include contractors) for review and consideration.*
>
> *All submitted White Papers meeting the requirements of this broad agency announcement (BAA) will be reviewed and evaluated as they are received. Each White Paper will undergo an initial screening. The initial screening will result in a determination that either (1) the White Paper has a potential for immediate benefit to the spill response effort, (2) the White Paper submission needs more detailed investigation or evaluation and will be forwarded to the appropriate Government Agency overseeing that portion of the Deepwater Horizon Response, or (3) the White Paper submission does not support this incident. A Contracting Officer will provide a response to all properly submitted White papers identifying the initial screening determination.*
>
> *With regard to Item (1), if it is determined that the White Paper has a potential for immediate benefit to the spill response effort, the White Paper will be forwarded to the Deepwater Horizon Response Federal On-Scene Coordinator (FOSC) for further action. Further action may include contract actions by the responsible party or other federal agencies. Other parties are to contact the offeror directly should they desire a ROM regarding their oil spill recovery efforts.*
>
> *With regard to Item (2) above, if it is determined that the White Paper submission needs more detailed investigation or evaluation and it is forwarded to the appropriate Government Agency*

overseeing that portion of the Deepwater Horizon Response, that Agency will be responsible for any further action. The Agency may request additional information including a request for proposal.

Screening of White Papers will be accomplished through a peer or scientific review of the Offeror's proposed approach using the following criteria:

1. *Overall Scientific and Technical Merit*
2. *Feasibility*
3. *Availability of Proposed Solution*
4. *Rough order of Magnitude (ROM) Cost*
   Criteria 1 through 3 are of equal importance and more important than Criterion 4.

IATAP staff assign each paper a tracking number within 24 hours, review the ideas and either send the submission to the FOSC, dismiss them, or refer them to the appropriate federal agency for analysis. From June 4 through July 15, the center fielded more than 3,500 submissions; 80 ideas have been selected for either immediate consideration or further evaluation. The bulk of the center's efforts are on ideas that focus on oil collection and removal.

It appears that the government's solicitation for suggestions has been viewed as a successful model in light of the following EPA response after the July 26, 2010 spill of 800,000 gallons of crude oil near Battle Creek, Michigan:

EPA Solicits Ideas for Enbridge Oil Spill, Aug 04, 2010

The US Environmental Protection Agency on Aug. 1 announced a voluntary submittal process to allow for faster review of the suggestions being offered to manage the Enbridge oil spill near Marshall, Mich., and to provide guidance regarding what information would be most useful to the reviewing officials.

The information received through this voluntary submittal process will be scrutinized for innovative ideas and technological solutions that are safe for the environment and public health and can be deployed along the Kalamazoo River to help with cleanup. The information submitted will be forwarded to the appropriate reviewing official who will contact submitters, if necessary.

Suggestions are sought in the following areas: surface water containment and cleanup, air monitoring and detection, landfall cleanup, wildlife protection and cleanup and other management activities such as data collection and management.

For more information or to submit a technical solution, go to the EPA Enbridge Oil Spill website at www.epa.gov/enbridgespill/technology/index.html

TECHNOLOGY EXAMPLES AND CONSIDERATIONS FOR THEIR USE

The following is just a sampling of several spill response options that were either suggested during the DWH spill or have been considered on a regular basis. These examples represent typical technology areas that may be received by a suggestion clearinghouse and are outside of the more commonly deployed non-mechanical options of chemical dispersant use and *in situ* burn. The list is by no means exhaustive.

Centrifugal Oil Water Separation

- Used during a spill response for Oil / Water separation and emulsion breaking
- Identified/offered to BP for evaluation by a commercial venture
  - Quickly examined a specific piece of equipment for suitability because of unique press/public awareness, ordered 32 centrifuge devices made by a company co-founded by actor Kevin Costner
  - The largest of the devices were said to process about 210,000 gallons a day, separating oil from water.
  - Deployed on barges, the centrifuges were intended to help skimmers work more efficiently by letting them unload the oil and water mix, cleaning it at sea instead of returning to port each time the tank was full.
  - The technology is not new and may not provide enough throughput for a very large spill.
  - There may be situations where their use is warranted, but there is a need to consider regulatory requirements associated with water discharge back into the environment (decanting).
  - Decanting at sea has been challenged a number of times by state and federal agencies. Onshore decanting would likely make this option impractical, especially if no permitted treatment facility is readily accessible. Need to compare with standard decanting methods for efficiency and costs.

