OIL POLLUTION RESEARCH AND TECHNOLOGY PLAN

Fiscal Years 2022-2027

INTERAGENCY COORDINATING COMMITTEE ON OIL POLLUTION RESEARCH (ICCOPR)

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DISCLAIMER

This Oil Pollution Research and Technology Plan (OPRTP) presents the collective opinion of the 16 departments and agencies that constitute the members of Interagency Coordinating Committee on Oil Pollution Research (ICCOPR), regarding the status and current focus of the federal oil pollution research, development, and demonstration program (established pursuant to section 7001(c) of the Oil Pollution Act of 1990 (33 U.S.C. 2761(c))). The statements, positions, and research priorities contained in this OPRTP may not necessarily reflect the views or policies of an individual department or agency, including any component of a department or agency that is a member of ICCOPR. This OPRTP does not establish any regulatory requirement or interpretation, nor implies the need to establish a new regulatory requirement or modify an existing regulatory requirement.

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AAAS	American Association for the Advancement of Science
ACER	Alabama Center for Ecological Resilience
ADAC	Arctic Domain Awareness Center
ADDOMEx	Aggregation and Degradation of Dispersants and Oil by Microbial Exopolymers
ADEC	Alaska Department of Environmental Conservation
AESC	Arctic Executive Steering Committee
AIP	Australian Institute of Petroleum
AIS	Automatic Identification System
AMOP	Arctic and Marine Oil Spill Program
AMOSC	Australian Marine Oil Spill Centre
AMSA	Australian Maritime Safety Authority
ANWR	Arctic National Wildlife Refuge
API	American Petroleum Institute
APICOM	Association of Petroleum Industry Co-op Managers
ARTES	Alternative Response Technologies Evaluation System
ASA	American Salvage Association
ASTM	American Society for Testing and Materials
ASV	Autonomous Surface Vehicles
AUV	Autonomous Underwater Vehicles
BAST	Best Available and Safest Technology
bbl (s)	Barrel (equals 42 U.S. Gallons)
BIA	Bureau of Indian Affairs
BIO COOGER	DFO Canada's Bedford Institute of Oceanography Center for Offshore Oil, Gas andEnergy Research
BLM	Bureau of Land Management
BOEM	Bureau of Ocean Energy Management
BP	British Petroleum
Bpd	Barrels per day
BSEE	Bureau of Safety & Environmental Enforcement
C-IMAGE	Center for the Integrated Modeling and Analysis of the Gulf Ecosystem
C-MEDS	Consortium for the Molecular Engineering of Dispersant Systems
CAOSPR	California Office of Spill Prevention and Response
CARMMHA	Consortium for Advanced Research on Marine Mammal Health Assessment
CARTHE	Consortium for Advanced Research on Transport of Hydrocarbon in the Environment
CASP	Center for Arctic Study & Policy
CBD	NRL's Chesapeake Bay Detachment
CCS	Center for Coastal Studies
CDFW	California Department of Fish and Wildlife
CEDRE	Centre of Documentation, Research and Experimentation on Accidental Water Pollution
CEQ	Council on Environmental Quality

CFR	Code of Federal Regulations
CIRCAC	Cook Inlet Regional Citizen's Advisory Committee
CMO	Churchill Marine Observatory
CMR	Center of Excellence for Maritime Research
CONCORDE	Consortium for Oil Spill Exposure Pathways in Coastal River-Dominated Ecosystems
COP	Common Operating Picture
CPF	Coastal Protection Fund
CRADA	Cooperative Research and Development Agreement
CRGC	Consortium for Resilient Gulf Communities
CRRC	Coastal Response Research Center
CRREL	USACE's Cold Regions Research and Engineering Laboratory
CSE	Center for Spills and Environmental Hazards
CSIRO	Commonwealth Scientific and Industrial Research Organization
CSOMIO	Consortium for Simulation of Oil-Microbial Interactions in the Ocean
CWA	Clean Water Act
CWC	Coastal Waters Consortium
DECC	Department of Energy and Climate Change
DEEP-C	Deep Sea to Coast Connectivity in the Eastern Gulf of Mexico Consortium
DEEPEND	Deep Pelagic Nekton Dynamics of the Gulf of Mexico Consortium
DEI	Diversity, Equity, and Inclusion
DEP	Department of Environmental Protection
DFO	Department of Fisheries and Oceans Canada
DHHS	Department of Health and Human Services
USDHS	Department of Homeland Security
USDOE	U.S. Department of Energy
DOI	U.S. Department of the Interior
USDOT	U.S. Department of Transportation
DPP	Disaster Preparedness Program
DRC	Disaster Response Center
DROPPS	Dispersion Research on Oil: Physics and Plankton Studies Consortium
DSD	Dispersant Spray Drift
DWH	*Deepwater Horizon*
EC	European Commission
ECCC	Environment and Climate Change Canada
ECOGIG	Ecosystem Impacts of Oil and Gas Inputs to the Gulf Consortium
EEP	Environmental Emergencies Program
EEZ	Exclusive Economic Zone
EIA	U.S. Energy Information Administration
EMSA	European Maritime Safety Agency
EO	Environmental Observing

USEPA	U.S. Environmental Protection Agency
EPPR	Emergency Prevention, Preparedness and Response Working Group
ERDC	USACE Engineer Research and Development Center
ERRC	European Response Coordination Center
ERT	Environmental Response Team
ERW	Electric Resistance Welded
ESB	Environmental Specimen Bank
ESI	Environmental Sensitivity Index
ESP	BOEM Environmental Studies Program
EU	European Union
FACA	Federal Advisory Committee Act
FMSAS	Florida Marine Spill Analysis System
FEMA	Federal Emergency Management Agency
FIO	Florida Institute of Oceanography
FLRACEP	Florida RESTORE Act Center of Excellence Program
FOSC	Federal-On Scene Coordinator
FOSTERRS	Federal Oil Spill Team for Emergency Response Remote Sensing
FRA	Federal Railroad Administration
FRP	Facility Response Plan
FY	Fiscal Year
GAO	Government Accountability Office
GEBF	NFWF Gulf Environmental Benefit Fund
GIS	Geographic Information Systems
GISR	Gulf of Mexico Integrated Spill Response Consortium
GMFMC	Gulf of Mexico Fishery Management Council
GOMA	Gulf of Mexico Alliance
GoMOSES	Gulf of Mexico Oil Spill and Ecosystem Science
GoMRI	Gulf of Mexico Research Initiative
GOMURC	Gulf of Mexico University Research Collaborative
GRIIDC	Gulf of Mexico Research Initiative Information and Data Cooperative
GRP	National Academy of Sciences Gulf Research Program
GSMFC	Gulf States Marine Fisheries Commission
GuLF Study	Gulf Long-Term Follow-up Study
GW	Gigawatts
HML	Hollings Marine Laboratory
HMTA	Hazardous Materials Transportation Act
HPHT	High Pressure/High Temperature
HRI	Harte Research Institute

HROV	Hybrid ROV
IARPC	Interagency Arctic Research Policy Committee
ICCOPR	Interagency Coordinating Committee on Oil Pollution Research
ICECON	Ice Conditions Index
IISD-ELA	International Institute for Sustainable Development Experimental Lakes Area
ILI	In-Line Inspection
IMO	International Maritime Organization
IOGP	International Association of Oil and Gas Producers
IoNS	Incidents of National Significance
IOOS	Integrated Ocean Observing System
IOSC	International Oil Spill Conference
IOSPP	DOI’s Inland Oil Spill Preparedness Program
IPIECA	International Petroleum Industry Environmental Conservation Association
ISB	*In-situ* Burn
ISCO	International Spill Control Organization
ITAC	Industry Technical Advisory Committee
ITOPF	International Tanker Owners Pollution Federation Limited
IWI	Intentional Wellhead Ignition
JCP	Joint Contingency Plan
JITF	Joint Industry Task Force
JIP	Joint Industry Program
LA-COE	RESTORE Act Center of Excellence for Louisiana
LADC-GEMM	Littoral Acoustic Demonstration Center - Gulf Ecological Monitoring and Modeling Consortium
LEGEEPA	General Law of Ecological Equilibrium and Environmental Protection
LiDAR	Light Detection and Ranging
LNG	Liquefied Natural Gas
LRAUV	Long Range AUV
LSU	Louisiana State University
LTDM	Long Term Data Management
MARAD	Maritime Administration
MARPOL	Marine Pollution (International convention for the Prevention of Pollution from Ships)
MBARI	Monterey Bay Aquarium Research Institute
MBRACE	Mississippi Based RESTORE Act Center of Excellence
MCA	Maritime and Coastguard Agency
MEMAC	Marine Emergency Mutual Aid Center
META	Maritime Environmental and Technical Assistance
MMC	U.S. Marine Mammal Commission
MMPA	Marine Mammal Protection Act
MMS	[former] Minerals Management Service
MOC-A	Marine Operations Center, Atlantic
MOC-P	Marine Operations Center, Pacific
MOC-PI	Marine Operations Center, Pacific Islands

MOSSFA	Marine Oil Snow Sedimentation and Flocculent Accumulation
MPD	Managed Pressure Drilling
MPRI	Multi-Partner Research Initiative
MRS	Marine Rescue Service
MSA	China Maritime Safety Administration
MSL	PNNL Marine Sciences Laboratory
MW	Megawatts
NAS	National Academy of Sciences
NASA	National Aeronautics & Space Administration
NAVSEA	Naval Sea Systems Command
NAWCA	North American Wetlands Conservation Act
NCOE	National Center of Excellence
NCP	National Contingency Plan
NDRF	National Defense Reserve Fleet
NEBA	Net Environmental Benefit Analysis
NEEC	National Environmental Emergencies Center
NEPA	National Environmental Policy Act
NESDIS	NOAA's National Environmental Satellite, Data, and Information Service
NETL	USDOE's National Energy Technology Laboratory
NFWF	National Fish and Wildlife Federation
NGO	Non-governmental Organization
NIEHS	National Institute of Environmental Health Sciences
NIH	National Institutes of Health
NIMS	National Incident Management System
NIST	National Institute of Standards and Technology
NMFS	NOAA's National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOS	NOAA's National Ocean Service
NOSAC	National Offshore Safety Advisory Committee
NOWPAP MERRAC	Marine Environmental Emergency Preparedness and Response RAC of NOWPAP
NPC	National Petroleum Council
NPFC	United States Coast Guard's National Pollution Funds Center
NPS	National Parks Service
NRC	National Response Center
NRDA	Natural Resource Damage Assessment
NRL	U.S. Naval Research Laboratory
NRMRL	U.S. EPA National Risk Management Research Laboratory
NRPT	NOAA Regional Preparedness Trainings
NRT	U.S. National Response Team
NSAR	National Strategy for the Arctic Region
NSAR-IP	National Strategy for the Arctic Region Implementation Plan
NSCS	National Spill Control School
NSF	National Science Foundation
NT	Northern Territory

NTNU	Norwegian University of Science and Technology
NTSB	National Transportation Safety Board
NUI	Nereid Under Ice
NURail	National University Rail (NURail) Center
NWS	NOAA’s National Weather Service
OCS	Outer Continental Shelf
OESI	Ocean Energy Safety Institute
OG21	Oil and Gas for the 21st Century
OMAO	NOAA's Office of Marine and Aviation Operations
OPA 90	Oil Pollution Act of 1990
OPRTP	Oil Pollution Research & Technology Plan
OR&R	NOAA’s Office of Response & Restoration
ORSEC MARITIME	Organisation de la Réponse de SÉcurité Civile
OSATF	Oil Spill Academic Task Force
OSC	On Scene Coordinator
OSHA	Occupational Safety & Health Administration
OSIM	Ocean-Sea Ice Mesocosm
OSLTF	Oil Spill Liability Trust Fund
OSMRE	Office of Surface Mining and Reclamation and Enforcement
OSR	Oil Spill Response
OSRI	Oil Spill Recovery Institute
OSRO	Oil Spill Response Organization
OSP	Oil Sands Products
OSPR	Oil Spill Preparedness and Response
OSPD	BSEE’s Oil Spill Preparedness Division
OSV	Ocean Survey Vessel
OSWG	Oil Spill Working Group
PAH	Polycyclic Aromatic Hydrocarbons
PCT	Pew Charitable Trusts
PDARP	Programmatic Damage Assessment and Restoration Plan
PEIS	Programmatic Environmental Impact Statement
PEMEX	Petróleos Mexicanos
PEMSEA	Partnerships in Environmental Management for the Seas of East Asia
PERF	Petroleum Environmental Research Forum
PERSGA/MEMAC	PERSGA Marine Emergency Mutual Aide Center
PHMSA	Pipeline & Hazardous Materials Safety Administration
P.L.	Public Law
PLET	Pipeline End Termination
PNNL	Pacific Northwest National Laboratory
PRCI	Pipeline Research Council International
PROMAM	Navy’s Marine Environment Protection Division
PSBCOSTF	Pacific States/British Columbia Oil Spill Task Force
PSC	Polar Security Cutter
PWS	Prince William Sound
PWSRCAC	Prince William Sound Regional Citizen’s Advisory Committee
RAC	Regional Activity Center
RAPID	Rapid Response Research

RAR	Resources at Risk
RB&P	Regions, Budget, and Policy
RDC	USCG Research & Development Center
RDT&E	USCG Research, Development, Test, and Evaluation
R&D	Research & Development
R&T	Research & Technology
RECOVER	Relationships of Effects of Cardiac Outcomes in Fish for Validation of Ecological Risk Consortium
REMPEC	Regional Marine Pollution Emergency Response Center for the Mediterranean Sea
REMPEITC-Caribe	Regional Marine Pollution Emergency Information and Training Center for the Wider Caribbean
REMUS	Remote Environmental Monitoring Unit
RESTORE	Resources and Ecosystem Sustainability, Tourist Opportunities, and Revived Economies of the Gulf Coast States Act
RFP	Request for Proposal
ROPME	Regional Organization for the Protection of the Marine Environment
ROV	Remotely Operated Vehicle
ROW	Right of Way
RRS	Rapid Response Solution
RRT	Regional Response Team
RSPA	[former] Research and Special Projects Administration
RV	Research Vessel
S&L	GoMRI Synthesis and Legacy
S&T	Science and Technology
SCAA	Spill Control Association of America
SCAT	Shoreline Cleanup Assessment Technique
SETAC	Society of Environmental Toxicology and Chemistry
SIO	Scripps Institution of Oceanography
SIT	Stevens Institute of Technology
SMART	Special Monitoring of Applied Response Technologies
SME	Subject Matter Expert
SONS	Spill of National Significance
SPCC	Spill Prevention, Control & Countermeasures
SRA	Standing Research Area
SRM	Standard Reference Materials
SSC	NOAA Scientific Support Coordinator
SSI	Subsea Systems Institute
STEM	Science, Technology, Engineering, and Mathematics
SUPSALV	NAVSEA Supervisor of Salvage and Diving
TAP	Trajectory Analysis Planner
TC	TransCanada
TDC	Technology Development Center
TEES	Texas A&M Engineering Experiment Station
TXGLO	Texas General Land Office
UAA	University of Alaska Anchorage
UAS	Unmanned Aerial Systems
UIUC	University of Illinois Urbana-Champaign

UNEP	United Nations Environment Program
UK	United Kingdom
UNH	University of New Hampshire
USACE	United States Army Corps of Engineers
USARC	United States Arctic Research Commission
USBR	U.S. Bureau of Reclamation
USCG	United States Coast Guard
USCGA	United States Coast Guard Academy
USDA	United States Department of Agriculture
USGS	United States Geological Survey
USFA	United States Fire Administration
USFWS	United States Fish and Wildlife Service
USV	Unmanned Surface Vehicle
UTC	University Transportation Center
VOC	Volatile Organic Compound
WADOE	Washington Department of Ecology
WHOI	Woods Hole Oceanographic Institution
WWF	World Wildlife Foundation

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DEFINITIONS

ICCOPR uses the following definitions solely for purposes of this Oil Pollution Research and Technology Plan (OPRTP). These definitions do not reflect all existing/relevant statutory and/or regulatory definitions and do not supersede any statutory or regulatory requirements.

Allision is the running of one vessel against another vessel or structure that is stationary. An allision is different from a collision in that a collision is the running of two moving vessels against each other.

Applied Research is any systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met, in this case related to advancing knowledge about oil spill prevention, preparedness, response, mitigation, and restoration/recovery.

Basic Research is any systematic study directed toward fuller knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications towards processes or products in mind.

Baseline Study refers to studies conducted to gather a set of critical observations or datathat provide a basis for comparing conditions before and after an action or event.Baseline studies document the ecological and socioeconomic conditions of an area before an oil system activity or potential spill occurs. These studies provide a basis for assessing changes or damages that occur as a result of the activities ora spill.

Collision means the running of two vessels against each other (both under power). A collision is different from an allision where only a single vessel is underway and strikes a stationary vessel or structure.

Damages means injury to natural resources, to real or personal property, loss of subsistence use of natural resources, loss of governmental revenues, loss of profits or earning capacity, and increased cost of additional public services. Damages also include the cost of assessing these injuries. Removal costs and damages covered by OPA 90 are defined in 33 U.S.C § 2702(b)(2).

Demonstration refers to activities that are part of research or development (i.e., that are intended to prove or to test whether a technology or method does, in fact, work). Demonstrations intended primarily to make information available about new technologies or methods should not be included in this definition (NSF, 2009).

Development is any systematic application of knowledge or understanding, directed toward the production of useful materials, devices, and systems or methods, including design, development, and improvement of prototypes and new processes to meet specific requirements.

Discharge means any emission (other than natural seepage), intentional or unintentional, and includes, but is not limited to spilling, leaking, pumping, pouring, emitting, ordumping of oil that is not permitted.

Dispersants means those chemical agents that emulsify, disperse, or solubilize oil into the water column or promote the surface spreading of oil slicks to facilitate dispersal of the oil into the water column

Facility means any structure, group of structures, equipment, or device (other than a vessel) that is used for one or more of the following purposes: exploring for, drilling for, producing, storing, handling, transferring, processing, or transporting oil. This term includes any motor vehicle, rolling stock, or pipeline used for one or more of these purposes. The OPA 90 definition of a facility is codified at 33 U.S.C § 2702(b)(2).

National Contingency Plan refers to the National Oil and Hazardous Substances Pollution Contingency Plan (40 CFR Part 300), the federal government's blueprint for responding to both oil spills and hazardous substance releases. The NCP is the result of efforts to develop a national response capability and promote coordination among the hierarchy of responders and contingency plans.

Natural Resource Damage Assessment (or assessment) means the process of collecting and analyzing information to evaluate the nature and extent of injuries resulting from an incident and determine the restoration actions needed to bring injured natural resources and services back to baseline and make the environment and public whole for interim losses.

Natural Resources, for purposes of injury assessment and restoration, refers to land, fish, wildlife, biota, air, water, ground water, drinking water supplies, and other such resources belonging to, managed by, held in trust by, appertaining to, or otherwise controlled by the United States (including the resources of the exclusive economic zone), any State or local government or Indian tribe, or any foreign government. Natural resources, for other purposes, may include minerals such as oil and gas.

Oil refers to oil of any kind or in any form, including, but not limited to, petroleum, fuel oil, sludge, oil refuse, and oil mixed with wastes other than dredged spoil. It may also refer to: fats, oils, or greases of animal, fish, or marine mammal origin; vegetable oils, including oils from seeds, nuts, fruits, or kernels; and, other oilsand greases, including synthetic and mineral oils. The Clean Water Act (CWA) definition of oil is codified at 33 U.S.C. § 1251 *et seq*.; the OPA definition of oil is codified at 33 U.S.C. § 2701 *et seq*.

The ***Oil Pollution Act of 1990*** (OPA 90), codified at 33 U.S.C § 2701 *et seq.*, is a law that amended the CWA and addressed the wide range of problems associated with preventing, responding to, and paying for oil pollution incidents in navigable waters of the United States. Title VII of OPA 90 established ICCOPR.

An ***Oil Spill*** is a non-permitted occurrence or series of occurrences having the same origin, involving one or more vessels, facilities, or any combination thereof, resulting in the discharge or substantial threat of discharge of oil into or upon navigable waters of the United States, adjoining shorelines, or the exclusive economic zone (e.g., oil spill in coastal waters from a tanker). This term also includes discharges of oil on land with the potential to reach any waters of the United States.

Oil Spill Response Organizations (OSROs) are companies that specialize in cleaning up oil spills. They often serve as contractors or subcontractors for spill response efforts.

An ***On-Scene Coordinator*** (OSC) is the federal official pre-designated by EPA or the USCG to coordinate and direct responses under Subpart D of the NCP. It also refers to a designated representative of a lead Federal agency to coordinate and direct removal actions under Subpart E of the NCP. General responsibilities of OSCs are found in 40 CFR 300.120. OSCs are sometimes referred to as Federal On-Scene Coordinators (FOSCs).

Preparedness is an activity, program, or system developed prior to an oil spill to support and enhance the ability of personnel and organizations to prevent, respond to, and recover from an oil spill or other adverse event.

Prevention is an on-going activity to minimize the likelihood of discharges of oil into the environment. Prevention may be a long-term approach to looking at the fundamentals of minimizing the potential of oil spills with the goal to identify, minimize, and mitigate risks.