Heat Treating

- Used during a spill response for Oil / Water separation and emulsion breaking.
- Similar comments apply as for centrifugal oil/water separation, although some methods exist in oil fields for use in separating drilling muds and water.

Chemical Herders

- Used during a spill response for slick thickening and oil exclusion.
- Technology is not new but there may be new chemicals with less toxicity and bioaccumulation concerns than prior materials.
- They may be used to promote the formation of thicker slicks for use in conjunction with *in situ* burn and mechanical containment / recovery
- Papers on the subject have been presented by SL Ross (Ottawa, Canada) and BOEMRE.

Nanotechnology / Microencapsulation

- Used during and after a spill response for the consolidation of small slicks in calm areas
- May be used to enhance dispersion and microbial degradation
- In many cases, materials are essentially a fine sorbent powder and are therefore not new ideas
- Another "nanotech" project is a nano-woven sorbent paper that is essentially an expensive sorbent pad that that offers incremental improvement
- May have a problem with getting permission to broadcast loose particles, i.e. local RRT concerns
- Deployment and recovery techniques may be problematic

Solidifiers / Gelation Agents

- Used during and after a spill response for the consolidation of small slicks in calm areas
- Technology is not new (although new materials are being developed / examined) and has been used on a small scale, calm (e.g., near-shore) spills
- May be suitable for some specific areas of the DWH spill near shore
- Generally requires a high treat rate, e.g., 1:1, and some means to collect the material after it has gelled
- There may be the same concern regarding permission for broadcasting of loose materials in open water.

Bioremediation

- Generally considered for use following a spill to clean up lightly contaminated areas although could possibly be used during the response, potentially on-water or on-shore, in marshes, etc
- Technology is not new and has been used in a variety of spills – primarily on shore and post-spill
- The technique entails supplying nutrients to enhance the complete biodegradation of contaminants and may be used on water as well, e.g., supply of iron to enhance microbial activity
- A number of examples exist for water as well as a variety of other substrates
- A recent study is available: *Developing Treatment Products for Increased Microbial Degradation of Petroleum Oil Spills across Open-Water Surfaces*, by Grethe Kjeilen-Eilertsen[20], Josep Jersak[21], and Stig Westerlund[22].

[20] IRIS Biomiljø, IRIS - International Research Institute of Stavanger, Norway

Washing / Solvent Extraction

- Probably a post response option for use in cleaning contaminated areas, especially sand, rip rap, "shell hash," but could be used during the response where on-water recovery is locally complete.

ADDITIONAL INNOVATION EFFORTS

In addition to more traditional formalized research and development programs, there are other avenues for collecting the ideas of a wide ranging public. For example, "The X PRIZE Foundation" is an educational nonprofit organization whose mission is to create radical breakthroughs for the benefit of humanity thereby inspiring the formation of new industries, jobs and the revitalization of markets that are currently stuck. Today, it is widely recognized as the leader in fostering innovation through competition. (http://www.xprize.org/)." On July 29, 2010 the X PRIZE Foundation announced the creation of the Wendy Schmidt Oil Cleanup X Challenge[22]**:**

The goal of the Wendy Schmidt Oil Cleanup X CHALLENGE is to inspire entrepreneurs, engineers, and scientists worldwide to develop innovative, rapidly deployable, and highly efficient methods of capturing crude oil from the ocean surface. In making the announcement, the X PRIZE Foundation hopes to attract philanthropic and venture capital to support development of this important capability and provide a global platform where new technologies can be competed head-to-head, and the best approaches demonstrated, to prepare for future catastrophes.