Release means any spilling, leaking, pumping, pouring, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of oil into the environment.

Research is the systematic study directed toward fuller scientific knowledge or understanding of the subject studied. (NSF, 2009)

Response includes all activities involved in containing and cleaning up oil to: 1: maintain safety of human life; 2: stabilize a situation to preclude it from worsening, and; 3: minimize adverse environmental and socioeconomic impacts by coordinating all containment and removal activities to carry out a timely, effective response.

Restoration is the process of restoring an affected area or resource to its pre-incident state. Restoration can take several months to many years and may require technical and financial assistance from a variety of sources. Restoration efforts are primarily concerned with actions that involve rebuilding destroyed property, re-employment of effected stakeholders, rehabilitating, replacing, or acquiring the equivalent of injured natural resources and the services they provided prior to the damage being inflicted and the repair of other essential infrastructure.

Submerged and subsurface oil refers to oil that is not floating on the water surface.

Surface Washing Agent is any product that removes oil from solid surfaces, such as beaches and rocks, through a detergency mechanism and does not involve dispersing or solubilizing the oil into the water column.

Technology is the study, development, and application of devices, machines, and techniques for manufacturing and productive processes. Technology also includes tools, equipment, and methods or methodologies that apply scientific knowledge or tools. For purposes of this plan, technology represents the application of knowledge or widgets to the development and/or usage of equipment, systems and organizational capabilities for oil spill prevention, preparedness, response, and restoration.

Vessel means every description of watercraft or other artificial contrivance used, or capable of being used, as a means of transportation on water.

EXECUTIVE SUMMARY

Title VII of the Oil Pollution Act of 1990 (OPA 90) established the Interagency Coordinating Committee on Oil Pollution Research (ICCOPR) to coordinate a comprehensive program of oil pollution research, technology development, and demonstration. Pursuant to Section 7001(b) of OPA 90, ICCOPR developed the Oil Pollution Research and Technology Plan (OPRTP) to implement the Federal research and development program.

ICCOPR published its first version of the OPRTP in 1992 and published a revised version in 1997. These two versions provided an initial baseline assessment and analysis of: agency roles and responsibilities; status of knowledge of oil pollution prevention, response, and mitigation technologies; priority research and development needs; and an estimate of resources and time needed to implement the program.

The purpose of the FY 2015-2021 version of the OPRTP, and subsequent revisions, is to provide current assessments of the oil pollution research needs and priorities. ICCOPR intends to update this OPRTP every six years to reflect advancements in oil pollution technology and changing research needs. This ongoing planning process will capitalize on the unique roles and responsibilities of member agencies to address oil pollution research and development needs and maintain awareness of research needs.

The OPRTP includes two parts. Part One, Oil Pollution Research, explains why oil pollution research is needed, the parties that are involved in the research, and presents ICCOPR's Oil Pollution Research Categorization Framework used for organizing the priority Research Needs. Part Two, Establishing Research Priorities, presents ICCOPR's priority Research Needs. It also explains the process that ICCOPR used to identify the research gaps and priorities, noteworthy oil spill events, and the current state of oil pollution knowledge. In future versions, Part One will remain relatively static; however, Part Two is expected to change significantly as research advances the state of knowledge and priority Research Needs are successfully addressed.

The **Introduction** and **Chapter 1, The Need for Oil Pollution Research**, describes the historical basis for oil pollution research and reviews trends in oil spills from different sources. ICCOPR member agencies share responsibilities to monitor changes in the oil spill system and find opportunities to improve technologies to meet changing needs. ICCOPR recognizes that activities in the: Arctic and Alaska; Inland Rivers and Laurentian Great Lakes; Gulf of Mexico, Atlantic, and Pacific Outer Continental Shelf (OCS) are all of high importance at this time.

Chapter 2, Federal Oil Pollution Research, describes the Federal entities involved in oil pollution research including the ICCOPR member agencies, other Federal research organizations and facilities. Similarly, **Chapter 3, Non-Federal Oil Pollution Research Entities**, describes state, industry, tribal, independent organizations, academia, and international oil pollution research entities.

Chapter 4, Structuring Oil Pollution Research, presents ICCOPR's Oil Pollution Research Categorization Framework, which provides a common language and planning regime that would enable researchers and interested parties to identify and track research in each topic area. The Framework groups research into four broad Classes: Prevention, Preparedness, Response, and Injury Assessment and Restoration. ICCOPR further classified research within each Class into Standing Research Areas (SRAs), which represent the most common research themes encountered for spills.

Chapter 5, Knowledge Transfer and Advancement, describes ICCOPR's efforts to promote continuous improvement in the nation's ability to address oil pollution by monitoring the state of knowledge and adjusting the program to meet changing needs. The OPRTP planning process emphasizes and strengthens the roles and responsibilities of the member agencies to assure that research advances the capabilities to reduce oil pollution.

Chapter 6, Oil Pollution Research Needs Identification and Prioritization Process, documents the process ICCOPR employed to establish the research priorities. ICCOPR established an R&T Working Group that identified more than 2,350 research gaps, consolidated them into 737 unique Research Needs, and evaluated them with the assistance of the results from a survey of 410 subject matter experts.

Chapter 7, Assessment of Oil Spill Technologies and Noteworthy Oil Spills, includes a summary of the different classes of oil and research on prevention, response, and mitigation technologies. This chapter also describes important oil spill events and lists the oil pollution research gaps that they illuminated. Spills associated with vessels, drilling operations, onshore pipelines, and facilities are included.

Chapter 8, Current State of Oil Pollution Knowledge, describes the sources and mechanisms that ICCOPR uses to obtain and share information on research needs and accomplishments.

Chapter 9, Oil Spill Research and Technology Research Priorities, presents ICCOPR's priority Research Needs. ICCOPR identified three top priorities for each SRA. For SRAs with many Research Needs (i.e., Dispersants), ICCOPR established subcategories of similar research. Three priority Research Needs were assigned to each subcategory. Below is a list of the SRAs and Subcategories for each Research Class.

PREVENTION (10000 Series)	
SRA	**Subcategory (s)**
Human Error Factors	
Offshore Facilities and Systems	Met-Ocean Effects; Surface Systems and Umbilicals
Onshore Facilities and Systems	Tank/Piping Inspection, Operations, Design and Data; Emerging Issues
Waterways Management	
Vessel Design	
Drilling	Deepwater Drilling/Technology; Reservoir Characterization
Rail and Truck Transportation	
Pipeline Systems	Threat/Damage Prevention; Leak Detection; Anomaly Detection/Characterization
Geohazards	Monitoring; Identification & Characterization
Subsea Systems Automation and Reliability	
PREPAREDNESS (20000 Series)	
SRA	**Subcategory (s)**
Pre-Spill Baseline Studies	Habitats and Species Baselines; Oceanographic/Geologic Baselines; Environmental Baseline Planning
Response Management Systems	
Renewable Energy Systems	
RESPONSE (30000 Series)	
SRA	**Subcategory (s)**
Structural Damage Assessment and Salvage	
At Source Control and Containment	
Chemical and Physical Modeling and Behavior	Arctic Behavior and Modeling; Oil Behavior Models; Transport Models; Oceanographic Models; Emerging Crude; Sinking Oil and Marine Oil Snow (MOS) Sedimentation and Flocculent Accumulation (MOSSFA)
Oil Spill Detection and Surveillance	Remote Detection; Monitoring; Submerged Oil Detection
In- and On-water Containment and Recovery	Control and Recovery Technology; Recovery Operations and Testing
Shore Containment and Recovery	
Dispersants	Cold Water and Ice Conditions; Behavior; Environmental Effects; Efficacy and Effectiveness; Fate; Subsurface
In-situ Burning	Effectiveness and Impacts; Planning and Technology
Alternative Countermeasures	
Oily and Oil Waste Disposal	
Bioremediation	

INJURY ASSESSMENT AND RESTORATION (40000 Series)	
SRA	**Subcategory (s)**
Environmental Effects and Ecosystem Recovery	Species Impacts; Toxicological and Sublethal Impacts; Sunken and Submerged Oil Impacts; Ecosystem and Habitat Impacts; Recovery; Risk Assessment and Impact Metrics
Environmental Restoration Methods and Technologies	
Human Safety and Health	Safety; Human Exposure
Sociological and Economic Effects	Community and Economic Impacts; Human Impacts

INTRODUCTION

Title VII of the Oil Pollution Act of 1990 (OPA 90) established the Interagency Coordinating Committee on Oil Pollution Research (ICCOPR) to "… coordinate a comprehensive program of oil pollution research, technology development, and demonstration among the federal agencies, in cooperation and coordination with industry, universities, research institutions, State governments, and other nations, as appropriate, and shall foster cost-effective research mechanisms, including the joint funding of research." Section 7001(c) of OPA 90 required ICCOPR to establish a federal oil pollution research and development (R&D) program. Pursuant to Section 7001(b) of OPA 90, ICCOPR developed the Oil Pollution Research and Technology Plan (OPRTP) to implement the federal research and development program.

Background

Federal oil pollution research efforts began to take shape in the late 1960s following the *Torrey Canyon* oil spill off the coast of England (Figure 1-1). At that time, the U.S. had neither the technical nor operational capacity to address a large oil spill in the marine environment. The federal government developed the first National Contingency Plan (FWPCA, 1968) to formalize the response and management to oil spills and began extensive oil pollution research over the next 20 years. Coordination of the federal research efforts was informal and on an ad hoc basis through conferences, workshops, and committees of researchers scheduling their projects at the National Oil and Hazardous Materials Simulated Environmental Test Tank (Ohmsett) facility. Nearly 30 years after the Torrey Canyon incident, the challenges posed by the response to the *Exxon Valdez* oil spill in 1989 continued to reveal the need for federal agencies to better coordinate their research. This need resulted in Title VII of OPA 90 establishing ICCOPR and creating the requirement for a comprehensive and coordinated research and technology plan.

ICCOPR submitted the original OPRTP to Congress in April 1992. As directed by OPA 90, ICCOPR provided the OPRTP to the National Research Council's Committee on Oil Spill Research and Development for review. Using input from the Councils Marine Board, ICCOPR started a revision of the plan to include topics related to spill prevention, human factors, and the field testing/demonstration of developed response technologies, ICCOPR released revised versions in 1997 and 2015.

Figure 1- 1 Torrey Canyon oil spill in 1967 (Source: ITOPF, 2017)

As set forth in the 2015 plan, this 2022 updated plan will cover a six-year planning cycle (2022-2027). This ongoing planning process will capitalize on the unique roles and responsibilities of member agencies to address oil pollution research and development needs.

The OPRTP includes two parts. Part One, Oil Pollution Research, explains why oil pollution research is needed, the parties that are involved in the research, and presents ICCOPR's Oil Pollution Research Categorization Framework used for organizing the priority Research Needs. Part Two, Establishing Research Priorities, presents ICCOPR's priority Research Needs. It also explains the process that ICCOPR used to identify the research gaps and priorities, noteworthy oil spill events, and the current state of oil pollution knowledge. In future versions, Part One will remain relatively static; however, Part Two is expected to change significantly as research advances the state of knowledge and priority Research Needs are successfully addressed.

Purpose of the Plan

The 1992 version of the OPRTP provided Congress with an implementation plan for the new research and development program established by OPA 90. The 1992 Plan, and the 1997 revisions, provided an initial baseline assessment and analysis of: agency roles and responsibilities; status of knowledge of oil pollution prevention, response, and mitigation technologies; priority research and development needs; and an estimate of resources and time needed to implement the program. The purpose of the fiscal year (FY) 2015-2021 version was to provide an updated assessment of the oil pollution research needs and priorities to establish a new baseline for the new series of OPRTPs. The FY 2022-2027 version updates the FY 2015-2021 OPRTP to provide a current assessment of the oil pollution research needs and priorities. As stated in the Elijah E. Cummings Coast Guard Authorization Act of 2020, the requirements of this OPRTP are to:

1. Identify "current research programs conducted by Federal agencies, States, Indian tribes, 4-year institutions of higher education, and corporate entities;"
2. Assess "the current status of knowledge on oil pollution prevention, response, and mitigation technologies and effects of oil pollution on the environment;"
3. Identify "significant oil pollution research gaps, including an assessment of major technological deficiencies in responses to past oil discharges;"
4. Establish "national research priorities and goals for oil pollution technology development related to prevention, response, mitigation, and environmental effects;"
5. Assess "the research on the applicability and effectiveness of the prevention, response, and mitigation technologies to each class of oil;"

6. Estimate “the resources needed to conduct the oil pollution research and development program established pursuant to subsection (e), and timetables for completing research tasks;”
7. Summarize “research on response equipment in varying environmental conditions, such as in currents, ice cover, and ice floes;” and
8. Include “other information or recommendations as the Interagency Committee determines to be appropriate.”

Scope and Use of the Plan

This OPRTP provides a basis for coordinating research to address oil pollution issues in the United States (U.S.). It is primarily directed at federal agencies with responsibilities for conducting or funding oil pollution research but can serve as a research planning guide for industry, academia, state governments, research institutions, and other nations.

Research, in the context of the OPRTP, includes both basic and applied developmental studies that are considered as peer-reviewed and published, as well as studies reported in the “grey literature,” which is publicly available scientific literature that has not been peer-reviewed. The following National Science Foundation definitions apply with respect to the OPRTP:

Basic research is any systematic study directed toward fuller knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications towards processes or products in mind.

Applied research is any systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met. ICCOPR interprets this to mean studies to advance knowledge about oil spill prevention, preparedness, response, mitigation, and restoration/recovery.

Development is any systematic application of knowledge or understanding, directed toward the production of useful materials, devices, and systems or methods, including design, development, and improvement of prototypes and new processes to meet specific requirements.

Technology is defined as making, usage, and knowledge of tools, machines, techniques, crafts, systems, or methods of organization in order to solve a problem or perform a specific function. ICCOPR believes this definition represents the application of knowledge as well as the development and usage of the equipment, systems and organizational capabilities concerning oil spill prevention, preparedness, response, mitigation, and restoration/recovery.

At the federal level, this OPRTP provides information that can be used as a basis to conduct interagency coordination and track progress toward addressing the nation's research needs. It can also help federal agencies identify high-priority research emphasis areas and promote needed research based on priorities.

Additionally, ICCOPR recognizes that there are many valuable oil pollution research programs conducted by non-federal organizations and the private sector. It is ICCOPR's hope that these entities will consider the research needs outlined in this plan to help address the nation's oil pollution research priorities.

PART ONE – OIL POLLUTION RESEARCH

1. The Need for Oil Pollution Research

Oil is a dominant source of energy in the U.S., supplying the nation with approximately 37% of its energy needs (EIA, 2020a). Oil provides fuel for the transportation, industrial, and residential sectors and serves as a primary feedstock for making plastics. Oil is expected to remain a major source of energy in the U.S. for at least the next decade (EIA, 2021). With historical, current, and projected use and constant movement of oil, it is inevitable that spills will occur.

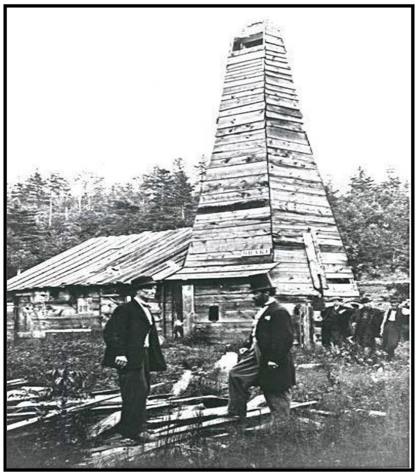


Figure 1- 2 The start of the commercial oil industry in the U.S. – Oil Creek, PA, 1859 (Source: Drake Wells Museum)

Spills of oil in the U.S. accompanied the inception of early commercial efforts for petroleum drilling in the early 19th century in the U.S. and continue to this day. The first oil discovery was on land at Oil Creek, PA in 1859 by George Bissel and Edwin Drake (Figure 1-2) (Pees, 2004). This success quickly led to additional commercial investments in oil drilling refining and marketing in the western Appalachian Mountains, where oil seeps were common. Commercial drilling projects rapidly spread to include areas in Southern California, Kansas, Oklahoma, Arkansas, Louisiana, and Texas by the late 1890s.

In 1910, the largest onshore blowout in the U.S. and the world occurred at the Lakeview No. 1 well in the San Joaquin Valley, CA (Figure 1-3). The initial flow estimates ranged from 125,000 barrels per day (bpd) at the start to 90,000 bpd after one month. The well remained uncontrolled for 544 days with an estimated 9.4 million barrels (bbl) of crude released into the environment (one bbl = 42 U.S. gallons).

Figure 1- 3 The Lakeview Gusher, CA; the U.S.'s single largest well blowout, 1910 (Source: San Joaquin Valley Geology)

Oil spills continued to occur, but it was not until the late 1960s that the national attention focused on the need to address the problems associated with them. In 1967, reaction in the U.S. to the *Torrey Canyon* oil spill off the coast of England resulted in the creation of the National Multiagency Oil and Hazardous Materials Contingency Plan in 1968 (FWPCA, 1968).

That Plan was superseded in 1970 when the Council on Environmental Quality (CEQ) published the National Oil and Hazardous Materials Pollution Contingency Plan in the Federal Register at 35 FR 8508 (CEQ, 1970).

In 1969, a well blowout and undersea faults spilled an estimated 42 million gallons of oil into the Santa Barbara Channel, one of the largest environmental disasters in the U.S. (NOAA, 2014). This spill further increased awareness of oil pollution problems and contributed to creation of the U.S. Environmental Protection Agency (USEPA), passage of the National Environmental Policy Act (NEPA), and establishment of the National Marine Sanctuaries System. It also prompted several federal agencies to begin oil pollution research programs.

Oil pollution research must continually evolve to keep pace with new oil spill risks and the environments where they occur. The process by which oil is produced, processed, and delivered to consumers is ever evolving. As technological advances make oil ventures more profitable, the oil industry seeks new areas for oil exploration and production. In turn, the transportation methods used to deliver that oil shift, affecting the location and magnitude of future oil spills. The technological advances that allow deep water oil exploration and production also pose new hazards and risks as evidenced by the British Petroleum (BP) *Deepwater Horizon* oil spill in 2010. This incident, and others such as the *Exxon Valdez* oil spill, posed response challenges and revealed the need for additional oil pollution research.

There will be a need for oil pollution research as long as there is a demand for oil-based products. Human errors, mechanical failures, natural events, and accidents all have the potential to cause spills. This chapter examines the oil production system and patterns of oil spills that affect the oil pollution research needs addressed in this OPRTP.

1.1 U.S. Oil Production

The U.S. Energy Information Administration (EIA) reviewed the production, import, and consumption of petroleum and other liquids for the last 70 years from 1949 to 2019 (Figure 1-4). Beginning in 1970, the U.S experienced a steadily growing consumption rate that outstripped the U.S. petroleum production capabilities, resulting in an increase in net imports of petroleum products to address this shortfall (EIA, 2020b). In 1975, the Energy Policy and Conservation Act banned almost all exports of domestic U.S. crude oil. This was not considered a significant policy issue because U.S. crude oil production continued to decline. However, in almost every year since 2008, the annual oil production in the U.S. has increased, with the highest production levels occurring in 2019 (EIA, 2020b). Due to the increase in U.S. oil production, Congress repealed the Energy Policy and Conservation Act in 2015, allowing the free export of U.S. crude oil worldwide.

There was a large decrease in U.S. energy consumption in 2020 from an economic downturn that was in large part due to the COVID-19 pandemic. Energy demand for four U.S. end-use sectors (residential, commercial, transportation, and industrial) decreased to 90% of its 2019 level (EIA, 2021). The COVID-19-related energy demand decline was about 70% larger compared to the U.S. financial crisis in 2008 (EIA, 2021). Initially, oil production remained constant as demand decreased, leading to a surplus of oil at storage facilities. Consequently, crude oil prices dwindled along with other petroleum product prices, specifically gasoline. According to the U.S. Bureau of Labor Statistics, the producer prices for crude petroleum fell 71% from January to April 2020 (Camp, 2020). According to the EIA Annual Energy Outlook 2021, a return to 2019 (pre-pandemic) U.S. energy consumption remains highly uncertain (EIA, 2021).