Other means to capture innovative solutions to challenging problems have included the use of broadcast search-based websites where the percentage of solutions to scientific problems can be reasonably good.[23] For a recent oil spill response example of this approach, InnoCentive posted the following challenge on July 12, 2010 with a deadline of September 9, 2010:

> *"We are looking for novel approaches to using assorted commercial vessels for oil cleanup in the Gulf of Mexico. Challenge ID: 9561385*
>
> *The unprecedented event on the Deepwater Horizon oil well in the Gulf of Mexico has resulted in the release of millions of gallons of crude oil into the Gulf. While conventional methods are being deployed, the capacity is limited by the availability of suitable vessels with the necessary onboard equipment. We are looking for commercially available equipment, technology and ideas that would enable the rapid conversion of commercial vessels (e.g., fishing) to oil recovery units."*

The use of monetary incentives to stimulate the input from a pool of technically capable "solvers" has proven to be a sustainable model in a variety of areas, e.g., chemical synthesis challenges and the launch of a reusable manned spacecraft.

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[21] Biologge AS, Sandefjord, Norway
[22] http://www.xprize.org/media-center/press-release/x-prize-foundation-announces-wendy-schmidt-oil-cleanup-x-challenge.
[23] see, for example, *The Value of Openness in Scientific Problem Solving*, Lakhani, Jeppesen, Lohse, and Panetta, Harvard Business School, October 2006.

SUCCESS STORIES FROM THE DWH RESPONSE

In recent years and in particular during the DWH spill, a number of technologies were employed that either hadn't been used as extensively or in quite the same manner as they are traditionally employed. As a result, new innovations continue to occur, something that should be encouraged and captured for future reference. Several of these are indicated below.

USE OF DISPERSANTS TO DISSIPATE CONCENTRATIONS OF VOLATILE ORGANIC COMPOUNDS (VOC)

In addition to its use in surface and subsea dispersal of crude oil, it was found that aerial dispersant application in areas with high surface concentrations of crude oil actually had the effect of significantly reducing VOC, a safety concern for personnel working near the DWH spill site.

SUBSEA INJECTION OF DISPERSANTS

The innovative use of subsea injection during the DWH spill was unparalleled in its magnitude and apparent success. While the method had been used to some extent in the past, it was never near the depth of the Macondo well nor did it approach the length of time that the technique was used. Because of the success of the method at reducing the surface expression of spilled crude oil, it is quite likely that it will become an integral part of future deepwater operations.

ENHANCED MECHANICAL SKIMMER EFFICIENCY WITH FABRIC COVERING FOR DRUM AND DISCS

The use of mechanical disc and drum skimmers is well established and the operating parameters and collection efficiencies documented. However, recent focus as a result of Alaskan requirements has led to significant improvement of the recovery rate of this approach by the addition of a fabric to the skimmer surfaces.

OTHER RESPONSE INNOVATIONS

Other response innovations include the Boom Vane, which allows for fast water oil boom deployment by only one vessel and the development of new easily deployed temporary dams for river use, and the Ocean Buster.

The three Ocean Boom Vanes worked well and eliminated the need for a second vessel to tend boom on skimming systems. The USCG and US Navy using these systems were very complimentary. The problem was that no additional boom vanes were available and two vessels were needed in most instances.

AREAS FOR IMPROVEMENT AND PRELIMINARY RECOMMENDATIONS

As in any area, especially where the potential impacts and the number of interested parties may be quite large, there are always aspects that may be improved. A particular challenge in the case of an oil spill is that during the early, reactive stage of a spill response, most of the knowledgeable personnel are actively engaged and not readily available to assist effectively with public/governmental inquiries and suggestions. Additionally, following a spill, so much information has been generated around the spill response and its myriad aspects that it is difficult to capture any lessons learned that may have occurred in a manner that lends itself to efficient sharing across a wide range of stakeholders. For example, it is always going to be difficult for the responsible party or the response organization to deal with an influx of large numbers of suggestions during the early stages of a spill response. Additionally, it is often the case that small innovations do occur over time, either during a response or during slack ties, but it is difficult to capture them effectively (e.g., the use of leaf blowers to corral small spills). Therefore, effective communication tools should be developed to convey the fact that oil spill response technology is not static, and improvements are being made regularly, even when no active oil spill response is occurring.