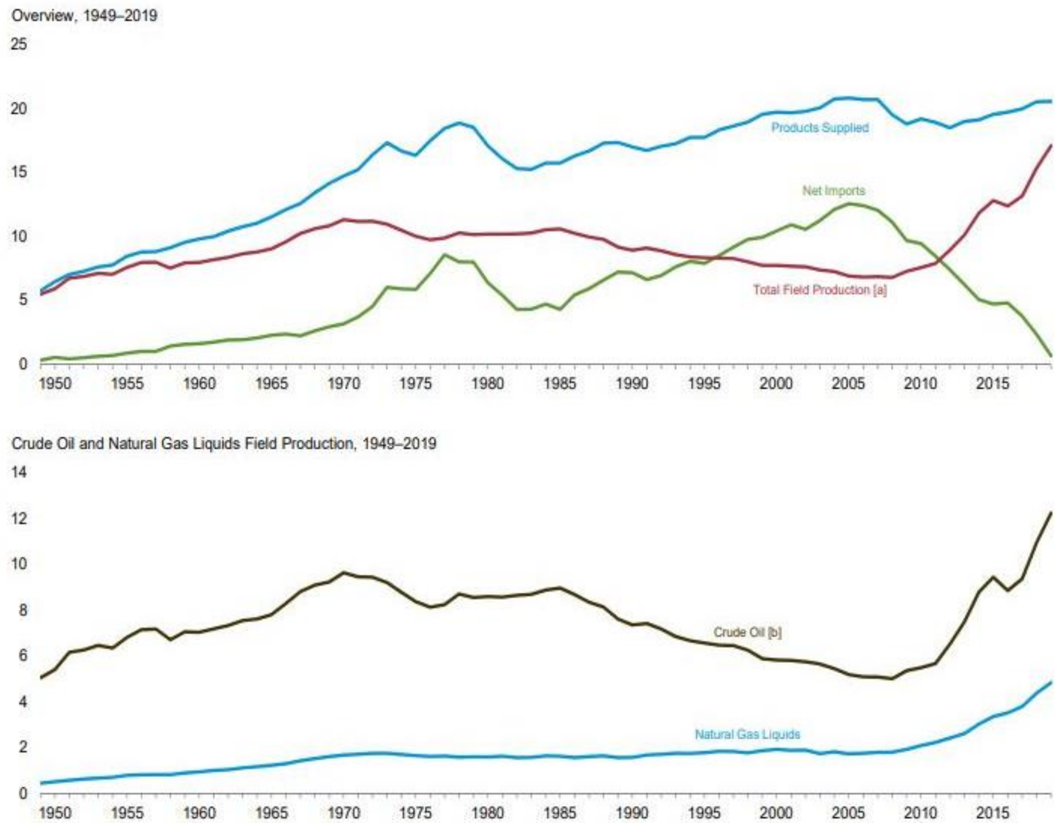


Figure 1- 4 Petroleum and other Liquid Estimated Consumption, Production and Net Imports (in million bpd) for 1949 - 2019 in the U.S. (Source: EIA, 2020b)

Of particular importance to the domestic production of oil was the discovery of the Bakken shale play in North Dakota and Montana (Figure 1-5). Shale plays are areas that have similar geological characteristics (e.g., basins, geologic depressions) that contain significant accumulations of oil or natural gas resources. Since 2000, Bakken production has steadily increased due to the application of hydraulic fracturing and horizontal drilling technologies. The Barnett Shale in Texas has been producing natural gas for more than two decades. Information gained from developing the Barnett Shale provided the initial technology template for developing other shale plays in the United States. Another important shale gas play is the Marcellus Shale in the eastern United States. While the Barnett and Marcellus formations are well-known shale gas plays in the U.S., more than 30 states overlie shale formations (Figure 1-5). The Marcellus natural gas play, which encompasses 104,000 square miles and stretches across Pennsylvania, West Virginia, and into southeast Ohio and upstate New York, is the largest source of natural gas in the United States.

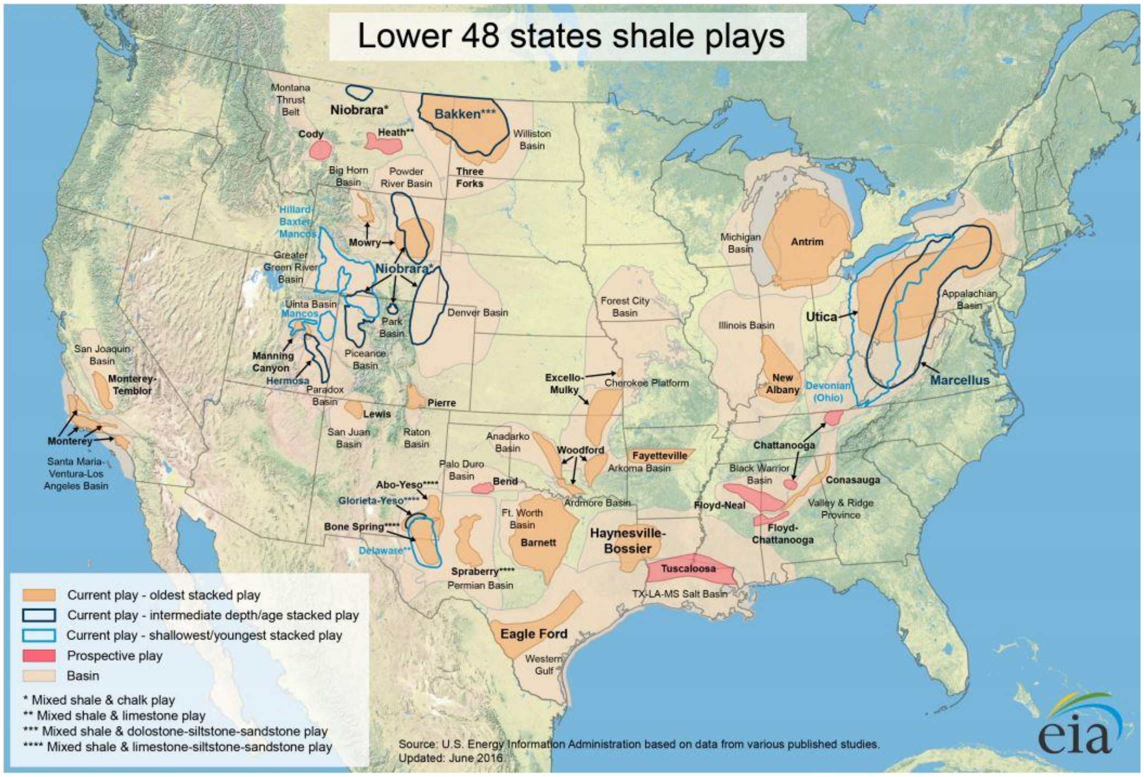


Figure 1- 5 U.S. domestic shale gas plays (Source: EIA, 2016)

The U.S. uses tank vessel (ship and barge), pipeline (offshore and onshore), tank railcar (unit trains), and tanker trucks to transport oil from wells to refineries, and refined products to consumers (Figure 1-6). The U.S. has over 200,000 miles of pipelines in place to transport crude oil, refined products, and natural gas liquids (Allison & Mandeler, 2018). From 2014 to 2017, the U.S. saw a 64% decrease in the amount of crude oil that was transported by rail (Allison & Mandeler, 2018). This decline was due to the construction of new oil pipelines and fewer oil shipments from the Midwest to the other parts of the country where the refinery capacity exists. The most versatile form of transportation is trucks, since they do not rely on pipelines, railways, or navigable waterways. However, trucks are not as energy efficient as other transportation methods and therefore are typically only used for short-distance travel. Tank vessels are used to transport oil through bodies of water. Barge usage increased during the development of the Bakken Shale as oil could be shipped south from the Midwest by river to refineries along the Gulf Coast. Inland water transportation, such as barges, use about 75% less energy than trucks and 25% less energy than rail, but rely on navigable rivers that are close to the source and destination (Allison & Mandeler, 2018). Tankers are typically used for seaborne oil trade over long distances.

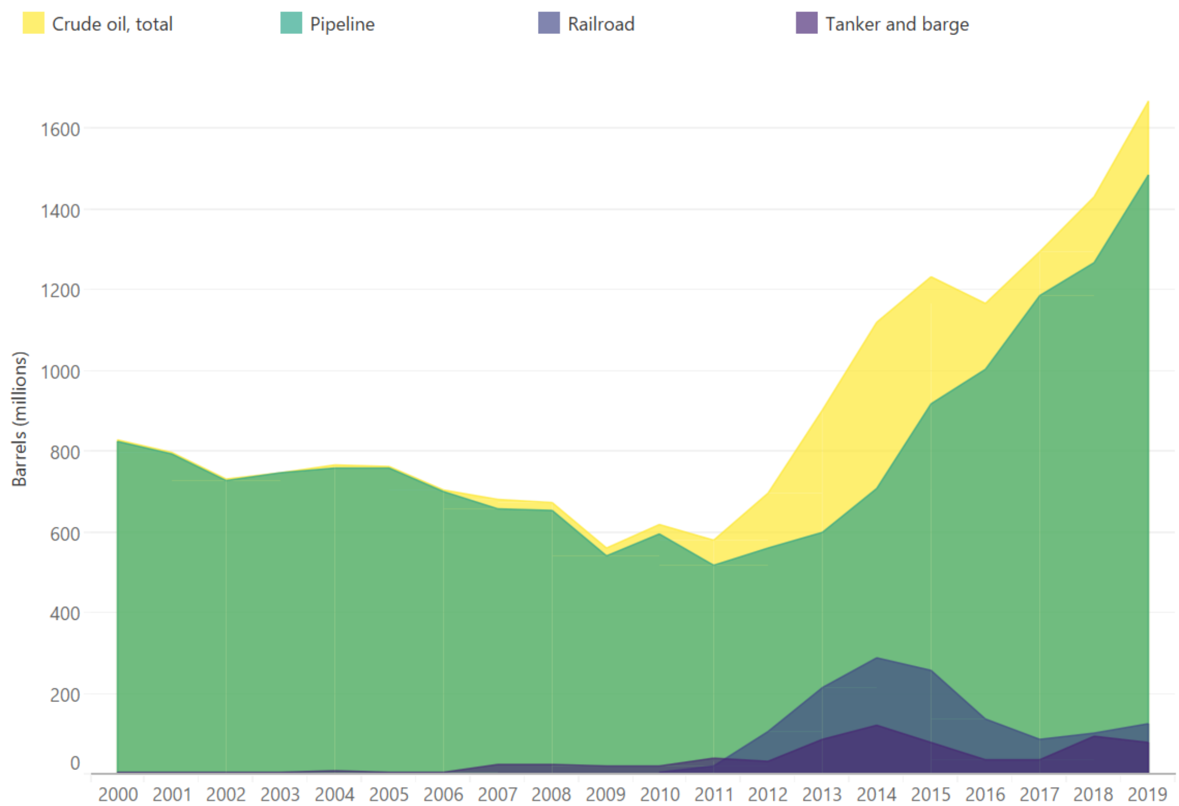


Figure 1- 6 Shipments of U.S. crude oil moved by pipeline, tanker and barge, and rail (millions bbls) (2000 – 2019) (Source: Bureau of Transportation Statistics, 2020)

1.2 History of Oil Spills in the U.S.

Oil spills can occur at any location where it is extracted, refined, transported, or used (Bureau of Transportation Statistics, 2018). The U.S. has experienced or been impacted by many marine oil spills (Figure 1-7):

1. *Deepwater Horizon* oil spill (April 20, 2010): an explosion occurred at the *Deepwater Horizon* drilling platform in the Gulf of Mexico causing 11 fatalities and more than an estimated 100 million gallons of oil to be released.
2. *Exxon Valdez* oil spill (March 24, 1989): the *Exxon Valdez* tanker ran aground in the Prince William Sound, AK causing a release of approximately 11 million gallons (0.26 million bbl) of oil.

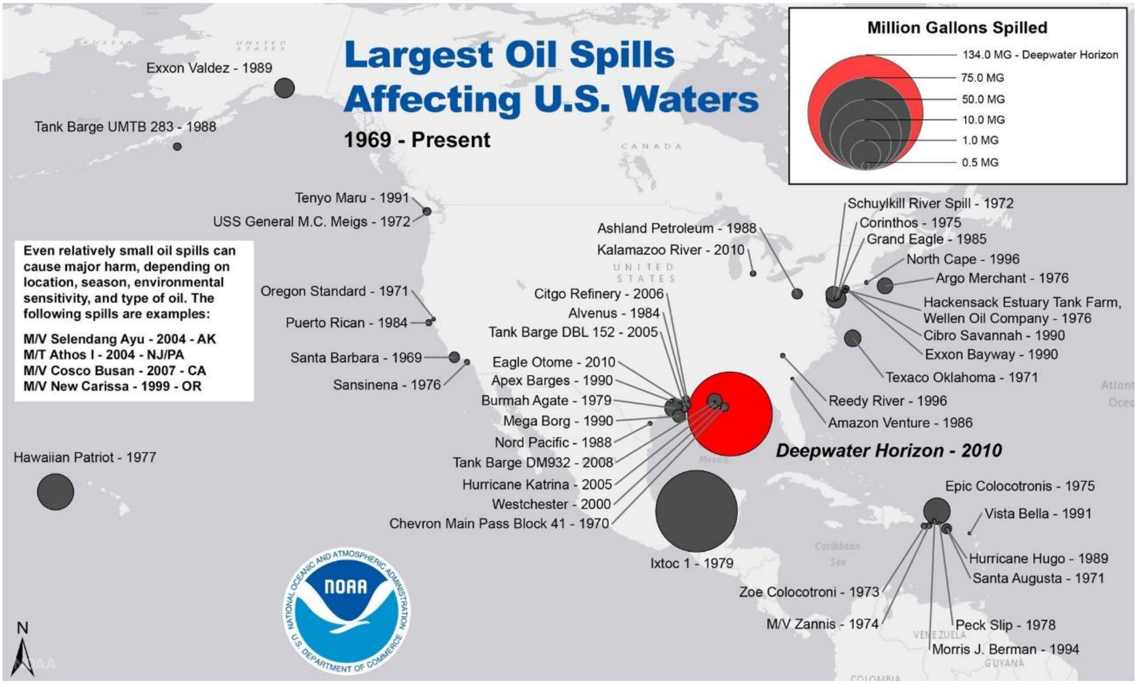


Figure 1- 7 Largest oil spills affecting U.S. waters (1969-2017) (Source: NOAA, 2017)

Annual oil spill volumes from all sources, particularly tankers and barges, have declined greatly since the 1990s in comparison to previous decades (Figure 1-8). OPA 90, which was enacted after the 1989 *Exxon Valdez* oil spill, resulted in comprehensive changes to U.S. oil pollution by increasing spill liability and expanding federal response authority. These changes are likely partially responsible for this historical decline. The 2010 *Deepwater Horizon (Macondo)* oil spill is not included on Figure 1-7 because the spill volume is too large to be included on the same scale in the analysis for annual spill volumes over time. Figure 1-8 shows a spike in the year 2005 that is attributed to Hurricane Katrina in Louisiana and Mississippi, which caused an estimate 8 million gallons of oil to be spilled.

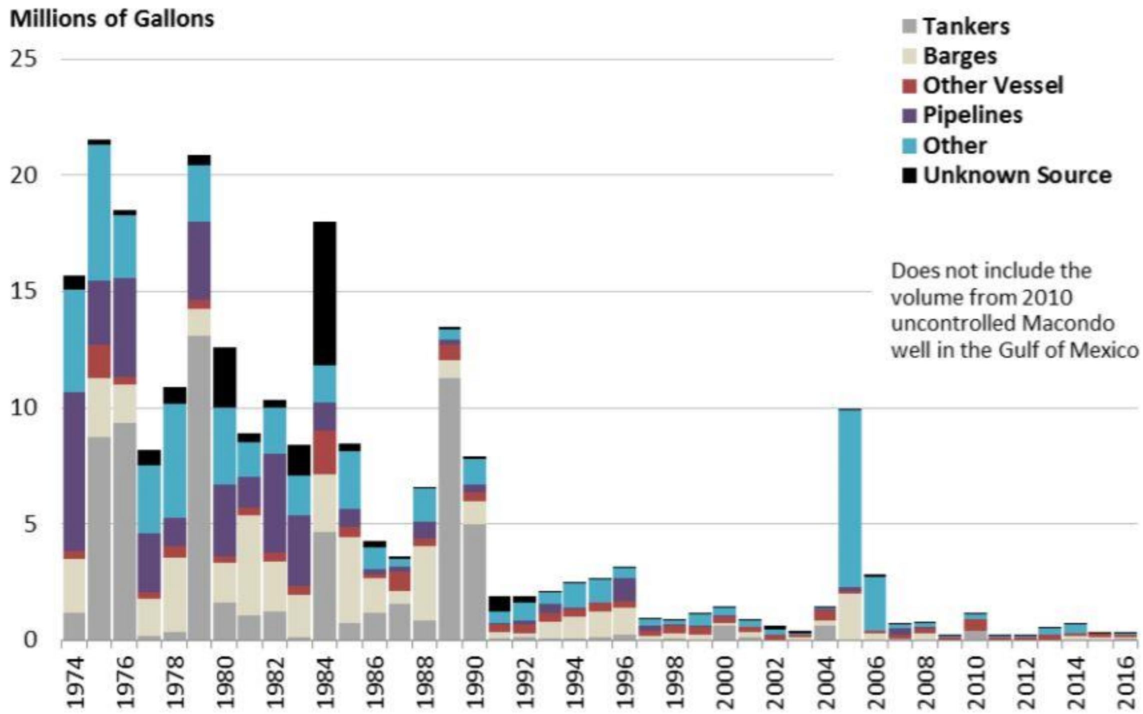


Figure 1- 8 Volume of oil spills by source in the USCG's jurisdiction (1974-2016) USCG states that its Oil Spill Compendium includes spills that have been "investigated" by USCG. Incidents that fall within the jurisdiction of other agencies, or that are not required to be reported under existing Coast Guard regulations, may be included in the compendium. For example, starting in 2007, USCG data did not include spill data from onshore pipelines. The spill volume from the 2010 uncontrolled Macondo well is not included in the above figure: the magnitude of its spill volume (estimated at more than 100 million gallons) makes it difficult to compare to annual spill volumes. The figure does include an estimate of oil released (approximately 400,000 gallons) from the Deepwater Horizon mobile offshore drilling unit (Source: Ramseur, 2017).

In recent years, pipelines and rail transportation have gained attention due to the increase in domestic oil production. Specifically, between 2009 and 2014, the spills from rail transportation increased in response to the increased demand of oil transportation by railroads. As crude oil transportation by rail decreased in 2015 and 2016, so did the number of rail-related oil spills. Figure 1-9 illustrates the number of oil spill incidents and the spill volume for both rail and pipeline spills from 2002 to 2016.

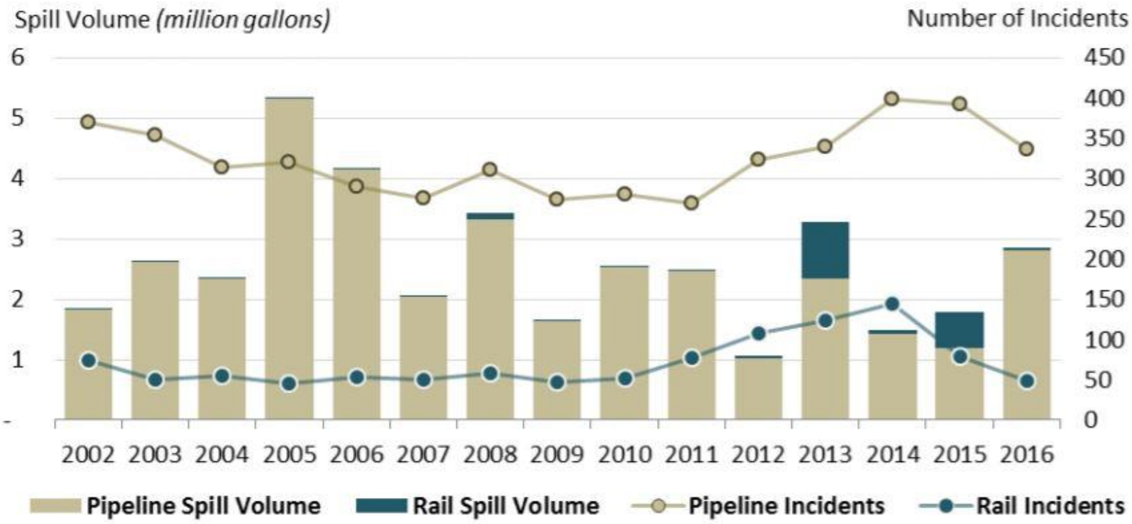


Figure 1- 9 Oil spills from pipeline and rail transportation (2002-2016) (Source: Ramseur, 2017)

1.3 Analysis of the Oil Spill System

In their congressionally mandated review of the 1992 OPRTP, the National Research Council Marine Board recommended "…an analysis of the marine oil spill system, which consists of a variety of subsystems beginning with drilling for oil and ending at delivery of the product to the consumer." As shown on Figure 1-10, the oil spill system described by the Council consists of all components and nodes of the oil supply chain including all aspects of the oil handling and transport processes, succeeding environments affected as a spill spreads, and intervention techniques for preventing or minimizing environmental damage (Marine Board, 1993; 1994). The Council advocated that such an approach would identify critical nodes of potential failure within the system where ICCOPR could focus its research planning efforts.

ICCOPR agreed with the Council on the value of a systems analysis approach in research planning, but full implementation has been beyond the funding capabilities of the ICCOPR membership. In 2007, the United States Coast Guard (USCG) Research & Development Center (RDC) completed an analysis of the response system and used the results to identify and evaluate research opportunities as part of strategic planning to improve spill response (VanHaverbeke, 2012). ICCOPR member agencies also have expertise on specific components of the oil spill system. This base of knowledge on the system components provides a general framework from which ICCOPR plans its research coordination, and measures of effectiveness. The oil spill research categorization scheme, discussed in Chapter 4, reflects how ICCOPR used its understanding of the oil supply chain and oil spill response system to focus research planning as envisioned by the Council.