Similarly, while research efforts into the enhancement of oil spill response occurs in an ongoing basis through a variety of mechanisms, it is important to have a robust process for supporting the additional creation of new ideas and the development of those ideas that look promising. Approaches to oil spill response that are proven to work should be documented, shared widely through a consistent, stable clearinghouse of information, and their use encouraged. And lessons learned after actual spills should be communicated to the oil spill response community in as timely a fashion as possible.

The responsibility generally should reside with the inventors and innovators and those who would benefit from the implementation of new ideas, including a wide range of individuals, organizations, companies and government agencies. However, the ability to leverage any and all well considered ideas could have significant value either by reducing the amount of surface oil that must be mitigated, increasing the efficiency and effectiveness of spill response equipment, or reducing the capital investment of an effective spill response organization. Areas that could benefit from additional research should be identified, prioritized, and funded and non-traditional approaches should be pursued to encourage invention, innovation and implementation of new oil spill response methods, (e.g., Wendy Schmidt Oil Cleanup X Challenge, InnoCentive, etc). Finally, the use of incentives should be considered by the Government, e.g., via tax deductions or by changing credits for spill response to extend beyond feet of boom deployed or amount of skimming capacity available to better measures of response effectiveness, such as oil "encounter rate."

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VIII. FUNDING SUBGROUP FINDINGS

INTRODUCTION

Beginning in 1990 after the *Exxon Valdez* spill, there was an increase in funding for oil spill response planning activities as well as research and development. The OPA 90 called for national oil spill R&D efforts, projects by various agencies, universities and ports. The target for Federal funding was $25 million annually. This goal was to be coordinated through an Interagency Coordinating Committee on Oil Spill Research.

However, with the significant efforts to prevent spills and the reduction in number and volume of spills, the spending gradually decreased over time until 2010. Therefore, the first section of this chapter discusses the history of funding post *Exxon Valdez*. The second section of this chapter will discuss the JITF's recommendations for what will likely be a coordinated approach to provide funding for R&D and for oil spill response planning, in the post-DWH environment. In order to develop the second section of this work, the recommendations and input from the other Sub-Groups (Mechanical Equipment, Dispersants, *In Situ* Burn, Alternative Technologies, etc.) is necessary. As those Sub-Groups are still in the early stages of their work, details regarding funding for post-DWH will be available as part of the final report of the JITF, at the end of 2010.

Both oil spill response planning as well as research and development in all of the sectors described in this document must be performed in a cooperative and non-competitive manner with industry, government, academia, and stakeholders jointly involved. The final section of this chapter discusses how the task force recommends we prioritize and coordinate this activity with a recommended process to coordinate the projects, funding, resources, and etc.

This chapter will explore the issues related to funding, including 1) a history of funding post *Exxon Valdez*, 2) recommended options for the projected funding post DWH, and 3) recommended Initiatives and proposed process for implementation of projects and funding, including resources worldwide that may be utilized.

HISTORY OF POST-*VALDEZ* FUNDING

It is expected that even at a time when no spill has occurred, there will be continued focus on improved methods for mitigating the effects of an oil spill. This is achieved as a result of industry funding through joint industry projects (JIPs) and through specific governmental innovation programs. It is not the case that no work is done when there is no spill.

The amount of research that has been conducted with respect to oil spill response is quite extensive. The work has been performed by industry, academia, and governmental agencies either independently or as joint industry projects (JIP) and the results have often been incorporated into an updated understanding of how to respond to oil spills as effectively as possible.

Research may be conducted and funded in a variety of ways, including:

- By an individual company
- As a JIP
- Through a trade association
- Led by a government agency coordinating work
- Led by industry with government agencies participating

A sampling of the organizations is given below. For a more complete description of these and specific research programs they have supported, see the following Funding chapter of this document.

Joint Industry Projects

Through JIP, research is conducted constantly in many areas associated with oil spill response. This work continues regardless of whether there is an active spill.

Government Agencies (Federal and State)

- BOEMRE
- Coastal Response Research Center – Established in partnership between NOAA and the University of New Hampshire
- USCG
- EPA
- Texas General Land Office (TGLO)
- Louisiana Oil Spill Research and Development Program

Oil Spill Response Organization (OSRO)

- Alaska Clean Seas (ACS)

International Research Organizations

- France's Centre de documentation, de recherché et d'expérimentations sur les pollutions accidentelles des eaux (CEDRE)
- Norway's SINTEF
- NOFO
- Canada's Centre for Offshore Oil, Gas, and Energy Research

The following sections briefly identify the major post-1990 research and development programs which have been, or are still in existence. Understanding the extensive body of knowledge produced through these programs is a key component of intelligent decisions for future work. In addition, these organizations represent likely key partners in any future research and development efforts.

INDUSTRY

Marine Spill Response Corporation (MSRC)

The industry investment through 20 years of funding of MSRC is just over $1.5 billion. MSRC initial estimates for capital equipment purchases was about US $325 million, annual operating budgets to be approximately US $100 million, and the initial estimate for R&D to remain at US $30-35 million for the five year program. At the end of its five-year program, MSRC eliminated its Research & Development program as its objectives had been achieved. Copies of research results are still available through MSRC and the API.

American Petroleum Institute

Prior to the establishment of the MSRC Research Program, API had an active research program for many years. It still serves as an industry focal point for information sharing and as a primary sponsor of the International Oil Spill Conference, which has taken place either biannually or triennially since 1969. Many papers describing Development and Research performed though Joint Industry Projects, by groups of operators, and by individual operators have been published as part of the International Oil Spill Conference and can be found at: www.iosc.org.

Alaska Clean Seas (ACS)

ACS has maintained an active oil spill Research and Development program since the early 1980's and acts as a facilitator for much of the research and development related to spill response in arctic conditions. The R&D program focuses on specific areas such as oil spill recovery techniques in, on, and under ice and during various broken ice conditions. Other areas of research include viscous oil pumping, methods to detect and track oil under ice, and alternative response options. ACS also manages R&D projects for individual operators to meet the requirements of the Charter for Development of the Alaskan North Slope commitment to the State of Alaska. Over a 10-year period, an average of $200,000 annually was spent on advancing arctic spill response through R&D. More details on specific projects at theACS yearbook http://www.alaskacleanseas.org/adobefiles/2010%20Yearbook_web.pdf

Norwegian Clean Seas Association for Operating Companies

NOFO is an organization for operating companies on the Norwegian continental shelf. NOFO's purpose is to manage and maintain a contingency which comprises personnel, equipment and vessels for responding to acute pollution, and it commands extensive oil spill response resources. These resources, together with governmental and municipal resources, shall reduce environmental damage related to possible oil spills from the petroleum activity. NOFO also conducts or participates in a variety of R&D

projects; one example is the project to identify new equipment for OSR. http://www.nosca.no/userfiles/presentation%20by%20NOFO.pdf

Oil Spill Response Limited (OSRL)

The mission of OSRL is to provide resources to respond to oil spills efficiently and effectively on a global basis. OSRL facilitates the Industry Technical Advisory Committee (ITAC) which provides the oil industry with pragmatic solutions to spill response issues, disseminated through technical papers and an open-access website.

The National Spill Control School at Texas A&M – Corpus Christi

The National Spill Control School was established in 1977 and was named as a consulting, training, and research resource for the National Response Team in the Oil Pollution Act of 1990. The NSCS offers specialized hands-on OSHA mandated training for professionals and workers in the Oil Spill, HAZMAT, and Emergency Management industries as well as others in exploration, production, and transportation who deal with spill prevention, planning, and response. http://www.sci.tamucc.edu/nscs/

JOINT INDUSTRY PROGRAMS

A large number of studies have been conducted by industry through Joint Industry Programs. These include:

- SINTEF JIP on Arctic spill response, http://www.sintef.no/Projectweb/JIP-Oil-In-Ice/
- NewFields JIP on Toxicity and biodegradation rates of dispersed oil in Arctic marine environment,
- SINTEF JIP on Coastal and shoreline response,
- Dispersant Studies,
- IPIECA/OGP JIP,
- PERF (Petroleum Environmental Research Forum) is a research and development joint venture whose members are corporations engaged in the petroleum industry that recognize the importance of a clean, healthy environment and are committed to supporting cooperative research and development. PERF does not itself participate in research projects but provides a forum for members to collect, exchange, and analyze research information relating to practical and theoretical science and technology concerning the petroleum industry, and a mechanism to establish joint research projects in that field. http://www.perf.org/

UNITED STATES GOVERNMENT AGENCIES

Bureau of Ocean Energy Management, Regulation, and Enforcement

BOEMRE is the principal United States federal agency that funds oil spill response research. For more than 25 years, BOEMRE has maintained comprehensive, long-term research programs to improve oil spill response technologies and evaluate the impacts of offshore oil and gas development. The major focus of the Technology Assessment Research (TAR) 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. Through the Environmental Studies Program, BOEMRE has funded over $600 million of research into the marine environments along the Gulf of Mexico, Alaska, Pacific and Atlantic coasts. http://www.boemre.gov/tarphome/

National Oceanic and Atmospheric Administration

The Coastal Response Research Center (CRRC) was established as a partnership between NOAA, through the Office of Response and Restoration, and the University of New Hampshire in 2004. The Center is administered by and located at the UNH campus in Durham, NH. This partnership stimulates innovation in spill preparedness, response, assessment, and implementation of optimum spill recovery strategies. The primary purpose of the Center is to bring together the resources of a research-oriented university and the field expertise of OR&R to conduct and oversee basic and applied research, conduct outreach, and encourage strategic partnerships in spill response, assessment and restoration. http://www.crrc.unh.edu/research.htm

United States Coast Guard

The USCG's Development, Test and Evaluation program enhances acquisition and mission execution by providing applied scientific research, development, testing, and evaluation of new technologies for the maritime environment. The Coast Guard Oil Spill R&D Program for the 1990s was well underway by the time OPA 90 was passed by Congress. OPA 90 added several additional R&D components, including grants, programs for university research, and port demonstration projects to promote technology transfer and public awareness. A detailed report about USCG OSR R&D projects is provided at http://www.environmental-research.com/erc_reports/ERC_report_11.pdf

Environmental Protection Agency

Research is managed through Environmental Protection Agency's (EPA) Land Remediation and Pollution Control Division in EPA's National Risk Management Research Laboratory, Cincinnati, Ohio. EPA's research includes development of practical solutions to mitigate spill impacts on freshwater and marine environments; development of remedial guidelines that address the environment, type of oil (petroleum and non-petroleum oils), and agents for remediation; and modeling fate and effects in the environment. Spill mitigation research includes bioremediation, chemical and physical countermeasures, and human and ecotoxicity effects. Fate and effects research focuses on modeling the transport of oil in a variety of settings with application to field situations. Oil Spill Response Appropriations from 2006-2008 for FY

2006 Actual $ spent totaled $15.9 million; for FY 2007 and FY 2008 (budgeted) of $16.5 million and $17.3 million for program projects.

STATE AGENCIES

Texas General Land Office (TGLO)

On March 28, 1991, The Oil Spill Prevention and Response Act (OSPRA) was adopted and signed into law by the Governor of Texas. OSPRA designated the Texas General Land Office (GLO) to serve as the lead state agency in preventing, and responding to, coastal and marine oil spills. This new legislation placed numerous and varied responsibilities on the Texas GLO, and created the Texas Coastal Protection Fund as the funding mechanism. The fund which is capped at 20 million dollars is financed by a 1.3 cent per barrel tax on all crude oil products that are loaded or offloaded at Texas ports. One of the many innovative and new responsibilities mandated by OSPRA is the formation of a research and development component in the GLO Oil Spill Prevention and Response Division. Section 40.302 of OSPRA establishes the availability of $1.25 million per fiscal year to be dedicated towards research and development activities. The section dictates how and where the research dollars may be spent. The Texas General Land Office has coordinated with other state agencies and private industry to establish viable research projects for oil spill prevention and response. http://www.glo.state.tx.us/oilspill/

Louisiana Oil Spill Coordinator's Office (LOSCO)