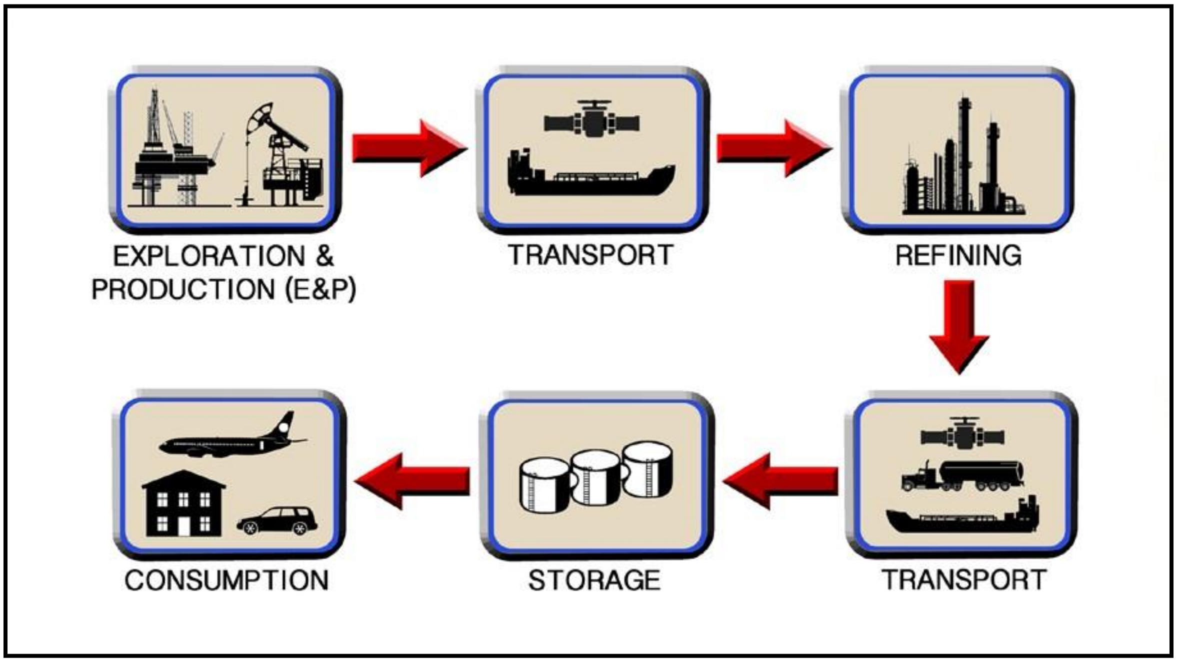


Figure 1- 10 Oil Supply Chain (Source: VanHaverbeke, 2012)

For planning R&D activities, the supply chain for petroleum oils consists of five subsystems (Figure 1-10):

- **Subsystem 1 Exploration and Production Facilities:** This is the origination point of crude oil and includes onshore and offshore exploration and production facilities.
- **Subsystem 2 Transportation:** This is the transportation of foreign and domestic oil products (generally crude oil) to refineries in the U.S. either by tank vessel (ship and barge), pipeline (offshore and onshore), tank railcar (unit trains), or tanker trucks.
- **Subsystem 3 Refining:** Refining of crude oil into petroleum products includes the storage of crude oil, refining operations, storage of refined products, and the loading of refined products on tank vessels (ship and barge), tank railcars, and tanker trucks. In addition, refining would also encompass those activities that produce biofuels or vegetable oils. The latter products present many common and novel challenges compared to their traditional petroleum counterparts.
- **Subsystem 4 Transport/Storage/Distribution:** This subsystem involves the transportation of refined products to a bulk distribution storage facility by various modes of transportation, (e.g., product pipeline, tank vessel (ship and barge), tanker truck, tank railcars). At this point, imported refined products would enter the U.S. system, and exported refined products would leave. Tanker trucks may also deliver directly from a refinery storage to the end user (e.g., residences, retail gas stations).
- **Subsystem 5 Consumption/Consumer/Retail/Industrial:** This subsystem includes the retail gas station and the residential home heating oil segments of the system as well as industrial users (e.g., electric generation facilities).

Historical data are available to support claims that improved safety and operating procedures implemented have generally reduced the risk of a spill at any point along the system. However, because accidents cannot be eliminated, efforts to improve pollution prevention and response must be sustained.

1.4 Potential High-Risk Spill Sources

In the following sections, potential high-risk spill sources (i.e., exploration and production, onshore and offshore pipelines, railroads, refining and storage, vessels, renewable energy systems) are examined to highlight existing weaknesses and concerns, and the efforts being made to address them.

1.4.1 Exploration and Production Facilities

The spill record for domestic drilling and production prior to 2010 suggested that technology and procedures for preventing oil spills were being employed effectively. However, that trend was interrupted in 2010 when the *Deepwater Horizon* drilling rig experienced an uncontrollable well blowout resulting in a major oil spill. Even with modern equipment and safety measures, spills are a part of the oil and gas industry. The *Deepwater Horizon* blowout occurred when human errors circumvented the modern technological safeguards designed to prevent such an accident (National Commission, 2011).

Key factors that drive long-term demand for energy are a growing economy and population; increasing use of renewables, natural gas, electricity; and changing technology, behavior, and policy that affects energy efficiency in vehicles, end-use equipment, and lighting (EIA, 2021). The price of oil is the primary driver of projected drilling activity and U.S. oil production rates. Even though the COVID-19 pandemic created uncertainty about these factors, the U.S. continues to be an integral part of the global oil and natural gas market and is a significant source of the global supply (EIA, 2021). However, global attention is increasingly focused on the need for clean energy in order to mitigate the risks of climate change. Non-hydroelectric renewable energy is the fastest growing energy source (EIA, 2021). This is in part due to policies that have created incentives for renewable energy and the technology continues to become more affordable. This trend will likely increase in the future, leaving uncertainty about the long-term growth of the oil industry.

Renewable energy facilities use OPA regulated products, which behave differently than traditional crudes when released into the environment posing new challenges for responders. Research is needed to better understand the nature of the fluids used in renewable energy facilities and to prepare for future releases. To addresses current knowledge gaps about these fluids and renewable energy facilities, ICCOPR included renewable energy system research.

1.4.2 Onshore and Offshore Pipelines

In 2019, the U.S. had 224,045 oil pipelines and over 1.6 million gas pipelines (Bureau of Transportation Statistics, 2019). These pipelines are an integral part of the U.S. energy supply chain and provide vital support to other critical infrastructure such as power plants, airports, and military bases. Canadian oil exports to the U.S. have been increasing, primarily due to growing extraction from the oil sands in Western Canada (Figure 1-11). In 2019, 96% of Canada's crude oil export was to the United States (Figure 1-11) (EIA, 2019).

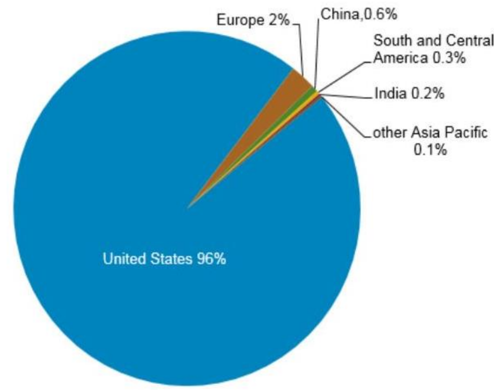


Figure 1- 11 Canada crude oil export by destination (2018) (Source: EIA, 2019)

Oil sands are a mixture of clay, sand, water, and heavy black viscous oil known as bitumen. After extraction, the bitumen is converted into an oil sands product (OSP) suitable for pipeline transport. Canada's OSPs are exported as either light, upgraded synthetic crude ("syncrude") or heavy crude oil that is a blend of bitumen diluted ("dilbit") with lighter hydrocarbons to ease transport. Figure 1-12 is a map of the active and proposed Canadian and U.S. oil pipelines carrying tar sands oil. In 2019, a presidential permit was issued to construct, connect, operate, and maintain pipeline facilities at the international boarder of the U.S. and Canada (i.e., the Keystone XL Pipeline). The Keystone XL Pipeline, as indicated on Figure 1-12, was proposed in 2008 to transport tar sands oil from Alberta, Canada to U.S. refineries through a more direct line than what is currently in place, therefore increasing the rate of oil that is transported to the U.S. In early 2021, further development was halted when the presidential permit was revoked for the Keystone XL Pipeline (Exec. Order 13990, 2021). In June 2021, the developer of the pipeline officially terminated the project.

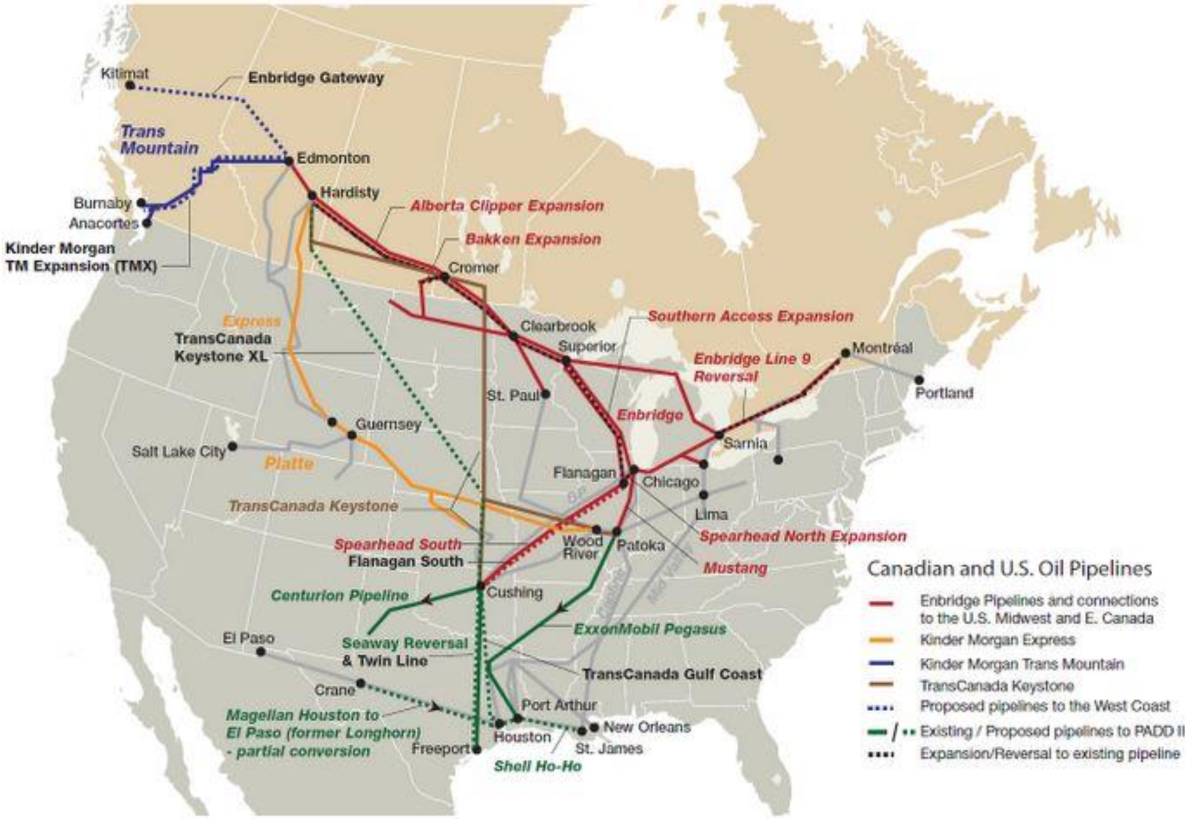


Figure 1- 12 Active and proposed Canadian and U.S. tar sands oil pipelines and refineries (Source: CAPP)

The expansion of petroleum pipelines from Canada has generated considerable controversy in the U.S. One specific area of concern was the potential new risks of the OSPs to pipeline integrity. A Council panel (TRB, 2013) concluded, however, that diluted bitumen does not have any unique properties that make it more likely to cause internal failure of pipelines than other types of crude oil. Additional research is needed to understand the fate and transport of unconventional oils, relative to that of traditional crude oils and refined products.

Natural disasters, particularly hurricanes, are one of the biggest threats to offshore pipeline integrity (ABSG Consulting, 2018). In 2017, there were over 9,000 miles of active oil pipelines in the Gulf of Mexico Outer Continental Shelf (OCS) (ABSG Consulting, 2018). Since 1972, there have been over 70 spills (>50 bbls) from these pipelines (ABSG Consulting, 2018). Oil infrastructure, most of which is now over 40 years old and need updates and repairs, are especially vulnerable to the high winds, rough seas, and flooding caused by hurricanes (Whaling, 2018). Examples of weather damage to offshore pipelines due to storms are:

- In 2005, Hurricane Katrina and Rita, struck the Gulf of Mexico back-to-back destroying 115 oil platforms, damaged 558 pipelines, and spilled nearly 11 million gallons of crude oil into the Gulf (Whaling, 2018).

- In 2012, Hurricane Isaac made landfall in Louisiana twice, which resulted in the release of 340,000 gallons of oil and hazardous chemicals and 192 tons of toxic gases from various energy facilities (Whaling, 2018).

Since the turn of the century, most pipeline spills have resulted from hurricanes while operational related oil spills have been gradually decreasing. The government and industry have taken numerous steps to improve pipeline safety, such as improved corrosion resistance, integrity testing, and requirements to identify pipelines before excavation; yet the offshore industry is still learning from previous incidents, making this factor an issue that will continue for the foreseeable future. Equipment failures are typically more likely to cause small to medium size oil spills, but can be a contributing factor in larger spills, as evidenced by the 2010 *Deepwater Horizon* oil spill in which a well blowout was cited as one factor in the duration of the incident. Due to the increase in natural disasters, coupled with the expansion of U.S. domestic production of oil and aging pipeline infrastructure, this will remain an area of great importance for the decades to come.

1.4.3 Railroads

Prior to the turn of the century, crude oil was transported mostly via pipeline and oceangoing tankers. Due to advancements in horizontal drilling and hydraulic fracturing, there was an increase in U.S. domestic oil production largely due to the oil produced from the Bakken formation. By 2010, oil production in the Bakken formation outpaced the growth of the pipeline capacity; this gap was filled by railroads. Due to the geographic location and lack of crude oil transportation infrastructure at the time, oil was transported from petroleum reserves to refineries by rail. The production from the Bakken field and the Canadian OSP areas resulted in a significant change in the number of trains and tank cars carrying petroleum. As shown in Figure 1-13, total crude oil transported by rail has declined since the peak in 2014. Several factors contribute to this decline, including the narrowing price difference between domestic and imported crude oil, the development of new crude oil pipelines, and declining domestic production in the Midwest and Gulf Coast onshore regions. In 2015, oil prices dropped significantly, and east coast refineries were able to buy oil cheaper from other sources than to transport Bakken oil by rail. Additionally, in 2017 the Dakota Access Pipeline began operating from the Bakken formation, thus further reducing the demand for rail transportation.

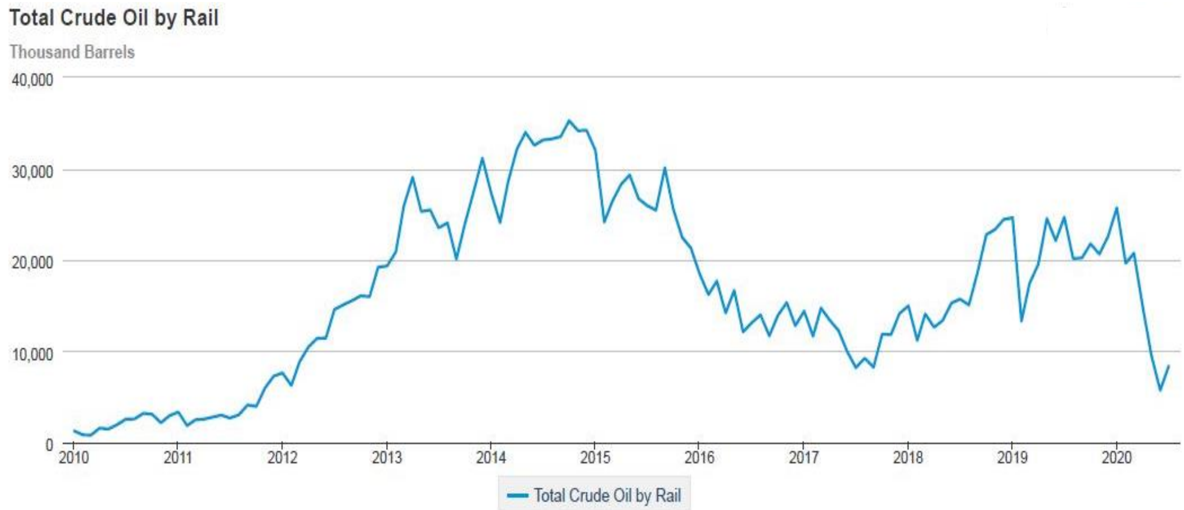


Figure 1- 13 Total crude oil transported by rail (thousand bbls) (Source: EIA, 2020c)

In July 2013, as a freight train carrying Bakken oil derailed into the town of Lac-Mégantic, a region of Quebec, Canada, resulting in an explosion and subsequent fires. This catastrophic event sparked emergency meetings of the U.S. Railroad Safety Advisory Committee to discuss this accident and future prevention methods (Lac-Mégantic Railroad, 2013). Subsequently, in May 2015, the U.S. Department of Transportation (USDOT) issued a comprehensive final rule on tank car standards and operations for moving large volumes of flammable liquids by rail- particularly crude oil, denatured alcohol, and ethanol/gasoline mixtures - due to the concern with the quantity of Bakken crude being transported by rail and the increase in accidents. New policies, such as this, in addition to better operating practices and a decrease in oil transported via railroad has led to overall decline in railroad incidents from 747 in 2010 to 421 in 2019 (PHMSA, 2020). However, transporting oil by rail still presents dangerous risks, even with these precautions. On June 22, 2018, a freight train carrying crude oil derailed and resulted in the release of 160,000 gallons of oil discharged in Doon, Iowa (NTSB, 2018a).

1.4.4 Refining and Storage Operations

Potentially damaging discharges of crude oil or petroleum products in a refinery or at a bulk storage terminal can and do occur at every point in this system (offloading, storage, loading). The factors that can influence the occurrence of these accidental discharges include: the design, construction, maintenance, operational activities, and human factors (e.g., extent of training).

Most of the crude oil produced in the U.S. is refined within the country to make petroleum products. As of 2020, the U.S. had 135 petroleum refineries in operation. This represents a decrease in the number of domestic refineries since 1982 when the U.S.

had 301 refineries. Despite this decrease, the U.S. combined daily throughputs have slowly increased due to the expansion of existing oil refineries to approximately 19 million bbl/day (EIA, 2020d). Increased throughput has occurred despite decreased numbers of refineries, because remaining refineries operate at increased capacities/efficiencies to compensate for the lack of production at decommissioned older facilities.

Thousands of above ground crude oil and refined product storage tanks are in service at refineries and other oil/product handling/storage facilities. Buried pipelines within refinery boundaries represent another source of leaks. Aging domestic refinery infrastructure increases the risk of spillage and better systems are needed to detect potential problems. The refinery process line is another possible source of leakage. In recent years, hurricanes have caused significant damage and oil spills at refineries and bulk storage terminals such as Hurricane Katrina in 2005 (Table 1-1). In 2017, Hurricane Harvey made landfall on the gulf coast of Texas. The storm damaged 22% of all oil refineries in the Houston, TX area, leaking 2 million pounds of toxic air pollutants in to neighboring communities (Whaling, 2018). Dozens of facilities burned off excess natural gas products because downstream production was halted, and storage was at capacity (Whaling, 2018). This was a similar protocol used by refineries in 2008 when Hurricane Ike hit the Gulf of Mexico and caused refineries to burn off hundreds of pounds of toxic chemicals as part of emergency protocol.

Table 1- 1 Spill Events that Occurred in the Path of Hurricane Katrina (2005) (Source: Pine, 2006)

Spill Events that Occurred in the Path of Hurricane Katrina (2005)	
Spill Location	**Quantity (bbls)**
Bass Enterprises (Cox Bay)	90,000
Shell (Pilot Town)	25,000
Chevron (Empire)	23,600
Murphy Oil (Meraux and Chalmette)	19,500
Bass Enterprises (Pointe à la Hache)	10,980
Chevron (Port Fourchon)	1,260
Venice Energy Services (Venice)	595
Shell Pipeline Oil (Nairn)	320
Sundown Energy (West Potash)	310

1.4.5 Maritime and Riverine Transport – Tank Vessels (Ships & Barge) and Non-Tank Vessels

A combination of federal, state, and international authorities is responsible for regulating tank and non-tank vessels in the U.S. These authorities are collectively responsible for creating and implementing legislation to prevent oil spills and handling the decisions and procedures that follow in the aftermath. There has been a reduction of operational and accidental oil spills in the U.S. that can largely be attributed to the domestic and international regulations that have improved shipping safety and increased limits of liability. These regulations required the phase-out of single hull tank vessels (ships and barges), and development of new tank vessels designs for double hulls to reduce accidental discharges in the event of grounding, collision, and allision. Operational preventative measures including mandatory tug escorts for tank ships transiting through environmentally sensitive areas in ports may also have contributed to the downward spillage trend by ensuring immediate assistance to a vessel experiencing a loss of propulsion or steerage.

There were over 1,000 U.S. oil spills from vessels that affected navigable U.S. waterways, releasing over 73,000 gallons of oil total (Table 1-2). This is a significant decrease from 2019, in which about 1,500 vessel spills released over 471,000 gallons of oil (Table 1-2). Typical causes of vessel spills include human error (e.g., inattention, procedural error, lack of situational awareness) and material failure or a combination of both.

Table 1- 2 Oil spills impacting navigable U.S. waterways from 2018 – 2020 (Source: USDHS, 2020)

Vessel Type	2018		2019		2020	
	Incident	Gallons Spilled	Incident	Gallons Spilled	Incident	Gallons Spilled
Tankship	18	1,520	24	47,710	16	636
Tank Barge	58	41,360	62	131,400	49	17,592
Other	1,901	299,574	1,414	291,929	1,219	54,782
Totals	1,977	342,454	1,572	471,039	1,284	73,010

*Note: 'Other' vessel sources include commercial vessels, fishing vessels, freight barges/ships, oil recovery vessels, passenger vessels, recreational boats, etc.

1.4.6 Oil Tankers

Stricter regulations and improved operations of oil tankers have reduced the number of large (> 5,000 bbls) and medium (50 – 5,000 bbls) oil spills from tankers globally, and in the U.S., despite an increase in marine transportation of oil. Figure 1-14 depicts the inverse relationship between an increase in oil tanker movement and a decreasing trend in tanker oil spills.

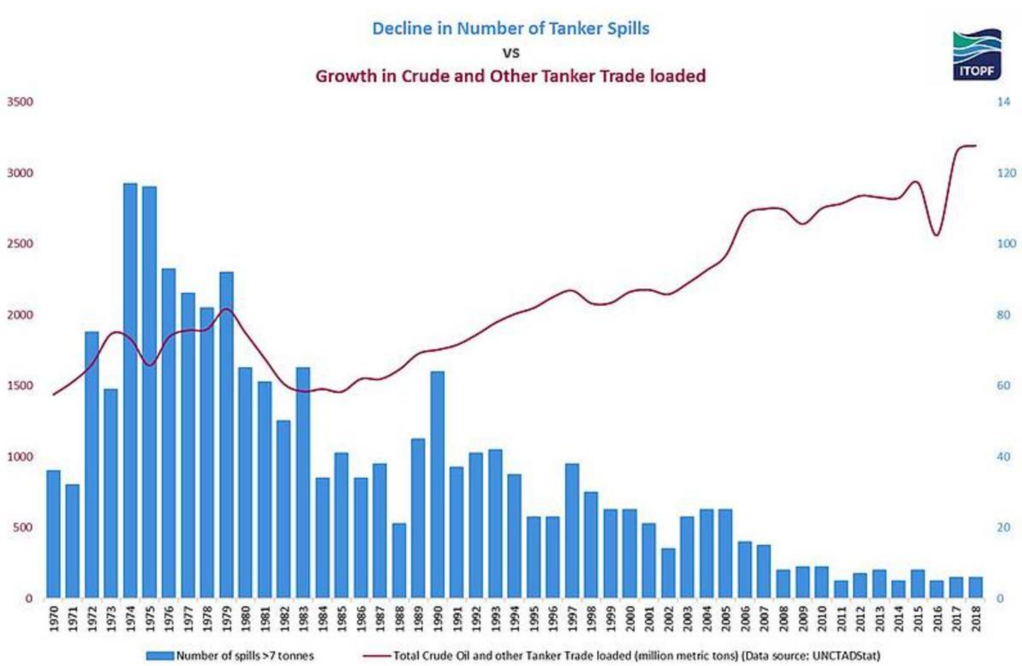


Figure 1- 14 Decline in the number of tanker spills vs the growth in crude, petroleum, and gas loaded (Source: ITOPF, 2019)

Following the grounding of the single-hull tank vessel *Exxon Valdez*, OPA 90 mandated that all newly built tank vessels have double hulls and that single-hull tank vessels be phased out and replaced by double-hulled vessels by January 1, 2015, for operations in U.S. waters. Similarly, requirements stemming from the International Convention for the Prevention of Pollution from Ships (MARPOL) have increased the safety of tanker transport. These changes have greatly reduced the number and volume of tanker spills.

The International Tanker Owners Pollution Federation Limited (ITOPF), which tracks oil spills from tankers, reports that 19 of the 20 largest spills from tankers occurred before 1970 (ITOPF, 2015). Figure 1-15 shows the downward trend in oil spills from tankers from 1970 to 2019. A similar trend is shown in Figure 1-16 indicating a decrease in the quantity of oil lost from tanker spills since the 1970s. It should be noted that a small amount of large oil spills comprises a large percentage of the total oil spilled.

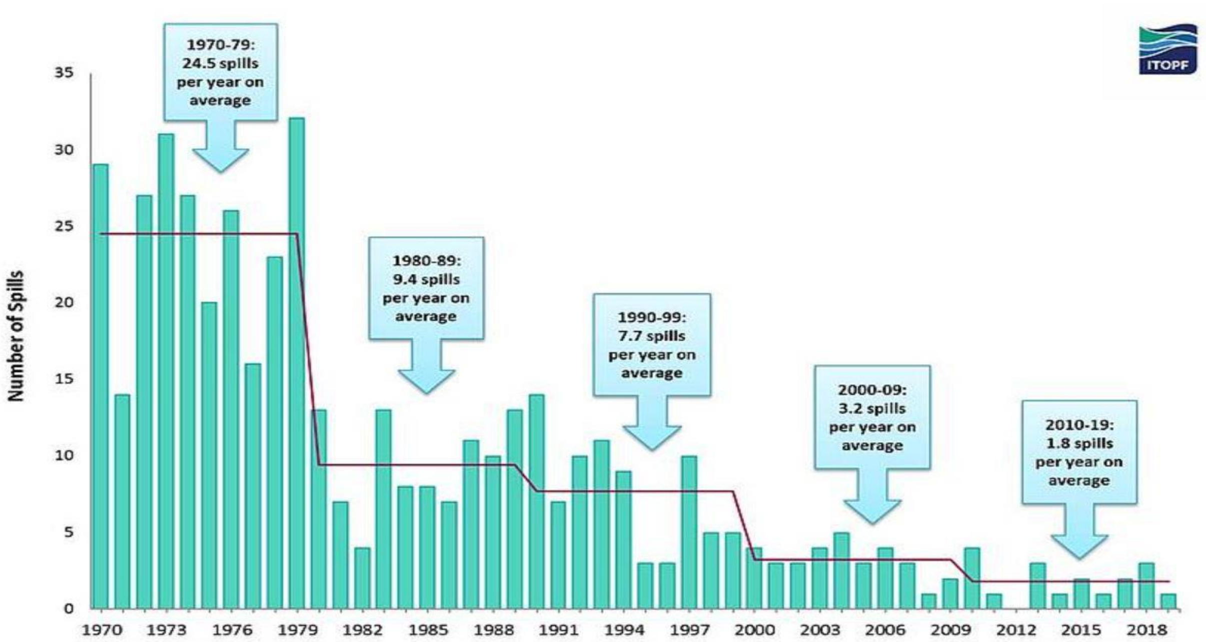


Figure 1- 15 Number of spills (>700 tonnes) from 1970 to 2019 (Source: ITOPF, 2019)

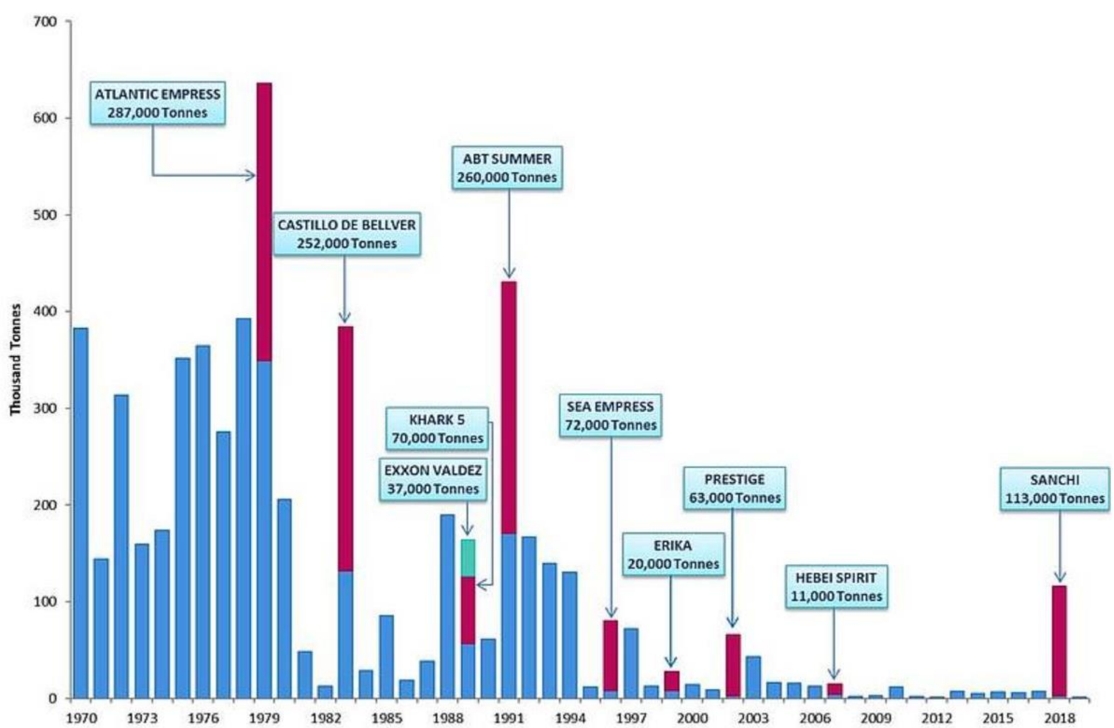


Figure 1- 16 Quantities of oil spilt 7 tonnes and over (rounded to nearest thousand) from 1970 to 2019 (Source: ITOPF, 2019)

Between 1970 and 2019, most tanker oil spills were caused by allisions/collisions and groundings. While the overall number of spills has decreased in that time period, the proportion of those spills caused by allisions/collisions has increased and those caused by groundings have decreased (ITOPF, 2019). While spills are decreasing, it is important to note that large tanker spills continue to occur and there is a need for continual research into vessel design and spill prevention measures.

1.4.7 Renewable Energy Systems

Energy consumption in the U.S. is trending toward greater use of renewable energy systems and there is a national push to develop wind and wave energy systems. As such, renewable energy systems will play a greater role over the six-year planning cycle. Prior to the mid-1800's, the U.S. used wood for almost all of its energy needs. From that point until the present, fossil fuels (coal, petroleum, and natural gas) have been the primary sources of energy in the U.S. (Figure 1-17). In recent decades, innovations and advanced technologies have resulted in the rise of using renewable energy and biofuels. Renewable energy is derived from natural sources or processes that are constantly replenished. For this reason, renewable energy is virtually inexhaustible. It includes biomass/biofuels (wood, wood waste, municipal solid waste, landfill gas, ethanol, biodiesel), hydropower, geothermal, wind, waves (hydrokinetic), and solar energy. As of 2019, renewable energy accounted for 11% of the U.S. primary energy consumption (Figure 1-18), surpassing coal energy consumption for the first time since 1885 (EIA, 2020a). EIA projects that the share of renewables in the U.S. electricity generation will increase from 21% in 2020 to 42% in 2050, with wind and solar generation largely responsible for the growth.

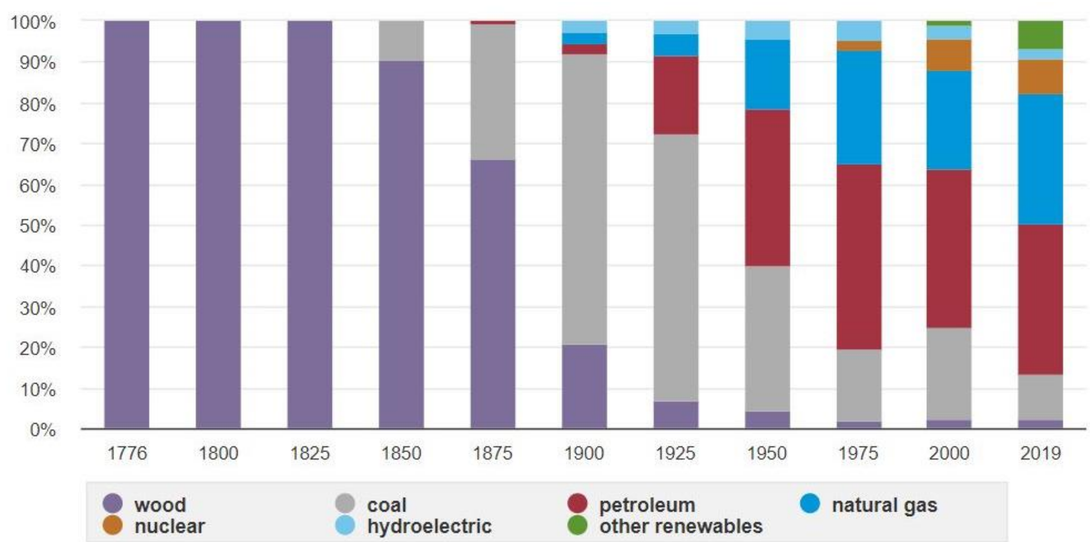


Figure 1- 17 Shares of total U.S. energy consumption by major sources (1776-2019) (Source: EIA, 2020a)

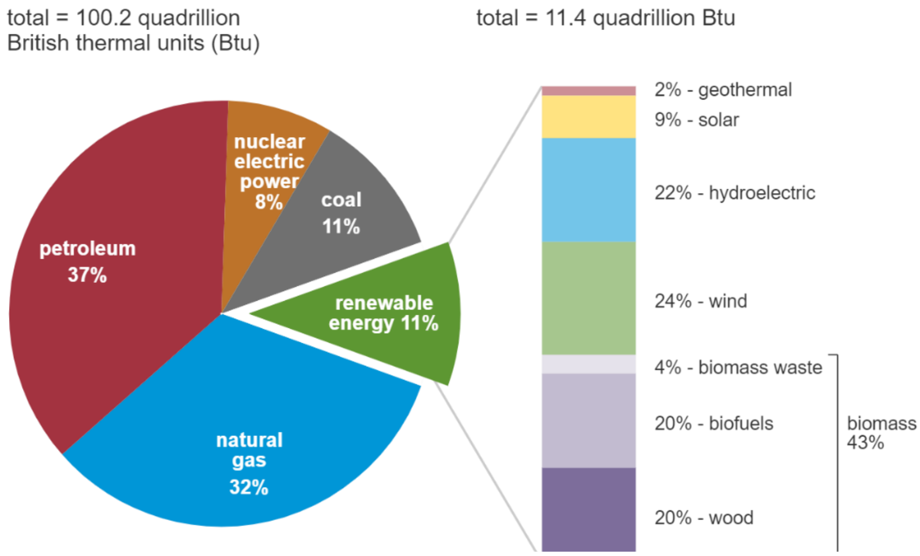


Figure 1- 18 U.S. primary energy consumption by energy source in 2019 (Source: EIA, 2020a)

Renewable energy systems, such as biofuel manufacturing facilities, use fuels that are subject to federal regulations, including OPA 90. In the case of offshore wind, wind turbines are connected to centralized electrical service platforms that have the potential to release dielectric fluids and oils into the marine ecosystem (Louisiana State University, 2011). The dielectric insulating fluid used in electrical service platforms is typically a mineral oil, but vegetable-based oils can also be used. Spills of refined biofuels and vegetable oil products present new challenges compared to their petroleum counterparts. Due to the lack of color in dielectric fluids, detection, and monitoring of a release into the environment is challenging and requires further research (Louisiana State University, 2011). Response, recovery, and clean up protocols are still being developed as this industry grows. As renewable energy continues to increase and become part of the U.S. energy consumption, research in this field will also need to increase for adequate spill mitigation.

1.5. Regional and Geographic Areas of Interest

ICCOPR considers regional issues an important element in executing an effective oil pollution research and technology program. The applicability of research results can vary significantly between geographic regions due to their unique environmental characteristics. ICCOPR considers the following regional and geographic areas to currently be of high importance during the next six-year planning cycle: the Arctic and Alaska, Inland Rivers and Laurentian Great Lakes, Gulf of Mexico OCS, Atlantic OCS, and Pacific OCS.

The Bureau of Ocean Energy Management (BOEM) is operating under the 2017-2022 National OCS Oil and Gas Leasing Program, which established a schedule of oil and gas lease sales proposed in areas of the OCS. As of May 2021, there are about 2,287 active oil and gas leases on over 14.2 million OCS acres (BOEM, 2016). Areas with current and potential leasing activities include the Gulf of Mexico OCS, Atlantic OCS, and Pacific OCS.

The Arctic and Alaska – Warming temperatures in the Arctic and Alaskan waters have reduced the extent of sea ice, making offshore oil exploration more accessible. Additionally, as global demand for goods continues to grow, increased shipping in the region will occur. As shipping increases, so do the risks associated with operating in this environment. The U.S. has recently shown interest in expanding the oil and gas leases in the region including opening the Coastal Plains of the Arctic National Wildlife Refuge (ANWR) and all areas of the Federal OCS not under a moratorium to be offered up for lease. However, in 2021, the U.S. canceled new oil and gas lease sales in the Gulf of Mexico and in Cook Inlet, AK and put a temporary drilling moratorium on oil and gas activities in the ANWR. In its research planning efforts, ICCOPR maintains visibility of regional issues by coordinating with Regional Response Teams (RRT), states, Federal trustees, and regional research groups.

The oil industry is also interested in conducting oil and gas operations offshore in the Arctic. The Liberty Project, if developed, would be the first oil production facility in Federal waters off Alaska. Proposed in 2010, the Liberty Project has yet to begin development as a federal appeals court overturned the project's approval in 2020.

There is an increase in commercial shipping on two trans-Arctic sea routes – the Northern Sea Route close to Russia, and the Northwest Passage close to Alaska. Arctic waters are remote and subject to extreme and harsh environmental conditions. This creates unique challenges for oil spill recovery operations when compared to other regions of the U.S. To address these risks, the Arctic council's Agreement on Cooperation on Marine Oil Pollution Preparedness and Response in the Arctic addresses the risk of oil spills in this region through increasing oil spill response readiness and cooperation among Arctic countries. Additionally, technologies and strategies for responding to oil spills in ice-covered waters are continuously being developed and are a focus for R&D programs. Gaining a better understanding of the causal factors of oil spills, especially bunker spills, and effectiveness of response options in the arctic region is necessary as pressure to expand oil exploration in this region continues.

Inland Rivers and Laurentian Great Lakes – The production of oil and gas from the shale plays in the U.S. and oil sands regions in Canada has continually increased. Continued transport of oil shipment via pipeline and rail emphasizes the importance research to prevent, prepare, and mitigate for oil spills from train accidents, pipeline breaks, and tankers. Although most inland spills are not as large as marine spills, infrastructure and associated spills often occur on public lands and private property which can have a direct impact on local communities (e.g., drinking water supplies, local fishing). The economic impact of the spill to these communities can be significant. In addition, the potential for these spills to affect freshwater rivers and lakes necessitates greater emphasis on research into non-marine response techniques.

Gulf of Mexico OCS and Deep Water Areas – A significant portion of U.S. oil related production and refining operations are located in the Gulf of Mexico. New offshore oil and gas exploration and development in this region is limited to the Central and Western Gulf of Mexico. In 2018, about 94% of the total acreage of Federal offshore waters was inaccessible to offshore oil and natural gas development, including the Eastern Gulf with a vast majority of it under a drilling moratorium until 2022 (API, 2020a). The deep water portion of the Gulf of Mexico continues to attract interest in oil and gas exploration and development. There are 1,261 active leases and 2,547 approved applications to drill at depths greater than 1,000 meters (BOEM, 2021). The Gulf of Mexico is increasingly exporting oil produced in the region, exporting over one million bbls in 2019. This is significant increase compared to five years earlier, when the Gulf had an annual export of just under 70,000 bbls in 2014 (EIA, 2020g).

Advances in drilling technology enabled industry to expand operations into progressively deeper areas of the Gulf. It is also the site of two of the largest oil spills from well blowouts, *Deepwater Horizon* and *Ixtoc I*, as well as numerous other smaller spills. Federal offshore oil production in the Gulf of Mexico makes up 17% of the total U.S. oil production (EIA, n.d.). Additionally, over 45% of the total U.S. refining capacity is located along the Gulf Coast. Given the activity in this region, and recent large oil spills, this region will continue to be important for oil spill response operations for the next several years.

Atlantic OCS – At present no oil leases are active in the Atlantic OCS Region and no oil and gas lease sales are proposed under the current 2017-2022 OCS oil and gas leasing program (BOEM, 2016). Historically, there have been leases and wells drilled in this OCS, but none are active. This region is being developed for wind and wave energy resources. As of March 2021, BOEM has issued 12 leases for offshore wind farms along the eastern seaboard. Future spills in this region will present unique challenges during response operations due to the nature of the oils used for the turbines, transformers, cables, and other systems, along with the unique geological features of the region.