The Louisiana Applied and Educational Oil Spill Research and Development Program (OSRADP) is a part of the Louisiana Oil Spill Coordinator's Office, Office of the Governor. The OSRADP's mission is to provide the Oil Spill Coordinator with peer-reviewed, scientifically valid tools. With 64 parishes in Louisiana producing oil and gas, the state provides the (OSRADP) $530,000 annually to develop between 10 to 15 applied science research projects every year. A list of the LOSCO projects is available here http://www.iosc.org/papers/00885.pdf

Alaska Prince William Sound Oil Spill Research Institute (PWS OSRI)

The purpose of the PWS OSRI is to support research, education, and demonstration projects designed to respond to and understand the effects of oil spills in the Arctic and sub-Arctic marine environments. Yearly projects could be found here http://www.pws-osri.org/programs/work_plans.shtml

California Office of Oil Spill Prevention and Response (CA OSPR)

The Scientific Study and Evaluation Program provides a mechanism for investigating, evaluating, and improving applied CA OSPR programs, best achievable technologies, and knowledge of the adverse effects of oil spills in the marine environment. The goals of the program are authorized in Government Code § 8670.12. The program also supports scientific and technical research that will enhance the department's natural resource damage assessments, injury quantification, and restoration capabilities and knowledge base. Total contract dollars encumbered thru FY 07-08: $2.0 million; No. of projects funded thru FY 07-08: 38; No. of projects projected for funding FY 08-09: 8. http://www.dfg.ca.gov/ospr/ .

Alaska Cook Inlet Regional Citizens' Advisory Council (CIRCAC)

OPA 90 directs the Council in its efforts to improved marine transportation and oil facility operations and mandates action to that end. Cook Inlet RCAC provides advice and recommendations on policies, permits and site-specific regulations for terminal and tanker operations and maintenance; monitor environmental impacts of the operation of terminals and tankers; monitor terminals and tanker operations and maintenance that may affect the environment near terminals; review the adequacy of oil-spill prevention and contingency plans for terminals and tankers; provide advice and recommendations on port operations, policies and practices; and review standards for tankers bound for, loading at, or exiting from oil terminals among other duties. http://www.circac.org/joomla/index.php

Alaska Prince William Sound Regional Citizens' Advisory Council (PWSRCAC)

The PWSRCAC is an independent non-profit corporation guided by its mission: citizens promoting environmentally safe operation of the Alyeska Pipeline marine terminal in Valdez and the oil tankers that use it. The council has an ongoing responsibility to sponsor accurate scientific research that monitors the environmental impacts of the Valdez Marine Terminal and tankers. The council regularly retains experts in various fields to conduct independent research on issues related to oil transportation safety. A list of projects can be found at http://www.pwsrcac.org/projects/index.html

INTERNATIONAL

Canada Centre for Offshore Oil, Gas and Energy Research (COOGER)

In November 2002, Fisheries and Oceans Canada (DFO) established COOGER to co-ordinate the department's nation-wide research into the environmental and oceanographic impacts of offshore petroleum exploration, production and transportation. http://www.dfo-mpo.gc.ca/science/coe-cde/cooger-crpgee/index-eng.htm

Canada Environmental Studies Research Funds (ESRF)

ESRF sponsors environmental and social studies designed to assist government decision making related to oil and gas exploration and development on Canada's frontier lands. The ESRF program, initiated in 1983 under the Canada Oil and Gas Act (COGA), now receives its legislated mandate through the superseding legislation, the Canada Petroleum Resources Act (CPRA) proclaimed in February 1987. Funding for the ESRF is provided by industry through levies on exploration and production properties on frontier lands. The ESRF is directed by a joint government / industry / public Management Board and is administered by a secretariat which resides within the National Energy Board in Calgary, Alberta. http://www.esrfunds.org/annrap_e.php