Pacific OCS - The Pacific OCS region has the development of conventional (e.g., oil and natural gas) and renewable energy, specifically wind and wave energy offshore of California, Oregon, Washington, and Hawaii. Currently, the Pacific OCS has 32 active leases consisting of 23 oil and gas platforms and over 200 miles of pipeline (BOEM, n.d.). The current 2017-2022 National OCS Program does not include any proposed leases off the U.S. Pacific coast. Federal lease sales within the Pacific OCS took place between the years of 1961-1984, with only Central and Southern California being offered after 1964.

With new development in this region, it is important to note that spills continue to occur, such as the 2015 Refugio Beach Oil Spill. Over 100,000 gallons of oil were spilt when an underground, onshore pipeline ruptured near Refugio State Beach.

2. Federal Oil Pollution Research

ICCOPR serves to coordinate research by its member federal agencies and other federal research entities to promote a coordinated approach to addressing oil pollution issues. This section describes ICCOPR and the other federal research entities.

2.1 ICCOPR

2.1.1 Origin

Congress created ICCOPR in Title VII of OPA 90. The Committee's membership, roles, and responsibilities are outlined in the original Public Law (P.L.) that mandated its creation, as amended, and codified in the United States Code. Consequently, when referencing ICCOPR, it is generally cited with: *Oil Pollution Act of 1990, § 7001, 104 Stat. 484, 559-564 (1990) (33 U.S.C. 2761).*

ICCOPR is charged with two general responsibilities to: (1) prepare a comprehensive, coordinated federal oil pollution research and development plan; and (2) promote cooperation with industry, universities, research institutions, state governments, and other nations through information sharing, coordinated planning, and joint funding of projects. ICCOPR reports on its activities to congress every two years.

2.1.2 ICCOPR Membership

ICCOPR is comprised of sixteen (16) federal independent agencies, departments, and department components. The USCG chairs ICCOPR. The National Oceanic and Atmospheric Administration (NOAA), the Bureau of Safety and Environmental Enforcement (BSEE), and USEPA rotated as the vice chair every two years from FY2012 to FY2021. NOAA will serve as the permanent vice chair upon completion of this report.

OPA 90 originally stipulated that ICCOPR include representation from the: Department of Commerce, including NOAA and the National Institute of Standards and Technology (NIST); the Department of Energy (USDOE); Department of the Interior (DOI), including the Minerals Management Service (MMS) and the U.S. Fish and Wildlife Service (USFWS); USDOT, including the USCG, the Maritime Administration (MARAD), and the Research and Special Projects Administration (RSPA); Department of Defense, including the U.S. Army Corps of Engineers (USACE) and the Navy; USEPA; National Aeronautics and Space Administration (NASA); and U.S. Fire Administration (USFA) in the Federal Emergency Management Agency (FEMA).

Today ICCOPR's original membership remains mostly intact, but with some changes (Table 2.1). In 2012, USDOI reorganized MMS to form BSEE and BOEM – both of which are now members of ICCOPR. Additionally, USCG and FEMA reorganized under U.S. Department of Homeland Security (USDHS) and USDOT re-designated RSPA as the Pipeline and Hazardous Materials Safety Administration (PHMSA). In 2013, ICCOPR added the U.S. Arctic Research Commission (USARC) to help address emerging issues associated with the Arctic and cold weather environments. In 2021, ICCOPR welcomed its newest member, U.S. Geological Survey (USGS).

Table 2- 1 ICCOPR Membership

Member	Current U.S. Department	Notes
USCG	Homeland Security	Transferred from USDOT
FEMA/USFA	Homeland Security	Originally Independent
MARAD	Transportation	
PHMSA	Transportation	Agency renamed from RSPA
USFWS	Interior	
BSEE	Interior	Formerly part of MMS
BOEM	Interior	Formerly part of MMS
NOAA	Commerce	
NIST	Commerce	
Navy	Defense	
USACE	Defense	
USDOE	Energy	
USEPA	Independent	
NASA	Independent	
USARC	Independent	Added in 2013
USGS	Interior	Added in 2021

ICCOPR membership may continue to evolve to fully address new research challenges when agency missions change or there are changes in patterns of oil exploration, production, and transportation. OPA 90 provides that the President may designate other agencies as members of ICCOPR. The President delegated this power to the Secretary of the "Department in which the Coast Guard (USCG) operates" through Executive Order 12777 (October 18, 1991) Section 8(h) and as amended by Executive Order 13286 (March 5, 2003). The Secretary of Homeland Security delegated this power to USCG

Commandant in USDHS Delegation No. 0170.1, II.80. ICCOPR may also invite other federal agencies to participate in a non-voting observer role.

The diversity of ICCOPR's membership reflects Congress' intent to adequately address the full spectrum of oil spill prevention, preparedness, response, and restoration research. Each organization bears unique regulatory responsibilities, research capabilities and/or technical expertise that collectively give ICCOPR its knowledge and networks for tackling varying oil pollution research and technology issues. The following sections discuss each of ICCOPR's member organizations and their connections to oil pollution research. Some organizations directly oversee oil pollution research programs, while others provide guidance and resource support or specialized expertise.

2.1.2.1 U.S. Coast Guard (USCG)

USCG serves as the Chair of ICCOPR in accordance with OPA 90. It also serves as the vice-chair of the U.S. National Response Team (NRT) and a co-chair of RRTs. USCG, together with USEPA, has the primary responsibility for federal oil spill response activities. In accordance with the National Contingency Plan (NCP), USCG is the lead agency for response to spills in the U.S. coastal zone as defined in 40 CFR 300.5.

USCG provides pre-designated Federal On-Scene Coordinators (FOSCs) for spills in the coastal zone (all U.S. waters). In addition to spill response, USCG also has statutory and operational responsibility for oversight of ship design and construction, periodic vessel inspections, investigation of marine casualties, waterways management, and port safety and security (including the regulation of hazardous cargoes). These activities help USCG improve pollution prevention and response capabilities.

Since 1969, the USCG RDC in New London, CT, has been the agency's sole facility performing applied oil pollution research, development, testing, and evaluation (RDT&E), experimentation and demonstrations (see Section 2.3.2). A USCG National Center of Excellence (NCOE) is in development in the Great Lakes region to study the impacts of oil spills in freshwater environments and help develop effective responses (see Section 2.3.3).

USCG also hosts the National Response Center (NRC), which serves as the NRT communications center and the official federal point of contact for pollution incident reports. The NCP (40 CFR Part 300) requires that the NRC be notified in the event of an oil spill into navigable waters. The USCG's National Pollution Funds Center (NPFC) administers the Oil Spill Liability Trust Fund (OSLTF) and provides funding from the OSLTF Emergency Fund for responses, compensates claimants for cleanup costs and damages, and takes action to recover costs from responsible parties. The NPFC also provides funding from the OSLTF Principal Fund for operations and R&D.

2.1.2.2 National Oceanic and Atmospheric Administration (NOAA)

NOAA serves as the designated Vice Chair of ICCOPR. It provides science, service and stewardship for the oceans and atmosphere; with a goal of healthy ecosystems, communities and economies that are resilient in the face of change. Many components of NOAA may support response to a major oil spill including the National Ocean Service (NOS), National Weather Service (NWS); the National Marine Fisheries Service (NMFS); the National Environmental Satellite, Data, and Information Service (NESDIS); and the Office of Marine and Aviation Operations (OMAO). A core component of the support is NOAA's Office of Response and Restoration (OR&R) and its network of Scientific Support Coordinators (SSCs) who respond to approximately 120 oil spills annually, primarily in the coastal zone. The SSCs serve as the primary scientific advisors to FOSCs, coordinating scientific expertise from federal and state agencies, academia, industry, and the local community (40 CFR 300.145). NOAA support includes: assessments of hazards, predictions of fate and behavior (trajectories); recommendations on cleanup and mitigation methods and endpoints; emergency consultations on protected resources; environmental information and data management; wildlife operations; meteorological, hydrological, and oceanographic observations and forecasts; and satellite imagery access and analysis.

NOAA supports the NRT and RRTs with delegated Department of Commerce representatives and serves on workgroups and area committees on activities associated with preparedness, assessment, and restoration. NOAA develops and applies tools for emergency response support, transitioning research into operations. In coordination with states and other federal agencies, NOAA produces environmental sensitivity index (ESI) maps, which rank coastal areas and biota by sensitivity to oil and identify priority locations to be protected during a spill. Federal, state, and local agencies use these ESIs to plan for and respond to oil spills.

As a Federal Natural Resource Trustee for living marine resources and their habitat, NOAA is required to: assess the injuries that result from an oil spill, determine, and recover monetary compensation and using those sums, restore, rehabilitate, or recover the equivalent of the damaged resources. NOAA is also responsible for the issuance and implementation of regulations governing oil spill damage assessment.

2.1.2.3 National Institute of Standards and Technology (NIST)

Founded in 1901, NIST is a non-regulatory federal agency within the U.S. Department of Commerce. NIST's mission is to promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve quality of life. NIST has a long history of scientific, technical and measurement support to other federal agencies and U.S. industry on a reimbursable basis.

NIST maintains unique measurement facilities and has an experienced technical staff able to assist with oil spill response and oil pollution research providing a wide variety of scientific and measurement services. NIST can develop for sampling protected species, archive marine animal specimens associated with oil spills, conduct interlaboratory comparison exercises for laboratories involved in assessing oil contamination, provide measurements of contamination in archived marine mammals and seabirds, and assist with measuring oil flow from well blow-outs.

NIST develops Standard Reference Materials (SRMs) for crude oil and other fossil-fuel materials and additionally, has groups involved with research in Fire and Pipeline Safety. NIST maintains and manages the Marine Environmental Specimen Bank (ESB) that contains marine mammal samples dating back as far as the Exxon Valdez oil spill damage assessment and includes marine organism samples from the Pacific Islands, Alaska, and coastal regions of the lower 48 states. NIST has worked more than 30 years developing environmental specimen banking technology so that samples can be used to understand environmental exposure and effects from oil and other contaminants. Because samples have been collected continuously from many locations, they provide a resource to establish pre-spill baseline conditions.

2.1.2.4 U.S. Department of Energy (USDOE)

USDOE works to ensure America's energy security and prosperity by addressing energy and environmental challenges with research and technology solutions. They focus on ensuring the prudent development of America's oil and natural gas resources through R&D that improves the safety and environmental performance of oil and natural gas exploration and production.

In its offshore research program, USDOE works toward mitigating the risks and challenges associated with drilling and production operations through a research portfolio dedicated to oil spill prevention. Completed and ongoing research focuses on: geologic uncertainty; drilling and completions; surface systems and umbilicals; and subsea systems reliability/automated safety systems.

Onshore, USDOE focuses on prudent development of unconventional oil and gas resources with emphasis on resource characterization, protecting water quality, increasing water availability, protecting air quality, and reducing induced seismicity associated with wastewater injection. The advent of shale gas development also brings a host of safety and environmental issues including: 1) demand for water for use in hydraulic fracturing; 2) protection of drinking water aquifers; 3) evaluation of the safety of chemicals used in fracturing; 4) environmental impacts resulting from the treatment and/or disposal of produced or fracture flowback water; 5) air quality impacts; and 6) community safety issues.

USDOE's National Energy Technology Laboratory (NETL) conducts laboratory, field, and modeling research on offshore oil spill prevention, focusing on reducing and mitigating the risk of loss of well control. Onshore modeling includes life cycle analysis of natural gas and modeling of methane emissions.

Some of USDOE’s research programs are collaborative with other agencies. In 2020, USDOE and BSEE announced a collaboration for improved safety and environmental stewardship in offshore energy exploration and production operations. The agencies offered up to $40 million in funding over a 5-year period, for the Ocean Energy Safety Institute (OESI 2.0). OESI 2.0 expands the scope of OESI (established in 2013) and facilitates research and development related to offshore oil, natural gas, wind, and marine hydrokinetic energy production, with a focus on safety, environmental monitoring, and operational improvements.

2.1.2.5 Bureau of Safety and Environmental Enforcement (BSEE)

The bureau works to promote safety, protect the environment, and conserve energy resources offshore through vigorous regulatory oversight and enforcement. BSEE develops standards and regulations to enhance operational safety and environmental protection in connection with the exploration and development of offshore oil, natural gas, and renewable energy sources on the U.S. OCS; and undertakes actions to ensure compliance with those standards and regulations. BSEE has two research programs that support its mission. The Technology Assessment Program supports research regarding operational safety and pollution prevention related to offshore oil and natural gas and renewable energy exploration and development. BSEE’s Oil Spill Preparedness Division (OSPD) oversees oil spill research, planning, preparedness, and response programs. OSPD administers the Oil Spill Response Research Program, which is dedicated to improving oil spill response options. The major focus of the Program is to support BSEE’s mission of ensuring offshore operators are prepared to respond to any potential oil spill. Research is conducted to improve the methods and technologies used for oil spill detection, containment, treatment, recovery, and cleanup.

As part of ensuring that offshore operators are prepared to respond to an oil spill, BSEE conducts: oil spill response plan reviews, government-initiated unannounced exercises, equipment inspections, audits of oil spill response organizations (OSROs), and spill management training. Risks identified through these activities are mitigated by directed changes to plans, training programs, equipment, response strategies, and BSEE-funded research projects.

BSEE also manages the operation of Ohmsett, the National Oil Spill Response Research & Renewable Energy Test Facility. Ohmsett is the only facility where full-scale oil spill response equipment testing, research, and training can be conducted in a marine environment with oil under controlled environmental conditions (waves and oil types). OPA 90 mandates continued operation of Ohmsett (See Section 2.3.1).

2.1.2.6 Bureau of Ocean Energy Management (BOEM)

DOI's BOEM manages the exploration and development of the nation's offshore energy resources on the U.S. OCS. It seeks to appropriately balance economic development, energy independence, and environmental protection through oil and gas leases, renewable energy development and environmental reviews and studies. BOEM conducts studies to improve pre-spill baseline information and estimates of oil spill transport, fate, and impacts to the environment. BOEM manages an Environmental Studies Program (ESP), which has included: development and use of oil transport and weathering models; measurement of oil effects in laboratory and field conditions on marine organisms including birds, fish, and mammals; identification of sensitive biological resources; and assessment of the social and economic impacts of oil development. While some of the ESP consists of in-house investigations, BOEM manages a substantially larger program that is conducted by contractors, industry, universities, and other federal agencies. BOEM formed a committee with NAS since 2015 to provide independent expertise on environmental science and assessment for offshore energy resources. All reports, conference proceedings, and peer-reviewed publications generated by the ESP studies are archived in the Environmental Studies Program Information System and are accessible at https://marinecadastre.gov/espis/.

2.1.2.7 U.S. Fish and Wildlife Service (USFWS)

The DOI's USFWS has trustee responsibility for migratory birds, threatened and endangered species, certain marine mammals, anadromous and catadromous fish, and national wildlife refuge lands. The USFWS is the primary DOI entity that responds to oil spills, provides information and advice on safeguarding sensitive habitats and protected species (including advice on use of dispersants and other chemicals) and oversees the rescue and the rehabilitation of oiled birds and certain marine mammals. It works closely with state fish and wildlife agencies to ensure the protection of potentially affected fish and wildlife and takes an active role in protecting USFWS lands, such as national wildlife refuges. USFWS, in its role as trustee, is also the most active DOI entity in natural resource damage assessment (NRDA) and restorations. In addition to civil actions, USFWS may also pursue criminal violations of the Migratory Bird Treaty Act, Marine Mammal Protection Act, and Endangered Species Act.

USFWS's R&D efforts are focused on identifying chemical pollutants and their metabolites in biological tissues; defining and mapping wetlands, other critical habitats, and natural resources; inventorying species of particular concern, including threatened and endangered species; developing biological indicators and economic tools for damage assessment; and determining biological requirements for sustaining viable populations and habitats and identifying factors contributing to their demise. The R&D efforts help DOI meet its operational needs and the requirements of OPA 90.

2.1.2.8 Maritime Administration (MARAD)

USDOT MARAD is tasked with promoting the use of waterborne transportation and its seamless integration with other segments of the transportation system, and the viability of the U.S. Merchant Marine. MARAD's role in maritime transportation spans many areas involving ships and shipping, shipbuilding, port operations, vessel operations, national security, environment, and safety. MARAD supports the Maritime Environmental and Technical Assistance (META) program, which focuses on environmental research and demonstration projects. MARAD collaborates extensively with stakeholders from all transportation sectors and modes to accomplish its mission to improve and strengthen the U.S. marine transportation system. Through long range planning and analysis, its Office of Policy and Plans develops plans for integrating the MARAD's activities with those of other appropriate government agencies, as well as private sector marine transportation stakeholders.

2.1.2.9 Pipeline & Hazardous Materials Safety Administration (PHMSA)

The mission of USDOT's PHMSA is to protect people and the environment from the risks of hazardous materials transportation by establishing national policy, setting, and enforcing standards, providing education, and conducting research to prevent oil spills and hazardous materials incidents. PHMSA's Office of Pipeline Safety promulgates and enforces regulations addressing the design, construction, operation, and maintenance of pipeline systems. PHMSA's Pipeline Safety Research Program supports the mission by funding technology development research and generating and sharing new technical knowledge with decision makers in support of planning, evaluation, and implementation of pipeline safety programs. This research focus provides near-term solutions that increase safety, reduce environmental impact, and improve reliability of the nation's pipeline system.

PHMSA, through its Office of Hazardous Materials Safety, provides support to federal agencies in oil spill related areas such as logistics management, transportation infrastructure, telecommunications, command and control systems, expert computer systems, facilities maintenance management, mobilization preparedness, and hazardous materials transportation by any mode.

2.1.2.10 U.S. Army Corps of Engineers (USACE)

USACE maintains specialized equipment and personnel that can be used in oil spill response activities. The Corps also maintain hydropower electric generating equipment, navigation channels, removing obstructions, and performing structural repairs. Their Engineering R&D Center (ERDC) supports soldiers, military installations, and civil works projects (e.g., water resources, environmental missions) as well as for other federal agencies, state, and municipal authorities (see section 2.3.9). USACE also works with U.S. industry through innovation agreements. ERDC has seven laboratories in four states: Cold Regions Research and Engineering Laboratory (CRREL) in Hanover, NH; Construction and Engineering Research laboratory in Champaign, IL (see section 2.3.8); Geospatial Research Laboratory in Alexandria, VA; and the Coastal and Hydraulics, Geotechnical and Structures, Environmental, and Information Technology Laboratories in Vicksburg, MS. CRREL maintains unique cold temperature facilities to conduct research on oil spill detection and response in Arctic and other ice-covered waters. Other USACE research with applicability to oil pollution issues includes providing technical support on wind and wave effects, diffusion, remote sensing, satellite imaging, image enhancement systems, alternative methods for removing oil, shoreline cleanup, and environmental evaluation, effects, and mitigation.

USACE also assists in design and construction and, on a reimbursable basis, provides technical manpower and support for federal agencies involved in any aspect of R&D described in this Plan. As the nation's engineering agency, the USACE manages one of the largest federal environmental missions: restoring degraded ecosystems; constructing sustainable facilities; regulating waterways; managing natural resources; and cleaning up contaminated sites from past military activities and has capabilities for assisting in the engineering aspects of conducting various research projects.

2.1.2.11 U.S. Navy

Naval Sea Systems Command's (NAVSEA) Directorate of Ocean Engineering, Supervisor of Salvage and Diving (SUPSALV) provides technical, operational, and emergency capabilities in marine salvage, pollution abatement, diving, diving system certification, and underwater ship husbandry to improve Fleet readiness and capability across the globe. SUPSALV provides the Navy with oil pollution expertise, as required by the Federal Water Pollution Control Act. SUPSALV has expertise in preventing and responding to oil spills from ships. Upon the request of an FOSC, it may provide technical assistance in the ocean engineering disciplines of marine salvage, shipboard damage control, pollution abatement, diving, diving system certification, and underwater ship husbandry.

SUPSALV maintains specialized containment, collection, and removal equipment designed for salvage-related and nearshore to open-sea pollution incidents. The equipment designs and systems make them transportable and sustainable in the field. SUPSALV has successfully deployed and operated its equipment at almost every major oil spill in the past 35 years.

2.1.2.12 U.S. Fire Administration (USFA)

As an entity of FEMA, USFA provides national leadership to foster a solid foundation for fire and emergency services in prevention, preparedness, and response. The Agency was established by Public Law 93-498, the Federal Fire Prevention and Control Act of 1974, which called for: 1) the establishment of a National Fire Academy to advance the professional development of the fire service personnel and of other persons engaged in fire prevention and control activities; 2) a technology program of development, testing, and evaluation of equipment for use by the nation's fire, rescue, and civil defense services; 3) the operation of a National Fire Data Center for the selection, analysis, publication, and dissemination of information related to the prevention, occurrence, control and results of fires of all types; and 4) education of the public to overcome indifference toward fire and fire prevention. USFA focuses on supplementing, not duplicating, existing programs of training, technology and research, data collection and analysis, and public education. While USFA does not directly conduct oil spill pollution research, it provides valuable emergency service expertise and connectivity to several emergency management programs.

2.1.2.13 U.S. Environmental Protection Agency (USEPA)

USEPA serves as the Chair of the NRT, as co-chair of all the RRTs. USEPA works closely with the USCG in coastal spill response activities. In accordance with the NCP, USEPA is the lead agency for response to spills in the inland USEPA provides pre-designated On-Scene Coordinators (OSCs) for the inland zone, and maintains assets that can be used for command, control, and surveillance of oil spills. USEPA also provides legal expertise on the interpretation of applicable environmental statutes.

USEPA issues and implements federal regulations regarding oil spills under the Clean Water Act (CWA), including the NCP. It implements spill prevention regulations for non-transportation-related facilities. Through Subpart J of the NCP, USEPA maintains a Product Schedule of dispersants and other oil spill mitigating substances and regulates their use during spill response.

USEPA provides expertise on cleanup technologies and the environmental effects of oil spills. Its Environmental Response Team (ERT) is a group of highly trained scientists and engineers whose capabilities include multimedia sampling and analysis, hazard evaluation, contamination monitoring, cleanup techniques, and overall technical support to the OSCs. The USEPA's R&D activities include the development of test protocols to evaluate the efficacy and toxicity of spill mitigating agents (e.g., dispersants), and research to determine the fate and effects of oil following a spill.

2.1.2.14 National Aeronautics and Space Administration (NASA)

NASA develops and maintains several technologically advanced airborne and satellite systems suitable for spill observation and mapping. The agency's multi-disciplinary team of scientists, engineers and computer modelers also analyzes vast archives of data for insights into Earth's interconnected systems atmosphere, ocean, ice, land, and biosphere; and provides that data to the global community. NASA designs and deploys airborne, ground-based, and ocean-going field campaigns to study the earth from the stratosphere and deep ocean to the remote ice caps at the poles. NASA also works with other government agencies and partner organizations to apply NASA data and computer models to improve decision-making and problem solving.

2.1.2.15 U.S. Arctic Research Commission (USARC)

The USARC is an independent federal agency created by the Arctic Research and Policy Act of 1984. It consists of a nonpartisan advisory body of scientists, physicians, indigenous leaders, and industry representatives appointed by the President and supported by staff located in Washington, D.C. and Anchorage, AK. The commission sets U.S. Arctic research policy and builds cooperative links in research including: 1) the U.S. Arctic research program, 2) international research partners, and 3) Alaska. The law requires the commission inform Congress on the progress of the executive branch in reaching goals set by the Commission and on their adoption by the Interagency Arctic Research and Policy Committee (IARPC). The commission plays an active role in the work of several interagency committees, including the Arctic Policy Group, chaired by the U.S. Department of State, which oversees U.S. participation in the eight-nation Arctic Council. The commission is a statutory member of the North Pacific Research Board and the North Slope Science Initiative. USARC is also a member of: various committees of the National Ocean Governance Structure; the interagency Extended Continental Shelf Task Force; the Scientific Ice Expeditions Interagency Committee, involving U.S. Navy nuclear submarines in the Arctic; the Alaska Ocean Observing System; the International Permafrost Association; and the Consortium for Ocean Leadership.

2.1.2.16 U.S. Geological Survey (USGS)

USGS supports an array of scientific capabilities and assets that address many elements of oil pollution research. As a science agency for DOI, the USGS provides science leadership and collaborations with other federal agencies during oil spill response. USGS research capabilities related to oil pollution include to inform policies and practices to avoid exposure to toxic substances, mitigate environmental deterioration from contaminants, provide cost-effective cleanup and waste- disposal strategies, and reduce future risk of contamination. USGS science primarily focuses on inland areas, but also includes nearshore and offshore environments.

USGS oil pollution related capabilities include long-term monitoring of the *Exxon Valdez*, *Deepwater Horizon*, and inland oil spills. USGS has expertise in water quality characterization, oil fingerprinting, submerged oil and oil-particle formation, transport, and resuspension of oil in fresh waters, riverine 2D particle transport/hydrodynamic simulations, ecotoxicology, time of travel studies for freshwater systems, and geospatial data collection of visible spill plumes, applicable to spill response events in marine and freshwater environments. In addition, USGS provides biological survey assistance for natural resources and contaminants and can contribute distribution information about sensitive species (e.g., seabirds, otters, invertebrates in the marine environment). USGS also provides extensive expertise and information for Natural Resource Damage Assessments (e.g., aerial surveys, abundance estimation, remote sensing).

2.2 Other Federal Stakeholders and Entities

Several Federal stakeholders and organizations also conduct research or affect oil pollution research. These include Federal independent organizations (e.g., committees, councils), agencies not currently members of ICCOPR, and ICCOPR member components that do not actively participate within ICCOPR. Other entities set Federal policies that guide or focus research initiatives on specific topics. ICCOPR maintains awareness of these stakeholders and works with them to coordinate research efforts.

2.2.1 Arctic Executive Steering Committee (AESC)

The AESC was formed in 2015 by Executive Order to provide guidance to executive departments and agencies and enhance coordination of Federal Arctic policies across agencies and offices, and, where applicable, with state, local, and Alaska Native tribal governments, Alaska Native organizations, academic and research institutions, and the private and nonprofit sectors. The AESC provides guidance and coordinates efforts to implement the priorities, objectives, activities, and responsibilities identified in National Security Presidential Directive 66/Homeland Security Presidential Directive 25, Arctic Regional Policy, the National Strategy for the Arctic Region (NSAR), the NSAR

Implementation Plan (NSAR-IP), and related agency plans. The AESC does not conduct oil pollution research but can influence the policies guiding research in the Arctic.

2.2.2 *Deepwater Horizon* Natural Resource Damage Assessment (NRDA) Trustee Council

After the *Deepwater Horizon* oil spill, federal and state agencies came together to form the *Deepwater Horizon* NRDA Trustee Council. The council studied the effects of the oil spill and continues to restore the Gulf of Mexico to its pre-spill condition. The trustee council consists of four federal agencies, the NOAA, DOI, USEPA, and U.S. Department of Agriculture (USDA). Each of the five Gulf states (Alabama, Florida, Louisiana, Mississippi, and Texas) also have representatives on the council. Currently, the trustees are coordinating with other restoration efforts in the Gulf as needed.

2.2.3 Department of the Interior (DOI) Inland Oil Spill Preparedness Program (IOSPP)

DOI developed the Inland Oil Spill Preparedness Program (IOSPP) in 2015 due to the growth in domestic oil production and inland transportation. IOSPP facilitate participation by DOI in nation-wide oil spill preparedness and response activities by providing: DOI participation and coordination in regional, area, and geographic committee planning activities and in inland oil spill response exercises and drills held by other federal agencies; developing an online library of guidance, templates, and technical resources; and the development of DOI training programs to support inland oil spill contingency planning and response activities, focusing on protecting natural and cultural resources and tribal lands. The IOSPP representatives include: Bureau of Indian Affairs (BIA), Bureau of Land Management (BLM), USFWS, National Parks Service (NPS), Office of Surface Mining and Reclamation and Enforcement (OSMRE), USGS, and U.S. Bureau of Reclamation (USBR).

2.2.4 National Offshore Safety Advisory Committee (NOSAC)

The National Offshore Safety Advisory Committee (NOSAC) was established in 1988 and serves in an advisory capacity to USDHS on matters relating to the safety of offshore mineral and energy industries. The committee consists of 15 members who have expertise in the technology, equipment and techniques that are used in the exploration and recovery of offshore mineral resources. NOSAC is represented by a broad range of personnel from the offshore industry including petroleum production, offshore drilling, support vessel operators, offshore construction, subsea operations, diving, geophysical services, and arctic operations. The committee is a platform to collect technical recommendations from industry on new regulations, policy, and industry standards.

2.2.5 Federal Oil Spill Team for Emergency Response Remote Sensing (FOSTERRS)

The Federal Oil Spill Team for Emergency Response Remote Sensing (FOSTERRS) is an interagency working group organized in 2015 to facilitate the sharing of remote sensing capabilities and to discuss improvements in disaster response using remote sensing. Specifically, FOSTERRS seeks to promote information on airborne and spaceborne asset availability, limitations, capabilities and performance, and ancillary data needs to stakeholders and responders. FOSTERRS includes members from NOAA, NASA and USGS that have remote sensing assets and key end users. It also reaches out to the larger community involved in marine disaster response and the development and implementation of remote sensing best practices.

2.2.6 Federal Rail Administration (FRA)

The Department of Transportation Act of 1966 created the FRA with a mission to enable the safe, reliable, and efficient movement of people and goods in the nation. It is one of ten agencies within the USDOT concerned with intermodal transportation.

FRA's Office of Railroad Safety promotes and regulates safety throughout the nation's railroad industry. The office executes its regulatory and inspection responsibilities using a diverse staff of railroad safety experts who are responsible for five safety disciplines focusing on compliance and enforcement in hazardous materials, motive power and equipment, operating practices, signal and train control, and tracks.

2.2.7 NOAA RESTORE Act Science Program

In 2012, Congress passed (P.L. 112-141) the “Resources and Ecosystem Sustainability, Tourist Opportunities, and Revived Economies of the Gulf Coast States Act” (RESTORE Act). It transfers 80% of all administrative and civil penalties paid by responsible parties in connection with the *Deepwater Horizon* incident to a Gulf Coast Restoration Trust Fund. The RESTORE Act also establishes several programs, funded by the Trust Fund, to aid in the ecological and economic recovery of the Gulf Coast states. Section 1604 of the RESTORE Act directs NOAA to establish a Gulf Coast Ecosystem Restoration Science, Observation, Monitoring, and Technology Program (NOAA RESTORE Act Science Program). This program is funded by 2.5% of the Gulf Coast Ecosystem Restoration Trust Fund plus 25% of the Trust Fund’s accrued interest. The Program can expend funds for marine and estuarine research; marine and estuarine ecosystem monitoring and ocean observation; data collection and stock assessments; pilot programs for fishery independent data and reduction of exploitation of spawning aggregations; and cooperative research.

2.2.8 Gulf Restoration Science Programs Ad Hoc Coordination Forum

The NOAA RESTORE Act Science Program is the lead of the Gulf Restoration Science Programs Ad Hoc Coordination Forum, which is a body focused on coordination and integration among entities funded through *Deepwater Horizon*-related penalty funds. Other members of this forum include the Gulf Coast Research Council, National Fish and Wildlife Foundation (NFWF), Gulf Environment Benefit Fund (GEBF), NAS, Gulf Research Program (GRP) serves to provide regular communication and coordination on Gulf of Mexico restoration related science between the ecological sciences programs funded from criminal penalties, settlement agreements, and programs funded due to the *Deepwater Horizon* oil spill.

2.2.9 Gulf Coast Ecosystem Restoration Council

In July 2012, the RESTORE Act established a Gulf Coast Ecosystem Restoration Council (the Council) to develop and implement a comprehensive plan to restore the ecosystem and the economy of the Gulf Coast region. The Initial Comprehensive Plan was approved in 2013 and provided a framework to implement a coordinated, region-wide restoration effort. The council updated it in 2016 to include the resolution of the *Deepwater Horizon* oil spill civil claims against BP. The council also holds public meetings to collect feedback on the funded priorities list. The council is comprised of governors from the five Gulf States affected by the *Deepwater Horizon* oil spill, the Secretaries from the DOI, DOC, USDA, USDHS, the Army, and the Administrator of the USEPA. The Gulf States recommended, and President Obama appointed the Secretary of Commerce as the Council’s first Chair. Currently, a representative from the USEPA serves as the council chair.

2.2.10 Gulf States Marine Fisheries Commission (GSMFC)

GSMFC was established by an act of Congress (P.L. 81- 66) in 1949 as a compact of the five Gulf States with a charge to: “to promote better utilization of the fisheries, marine, shell and anadromous, of the seaboard of the Gulf of Mexico, by the development of a joint program for the promotion and protection of such fisheries and the prevention of the physical waste of the fisheries from any cause."

GSMFC provides coordination and administration for cooperative state and federal programs regarding marine fisheries resources. The GSMFC developed a fisheries disaster recovery program in response to Federal funding opportunities where fisheries disasters were declared. Since 2006, GSMFC has been responsible for the receipt and distribution of nearly $277 million used in the Gulf states as they addressed the impacts of Hurricanes Katrina, Wilma, and Rita in 2005, and the *Deepwater Horizon* oil spill in 2010.

2.2.11 Gulf of Mexico Fishery Management Council (GMFMC)

The GMFMC is one of eight regional Fishery Management Councils established by the Fishery Conservation and Management Act of 1976. The council prepares fishery management plans for fishery resources from where state waters end out to the 200-mile limit of the Gulf of Mexico. These waters are also known as the Exclusive Economic Zone (EEZ). The Council consists of voting members from the NMFS, the five Gulf state marine resource management agencies, and nominees of the Gulf state governors. In addition, there are four nonvoting members representing the USCG, USFWS, Department of State, and the GSMFC. The GMFMC provides an advisory role in directing scientists on where to focus their research. Current priorities include research on species recovering from the *Deepwater Horizon* oil spill and long-term fisheries data.

2.2.12 U.S. Marine Mammal Commission (MMC)

The MMC is an independent agency of the U.S. government established under Title II of the Marine Mammal Protection Act (MMPA). The Commission provides independent oversight of all science, policy, and management actions of federal agencies affecting marine mammals and their ecosystems. The commission's main oil spill related roles are to oversee agencies charged with response, assessment, and restoration activities, and convene interagency working groups to coordinate those activities.

In 2014, the Commission released a Strategic Plan for 2015-2019. The plan centers on five strategic objectives: offshore energy, international, health and strandings, the Arctic, and fishery activities. The Commission focuses on marine mammals that are considered most vulnerable to human activities and the role marine mammals play in the economy.

The Commission administers a small annual grant program that supports projects aimed at meeting the conservation and protection goals of the MMPA. In addition, the Commission conducted an online survey of federally funded marine mammal research and maintains a data repository that provides information on what marine mammal research is being supported by federal agencies (e.g., which species, where, and at what cost). The survey helps to identify research gaps, highlighting areas of strength in federal research investment, and recommendations on needed actions and budget priorities.

2.2.13 National Academy of Sciences Gulf Research Program (GRP)

As part of the criminal settlement agreements following the *Deepwater Horizon* Oil Spill, the federal government asked the National Academy of Sciences (NAS) to establish a new program. The GRP was established in 2013 with $500 million in criminal settlement funds entrusted to NAS as an endowment scheduled to end in 2043. The GRP works to advance and apply science, engineering and, public health knowledge to reduce the risk of future oil spill disasters and enables Gulf communities to prepare, mitigate, and recovery from future events if they should occur. There are five GRP initiatives that are in various stages of development and implementation: offshore situation room, enhancing community resilience, understanding gulf ocean systems, the Gulf scholars' program, and the data fellowship program. As GRP grows, these initiatives will continue to evolve to meet new needs and challenges as they arise.

2.2.14 National Institute of Environmental Health Sciences (NIEHS)

NIEHS is one of 27 research institutes and centers that comprise the National Institutes of Health (NIH) of the Department of Health and Human Services (DHHS). The mission of the NIEHS is to reduce the burden of human illness and disability by understanding how the environment influences the development and progression of human disease. The NIEHS provides timely and responsive services. Such as the Gulf Long-Term Follow-up (GuLF) Study on the health of the workers and volunteers most directly involved in responding to the *Deepwater Horizon* oil spill. The GuLF Study is determining if oil spills and the exposure to crude oil and dispersants, affects physical and mental health. Between 2011 and 2013, about 33,000 cleanup workers were enrolled in the 10-year health study, making a significant contribution to their communities and to answering important public health questions. More than 11,000 of the participants completed home examinations, which included questionnaires and the collection of biological and environmental samples. The GuLF Study is currently tracking the health of participants by conducting follow-up telephone interviews that include detailed health questionnaires. The first follow-up occurred from 2013 – 2016 with more than 19,000 participants undergoing a phone interview and over 3,500 participants completing a comprehensive clinical exam.

2.2.15 U.S. National Response Team (NRT) - Science and Technology (S&T) Committee

The NRT is an organization of 15 Federal departments and agencies responsible for coordinating emergency preparedness and response to oil and hazardous substance pollution incidents. USEPA and USCG serve as Chair and Vice Chair, respectively. The NCP and the Code of Federal Regulations (40 CFR part 300) outline the role of the NRT and RRTs. Various federal statutes cite the NRT and RRTs including the Superfund Amendments and Reauthorization Act - Title III and the Hazardous Materials Transportation Act (HMTA).

The NRT's Science and Technology Committee provides a forum to fulfill the NRT's NCP delegated responsibilities in R&D. Specifically, NCP regulation 40 CFR 300.110(h)(6) lists as one of the NRT's responsibilities "Monitoring response-related research and development, testing, and evaluation activities of NRT agencies to enhance coordination, avoid duplication of effort, and facilitate research in support of response activities." Additionally, 40 CFR 300.110(g) states, "the NRT may consider and make recommendations to appropriate agencies on ... necessary research, development, demonstration, and evaluation to improve response capabilities."

2.2.16 National Science Foundation (NSF)

NSF is an independent federal agency created by Congress in 1950 "to promote the progress of science; to advance the national health, prosperity, and welfare. NSF is the funding source for approximately 25% of all federally supported basic research conducted by U.S.'s colleges and universities with an annual budget of $8.3 billion (FY 2020). It is the only federal agency that supports all fields of fundamental science and engineering, except for medical sciences. In addition to funding traditional topics, NSF also supports "high-risk, high pay-off" ideas to keep the U.S. at the leading edge of discovery. NSF issues limited-term grants to fund specific research proposals judged to be the most promising by a rigorous and objective merit-review system. Currently, they issue about 12,000 new awards per year, with an average duration of three years. NSF is divided into seven directorates, each has applications to oil pollution research: Biological Sciences, Computer and Information Science and Engineering, Engineering, Geosciences, Mathematical and Physical Sciences, Social, Behavioral and Economic Sciences, and Education and Human Resources. NSF also has a Rapid Response Research (RAPID) mechanism that enables research on unanticipated events, which funded more than 60 awards totaling nearly $7 million during the *Deepwater Horizon* oil spill.

2.2.17 North American Wetlands Conservation Act (NAWCA) Gulf of Mexico Funds

The NAWCA through USFWS provides matching grants from the North American Wetlands Conservation Fund to organizations and individuals who have developed partnerships to carry out conservation projects in the U.S., Canada, and Mexico for the benefit of wetlands- associated migratory birds and other wildlife. As part of the *Deepwater Horizon* criminal settlement agreement, BP paid $100 million to the Fund for the purpose of wetlands restoration and conservation located in states bordering the Gulf of Mexico or otherwise designed to benefit migratory bird species and other wildlife affected by the spill. The projects include research to monitor and evaluate restoration success.

2.3 Federal Research Laboratories and Testing Facilities

Several federal facilities provide opportunities for oil pollution research.

2.3.1 Ohmsett

Ohmsett, located at the Naval Weapons Station Earle Waterfront in Leonardo, NJ, is managed by BSEE. The facility includes an above ground concrete test tank that is one of the largest of its kind, measuring 666 ft. long by 66 ft. wide by 8 ft. The tank holds with 2.6 million gallons of saltwater. The Ohmsett test tank allows testing of full-scale oil pollution response equipment. The tank includes a wave generator that creates realistic sea environments, while state-of-the-art data collection and video systems record test results.

Government agencies, academia, public and private companies use Ohmsett as a research center to: test oil spill containment/clean-up equipment and techniques, test new designs in response equipment, evaluate acquisition options, validate research findings, and conduct training with actual oil spill response technologies.

2.3.2 USCG Research, Development, Test and Evaluation (RDT&E)

The USCG RDT&E program comprises the Office of RDT&E in Washington, D.C., and the RDC at New London, CT. The RDC is the USCG's sole facility performing RDT&E experimentation and demonstrations. It is responsible for evaluating the feasibility and affordability of mission execution solutions and providing operational and risk-management analysis at all stages of the acquisition process.

At any given time, the RDT&E program is working on more than 80 projects that support USCG requirements across all mission areas. The program also provides USCG leadership with the knowledge necessary for making strategic decisions. The RDT&E program leverages partnerships with academia and other government agencies. It also leverages Cooperative Research and Development Agreements (CRADAs) under the Technology Transfer Act to work with private industry to develop solutions to current and future technological challenges.

2.3.3 USCG National Center of Expertise (NCOE) for the Great Lakes

The Great Lakes region (Coast Guard District 9, D9) is a uniquely challenging environment for oil-spill preparedness and response. This vast, interconnected freshwater environment of rivers, lakes, and connecting channels experiences changing circulation patterns, severe weather, and seasonal, but varying ice-cover. The Great Lakes are a key environmental and economic resource for much of the nation, which increases the criticality of effective oil-spill response in the region. The Great Lakes region has pipelines, railways, refineries, barge, and tanker traffic that transport the full scope of petroleum products (e.g., crude oils, bitumen, asphalt, gasoline, kerosene, other refined products) increasing the risk of damage from a spill and make response more challenging. The fact that four of the lakes straddle the U.S.- Canada boundary also means that any major response requires binational coordination. For all these reasons, Congress mandated that the Coast Guard establish the GL NCOE in 2018 (Public Law No: 115-282).