Environment Canada

Since 1970, Environment Canada has had the responsibility to coordinate response for environmental emergencies in Canada, to develop new understandings of how emergencies happen, their effects on Canada's environment, and to develop and test new techniques to protect the environment from their adverse repercussions. The Arctic and Marine Oil spill Program (AMOP) was initiated by Environment Canada in conjunction with many partners to improve capabilities to detect oil in the Arctic, to understand the fate and behavior of oil in ice and to counteract and limit the impacts of oil spills in the Arctic and marine environments. For the past thirty years, AMOP has sponsored and participated in hundreds of individual research projects in each of these fields of research. http://www.ec.gc.ca/default.asp?lang=En&n=FD9B0E51-1

France Centre de documentation, de recherché et d'expérimentations sur les pollutions accidentelles des eaux

CEDRE is a non-profit-making association created on 25 January 1979, as one of the measures taken in the aftermath of the Amoco Cadiz oil spill, to improve spill response preparedness and strengthen the national response organization. It is responsible, on a national level, for documentation, research and experimentation on pollutants, their effects and the response means and tools that can be used to combat them. It is charged with providing advice and expertise to the authorities responsible for responding to accidental pollution. CEDRE manages an annual budget of around 4.5 million euros. It is funded by public bodies (the State and public administrations, local authorities, public establishments, European Union) and private organizations (industry and professional unions) via subsidies or contracts and tenders. Around two thirds of the association's funding is of public origin. Forty percent of the total budget takes the form of a subsidy granted by the French Government, intended to cover CEDRE's public service mission. This subsidy is managed on behalf of the State by the Ministry of Ecology, Energy, Sustainable Development and the Sea. http://www.cedre.fr/index-en.php

Norway SINTEF

The SINTEF Group is the largest independent research organization in Scandinavia. Every year, SINTEF supports Norwegian and overseas companies via research and development activity. Details on Sintef oil spill research program can be found at http://www.sintef.no/Home/Materials-and-Chemistry/Marine-Environmental-Technology/

RECOMMENDATIONS FOR OIL SPILL DEVELOPMENT AND RESEARCH ACTIVITIES POST-DWH

This section discusses how the recommendations for potential new initiatives developed in the individual chapters (i.e. Mechanical Equipment, Dispersants, *In Situ* Burn, Alternative technologies, etc.) as summarized in the attached spreadsheet, will be evaluated. An initial ranking will be assigned for each recommended project, as well as an appropriate funding mechanism and an initial priority, based on the estimated cost of the project and the probability of the work leading to a major increase in knowledge or improvement in technology. Projects and studies also will be categorized as "Development" or "Research". Development would typically include equipment advances or projects that require strong knowledge by OSROs that may be better suited to coordinate that work. Research would typically include projects which are led by scientists looking to develop new methods, products (dispersants, herders, etc.), determine fate and effects, etc.

The available options for funding projects used in this ranking include:

- individual company
- JIP with a company coordinating
- JIP with a trade association coordinating (like API, OGP)
- JIP under an OSRO
- Trade association as part of their budget/dues
- Trade association by contribution of interested operators and other parties
- OSRO as part of their budget
- Led by a government agency coordinating work
- Led by industry with government agencies participating
- JIP organized by a contractor/consultant or academia

RECOMMENDED INITIATIVES AND PROPOSED PROCESS FOR IMPLEMENTATION AND FUNDING

The following spreadsheet is a proposed tool to assist the JITF with decision-making regarding the prioritization and funding of specific projects relating to each of the JITF's Sub Groups.

Criteria for project selection and prioritization:
1. Will demonstratively improve industry's ability to response to a SONS type incident
2. Not duplicative of previous or ongoing work
3. Enhances industry's OSR capabilities, facilitates public acceptance, & overcomes critical hurdle in public perception.
4. Addresses need to provide deliverables in the short-term, while addressing long-term issues.
5. Cost/Benefit – expected
6. Probability of successful outcome
7. Time required to complete project & industry need

Ranking and Project Number	Priority (H, M, L)	Focus Area/Sub Group	Specific Issues	Proposed Projects	Previous Work in this Area	Proposed Organizational "Owner" and Funding Model	Time Horizon (near = initiate < 6 months; long = initiate > 6 months)	Investment Level (Low = < $250K; Medium = $250k-1M; High = > $1M) US $	Comments
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									