The Great Lakes NCOE will examine the impacts of oil spills in freshwater environments and help develop effective responses. It will focus on identifying gaps in Great Lakes oil spill research, monitoring, and assessing the current state of knowledge, conducting research, development, testing, and evaluation of freshwater oil spill response equipment, training first responders, and collaborating with the academic and private sector. The USCG is currently deciding on a site location and planning the development of the NCOE.

2.3.4 USCG Marine Safety Laboratory

The USCG MSL located in New London, CT provides forensic oil analysis and expert testimony in support of the oil pollution law enforcement efforts for marine investigators, districts, hearing officers, the NPFC, Department of Justice, and other federal agencies. The laboratory is the USCG's sole facility for performing forensic oil analysis.

2.3.5 U.S. EPA National Risk Management Research Laboratory (NRMRL)

NRMRL in Cincinnati, OH is USEPA’s premier laboratory for risk management research and aims to advance scientific and engineering solutions to manage current and future environmental risks. NRMRL’s research supports efforts to improve air quality, manage chemical risks, clean up hazardous waste sites, and protect the nation’s waters. It conducts research at the basic bench and pilot-scale levels, exploring innovative solutions to pollution problems. The laboratory determines what environmental risks exist and how to manage those risks in a way best suited to protect human health and the environment.

2.3.6 USGS National Crude Oil Spill Fate and Natural Attenuation Research Site

The Minnesota National Crude Oil Spill Fate and Natural Attenuation Site located near Bemidji, MN, originated from an oil spill that occurred in 1979 when a pipeline transporting crude oil ruptured and released 10,000 bbl of crude petroleum to the land surface and shallow subsurface. In 1983, research began at the site through the support of the USGS' Toxic Substances Hydrology Program. Continuing USGS support has allowed hundreds of scientists from across the globe to visit this "underground observatory" and study the effects of a terrestrial crude oil spill including the physical, chemical, and biological processes driving the degradation and transport of crude petroleum. Research from the site has been included in more than 200 scientific papers.

In 2008 and 2009, the Minnesota Pollution Control Agency, Enbridge Energy LLC, the USGS and Beltrami County created several agreements to formally establish the "National Crude Oil Spill Research Site in Bemidji, MN." The objective of these agreements was to create a self-sustaining research facility that brings academic researchers and practitioners (e.g., consultants, petroleum and pipeline industry representatives and pollution control officials) together thereby linking novel ideas to practical, on-the-ground applications.

2.3.7 USACE Research and Development Center (ERDC)

As discussed in Section 2.1.2.10, the USACE's ERDC includes seven laboratories located in four geographic locations, provides a broad array of services ranging from basic research to test and evaluation. ERDC capabilities to support oil spill efforts focus on; Emergency Response/Mitigation, activities that enhance the ability to conduct emergency response and mitigation; Remediation, activities designed to support tasks such as active intervention to ameliorate the oil contamination; and Recovery/Long Term Monitoring/Assessment activities supporting the monitoring and assessment of long-term environmental impacts associated with the spill.

USACE CRREL, located in Hanover, NH, aims to solve interdisciplinary and strategically important problems by advancing and applying science and engineering to complex environments, materials and processes in all seasons and climates, with unique core competencies related to the Earth's cold regions. CRREL maintains several unique and specialized research facilities at its Hanover location, including: 26 low-temperature research cold rooms; a refrigerated Ice Engineering Facility comprised of a 12,800 sq. ft. research area, a 3,600 sq. ft. by 8 ft. deep test basin, and a 120 ft. long water flume with tilting bed; a 1,320 sq. ft. by 7 ft. deep outdoor Geophysical Research Facility; a 40 ft. working length portable wave tank that can be located indoors within a cold facility for year round cold research or outdoors to support *in situ* burn tests; and a 29,000 sq. ft. environmentally controlled Frost Effects Research Facility.

CRREL also maintains a research permafrost tunnel in Fox, AK a 135- acre permafrost research site near Fairbanks, AK, and has project offices in Anchorage and Fairbanks. CRREL works with partners from industry, government agencies and educational institutions to develop scientific tools that can aid in effective oil spill response and provides unique facilities and cold region expertise to stakeholders to create effective spill response techniques for ice covered environments.

2.3.8 Hollings Marine Laboratory (HML)

The Hollings Marine Laboratory, located in Charleston, SC, was established as a joint facility combining partners from NOAA, NIST, the Medical University of South Carolina, the College of Charleston, and the South Carolina Department of Natural Resources. The laboratory is operated by NOAA NOS and houses NIST's Environmental Specimen Bank and environmental chemistry laboratories. Immediately after the *Deepwater Horizon* oil spill, the co-location of NOAA and NIST personnel was instrumental in planning and mounting NOAA's archiving of sample, monitoring protected species, and evaluating the quality of chemistry data produced by different laboratories. Oil spill related research continues at the HML with projects on biomarkers of oil exposure in protected species and effects of dispersants on marine organisms and humans.

2.3.9 U.S. Naval Research Laboratory (NRL) Detachments

The NRL detachment located at Stennis Space Center, in Mississippi, focuses on marine geosciences, oceanography, and underwater acoustics. The Oceanography Division and Marine Geosciences Division conduct studies applicable to oil pollution research.

The Oceanography Division is known for its combination of theoretical, numerical, and experimental approaches to oceanographic problems. It numerically models the ocean on the world's most powerful supercomputers and operates several highly sophisticated graphics systems to visualize ocean model results. The division maintains two satellite receiving systems, a computer network with automated processing capabilities for ocean color and advanced optical instrumentation and calibration facilities.

The Marine Geosciences Division conducts a broadly-based, program of scientific research and advanced technology development. This multidisciplinary program is directed towards maritime and other national applications of geosciences, geospatial information, and related technologies. Research includes investigations of basic processes within ocean basins and littoral regions. The division develops models, sensors, techniques, and systems to enhance Navy and Marine Corps systems, plans, and operations.

NRL's Chesapeake Bay Detachment (CBD) conducts research and technology development in radar, electronic warfare, optical devices, materials, communications, and fire. Oil pollution research conducted at NRL focuses on testing and improving *in-situ* burn (ISB) capabilities.

2.3.10 Pacific Northwest National Laboratory (PNNL)

The PNNL's Marine Sciences Laboratory (MSL), located in Sequim, WA on the Strait of Juan de Fuca, provides a platform for marine and freshwater ecological research, instrument and method development, and biotechnology research. The laboratory has regional access to oceans and rivers that have experienced human impacts ranging from the uninhabited and protected coastlines of Olympic National Park to heavily developed shores around Seattle and Tacoma. The Marine Research Operations' Wet Laboratory performs innovative, water-oriented research. A variety of indoor and outdoor tanks provide capacity for bench-scale tests through large-scale outdoor mesocosm systems, including for studies using aquatic plants and animals.

2.4 Coastal and Ocean Research Vessels

2.4.1 USCG Vessels

USCG operational polar fleet includes one 399-ft heavy icebreaker (Coast Guard Cutter Polar Star, commissioned in 1976) and one 420-ft medium icebreaker (Coast Guard Cutter Healy, commissioned in 2000) and several other ice-capable tugs and tenders. These cutters are designed for open-water icebreaking. The first polar security cutter (PSC) is under design and is anticipated to be completed in 2024. PSCs will ensure continued access to polar regions and support the nation's economic, commercial, maritime, and national security needs.

2.4.2 USEPA Vessels

The USEPA operates two ships that monitor and assess impacts from ecological disturbances and ocean-based human activities on the ocean, Great Lakes, and coastal waters. USEPA's Ocean Survey Vessel (OSV) *Bold* operates under the statutory requirement to monitor the deposition of dredged materials under the Marine Protection, Research, and Sanctuaries Act of 1972. This Act regulates intentional ocean disposal of materials, authorizes any related research, and provides for the designation and regulation of marine sanctuaries. OSV *Bold* is equipped with state-of-the-art sampling, mapping, and analysis equipment and operates in the Atlantic and Pacific Oceans and the Caribbean Sea and monitors water quality, effects of dredged material, coral reef health, and other special assessments.

USEPA's Great Lakes National Program Office, based in Chicago, IL, operates R/V *Lake Guardian*, which conducts monitoring programs that sample water, aquatic life, sediments, and air to assess the health of the Great Lakes ecosystem.

2.4.3 MARAD Vessels

MARAD operates the National Defense Reserve Fleet (NDRF) of 100 ships that are available for use during oil spill exercises and education or training events and can provide housing during spill responses. The NDRF is available to support emergency shipping operations during war and national emergencies. The fleet has anchorages in Fort Eustis, VA; Beaumont, TX; Suisun Bay in Benicia, CA; and at designated port facility berths.

2.4.4 NOAA Vessels

NOAA operates a wide assortment of hydrographic survey, oceanographic research, and fisheries survey vessels. NOAA Ships are operated by NOAA's Office of Marine and Aviation Operations (OMAO) through Marine Operations Centers in the Atlantic, Pacific, and Pacific Islands that manage nine, five, and two ships, respectively.

NOAA operates the nation's largest fleet of federal research ships, ranging from large oceanographic research vessels capable of exploring the world's deepest ocean, to smaller ships and boats with research and operational missions. The fleet supports a wide range of marine activities including fisheries research, nautical charting, and ocean and climate studies. NOAA line offices operate small boats located around the coasts and Great Lakes in support of NOAA's science, service, and stewardship missions, including research vessels capable of extended overnight operations.

NOAA OMAO's aircraft operate throughout the world providing a wide range of capabilities including hurricane reconnaissance and research, marine mammal and fisheries assessment, and coastal mapping.

2.5 Oil Spill Field Research

Federal oil pollution research is not limited to research facilities and laboratories. Oil spills can provide opportunities for federal agencies to conduct research on the fate, effects, and physical and chemical behavior of the spilled oil and the response of the natural environment. NOAA and USGS have ongoing research projects to study the long-term fate and effects of the *Exxon Valdez* oil spill. The *Deepwater Horizon* oil spill also provides many opportunities to study both the near-term and long-term effects of the spill and response. The Santa Barbara oil seeps, other natural seeps, and ongoing leaks from shipwrecks or damaged structures have been used for oil spill research.

Intentional releases have been used by many countries, most notably Norway, to demonstrate the effectiveness of spill control equipment or processes. Under controlled circumstances, these releases may provide an opportunity to conduct tests under actual spill conditions.

3. Non-Federal Oil Pollution Research Entities

Consistent with the mandates of OPA 90, ICCOPR cooperates with research programs of state governments, industry, academia, non-governmental organizations (NGOs), and other nations. The cooperation of federal and non-federal entities provides a community approach to oil pollution research. The following sections describe non-federal entities that conduct or sponsor oil pollution research.

3.1 State Organizations

Several coastal states have established oil pollution research programs. These programs are in states affected by previous oil spills or where there are active oil exploration and production activities. Shale oil production has prompted some states to study the risks of hydraulic fracturing and transporting oil by rail and pipeline. This section describes state research programs.

3.1.1 Alaska Department of Environmental Conservation (ADEC)

Judgments entered in the criminal cases for the *Exxon Valdez* oil spill resulted in the appropriation of funds to the State of Alaska to enhance the ability of the state and industry to respond to oil spills. A total of $2.5 million was made available to ADEC for projects under this program. The funds are used for research programs directed toward the prevention, containment, cleanup, and amelioration of oil spills in Alaska. In cooperation with other stakeholders, ADEC has developed a list of R&D projects dealing with such subjects as cleanup technology, non-mechanical response techniques, the fate and effects of spilled oil, oil spill contingency planning and preparedness, spill response training, incident-management systems, and spill prevention. Alaskan oil spill response cooperatives, private consultants, universities, and other state and federal agencies have conducted research under the program.

3.1.2 California Office of Spill Prevention and Response (CAOSPR)

As a prevention and response organization, CAOSPR has the Department of Fish and Wildlife's public trustee and custodial responsibilities for protecting, managing, and restoring California’s fish, wildlife, and plants. It is one of the few state agencies in the nation with response and public trustee authority for wildlife and habitats. This joint mandate ensures that prevention, preparedness, restoration, and response will provide the best protection for California's natural resources.

In 2014, California expanded CAOSPR's program to cover all state surface waters at risk of oil spills from any source, including pipelines, production facilities, and railroad shipments. This expansion provided critical administrative funding for industry preparedness, spill response, and continued coordination with local, state, and federal governments along with industry and NGOs.

Every two years, CAOSPR and Chevron host an Oil Spill Response Technology Workshop to expand responders' understanding of current and emerging technologies and help them achieve the best available protection for California waters. Representatives from all levels of government, industry, and NGOs participate in the biennial workshops.

3.1.3 Florida

The Florida Fish and Wildlife Research Institute's work includes assessment and restoration of ecosystems and studies of freshwater and marine fisheries, aquatic and terrestrial wildlife, imperiled species, and red tides. The institute develops the scientific information required to analyze and disseminate research products and engages in outreach activities to complement all programs.

The Florida Marine Spill Analysis System (FMSAS) is a powerful geographic information system (GIS) application that allows users to conduct oil spill planning activities and manage response and mitigation efforts during spill. From simple notes on nautical charts to specialized maps showing the location of sensitive resources or the location of an oil slick, many of the essential information components of planning and response actions require geospatial data. The FMSAS is designed to address five aspects of oil spill management: contingency planning; on-scene spill tracking and "Resources at Risk" (RAR) analysis; long-term monitoring; damage assessment; and general oil spill data management.

3.1.4 Pacific States/British Columbia Oil Spill Task Force

In 1989, following the *Nestucca* and *Exxon Valdez* oil spills, the Governors of Alaska, Washington, Oregon, and California, and the Premier of British Columbia, signed a Memorandum of Agreement that authorized the Pacific States/British Columbia Oil Spill Task Force (PSBCOSTF). These events highlighted the U.S. and Canada's common concerns regarding oil spill risks and the need for cooperation across the shared borders. In June 2001, a revised Memorandum of Cooperation was adopted to include the State of Hawaii and expand the focus to oil spill preparedness and prevention in the 21st century.

Now in its third decade, the task force provides a forum where its members can work with stakeholders from the Western US and Canada to implement regional initiatives that protect 56,660 miles of coastline from Alaska to California and the Hawaiian archipelago.

3.1.5 Texas General Land Office (TXGLO)

TXGLO is a national leader in oil spill research. The TXGLO R&D program has funded work on oil dispersants, shoreline cleaners, bioremediation, and high frequency radar. The R&D program focuses on response technology and alternative methods for removing oil from coastal waters.

Over the years, the TXGLO has coordinated with other state agencies, Texas' higher education institutions, and industry to establish viable research projects for oil spill prevention and response. Projects studied preventive technologies, spill detection, environmental data collection, chemical countermeasures, recovered materials management, and *in situ* burning.

3.1.6 Washington Department of Ecology (WADOE)

WADOE has program offices for oil pollution prevention, preparedness, response, resource damage assessment and recovery. The department conducts studies on the risks of oil transportation through the state and provides guidance to industry and the public on oil pollution issues. WADOE manages a Coastal Protection Fund (CPF) that collects monies from oil and hazardous materials spill damage assessments and penalties. CPF money funds projects to: restore or enhance public natural resources; investigate long-term effects of oil spills; and develop and implement aquatic land GIS. Funds may also be allocated for R&D on the causes, effects, and removal of pollution caused by the discharge of oil.

3.2 Industry

The oil industry plays an important part in oil pollution research. Industry approaches to exploration, production, transportation, and spill prevention evolve as new techniques are identified and new resources are found. Industry has several research programs to improve their practice to prevent oil spills and better respond to spills when they occur.

3.2.1 American Petroleum Institute (API) Joint Industry Task Force (JITF)

In the wake of the *Deepwater Horizon* oil spill of 2010, the API launched four JITFs to critically assess capabilities and performance. Each JITF used subject matter experts to identify best practices in offshore drilling operations and oil spill response. The identified best practices were shared across the industry and response community with the goal of ensuring environmental protection through enhanced safety.

The Oil Spill Preparedness and Response JITF examined industry's ability to respond to a "Spill of National Significance (SONS)" and the response to the *Deepwater Horizon* oil spill. This program covered: spill response planning, oils sensing and tracking, dispersants, *in situ* burning, mechanical recovery, shoreline protection, and alternate response technologies. All formal work on the JITFs has been completed and has resulted in numerous publications in theses topic areas.

3.2.2 American Salvage Association (ASA)

The ASA was created in 2000 for professional salvors dedicated to improving marine casualty response in North American coastal and inland waters. The ASA promotes cooperation among its members and works with federal and state agencies to identify ways to improve salvage and firefighting response. ASA encourages research to identify risks from sunken vessels and uses its members' experience to identify areas for additional research or technology development.

3.2.3 Arctic Oil Spill Response (OSR) Joint Industry Program (JIP)

The Arctic OSR JIP was a collaboration of nine international oil and gas companies (BP, Chevron, ConocoPhillips, Eni, ExxonMobil, North Caspian Operating Company, Shell, Statoil, and Total) to advance oil spill response capabilities. The JIP was initiated in 2012 under the International Association of Oil and Gas Producers (IOGP) and was completed in 2017. The JIP further improved Arctic oil spill response capabilities and provided a way to share knowledge among the participants and a broad range of stakeholders. The specific objectives of the JIP were to: improve Arctic oil spill response capabilities in dispersants, ISB, mechanical recovery, environmental effects, trajectory modeling, and remote sensing; develop a knowledge base to better assess the net environmental benefits of different response options; demonstrate the viability of existing oil spill response technologies in the Arctic and determine their operating boundaries; develop new oil spill response technologies for the Arctic; and to disseminate information on best practices for Arctic response.

3.2.4 Association of Petroleum Industry Co-op Managers (APICOM)

APICOM, founded in 1972, is an association of unaffiliated petroleum industry oil spill cooperative managers. APICOM exchanges information related to the management of an oil spill response cooperative. It also serves as a forum for the exchange of ideas related to oil spill response technologies, operations, regulations, and other issues of common interest to its members.

3.2.5 Industry Technical Advisory Committee (ITAC)

ITAC includes members from the oil spill response community that have oil pollution preparedness and response as their principal goal. ITAC acts as a focal point for technical issues and as a forum for exchanging information on response operations, technology, and training, as well as preparedness.

3.2.6 International Petroleum Industry Environmental Conservation Association (IPIECA)

IPIECA is the global oil and gas industry association that focuses on environmental and social issues. It develops, shares, and promotes good practices and knowledge to help the industry improve its environmental and social performance. It is the industry's principal channel of communication with the United Nations.

IPIECA's Oil Spill Working Group (OSWG) was established in 1987 and serves as a key international industry forum to help improve oil spill contingency planning and response around the world. It enables members to exchange information and best practices; supports industry and government cooperation at all levels; encourages ratification and implementation of relevant international conventions; promotes 'Net Environmental Benefit Analysis' and the 'Tiered Response' approach to designing response strategies; and develops and communicates the industry's views and activities to external audiences.

3.2.7 International Spill Control Organization (ISCO)

ISCO is a not-for-profit organization established in London in 1984 with membership in 50 countries around the world. ISCO raises worldwide preparedness and co-operation in response to oil and chemical spills, promotes technical development and professional competency, and provides a focus for making the knowledge and experience of spill control professionals available to IMO, the United Nations Environment Program (UNEP), European Commission (EC), and other organizations. ISCO provides organizations with information on experiences, problems solved, and lessons learned by spill responders. It also keeps the spill response community informed of new developments and news through their website and newsletter.

3.2.8 International Tanker Owners Pollution Federation (ITOPF)

ITOPF is a not-for-profit organization established on behalf of the world's ship owners and their insurers to promote effective response to marine spills of oil, chemicals, and other hazardous substances. ITOPF provides a range of technical services including emergency response, advice on clean up techniques, pollution damage assessment, assistance with spill response planning, and training. It is a source of objective technical expertise on accidental spills of oil and chemicals from ships and as a source of comprehensive information on marine pollution. ITOPF invests in R&D to help fulfill its mission of promoting effective response to marine spills.

3.2.9 Petroleum Environment Research Forum (PERF)

PERF is a research and development joint venture, formed to provide a stimulus to and forum for the collection, exchange, and analysis of research information relating to the development of technology for health, environment and safety, waste reduction and system security in the petroleum industry. PERF is a non-profit organization comprised of member corporations in the petroleum industry. PERF does not participate in research projects, but provides a forum for members to collect, exchange, and study information relating to practical and theoretical science and technology. It provides a mechanism to establish joint research projects in the field.

3.2.10 Pipeline Research Council International (PRCI)

The PRCI was established in 1952 as the Pipeline Research Committee of the American Gas Association to address the problem of long-running brittle fractures in natural gas transmission pipelines. In substantially solving that problem within two years, the committee demonstrated the benefit of industry collaboration and leveraging voluntary industry funding. The mission of PRCI is to be the global leader in collaborative energy pipeline research that provides safe, reliable, environmentally conscious, and efficient means of energy delivery. PRCI's goal is to improve current inspection and integrity assessment technologies and promote the development of new technologies for pipeline integrity management. Some of PRCI's recent research has addressed: corrosion (location and assessment), mechanical damage (location and assessment), Right of Way (ROW) monitoring, growth of construction defects, compressor and pump station safety, and monitoring.

3.2.11 Spill Control Association of America (SCAA)

SCAA, organized in 1973, promotes the interests of all groups within the spill response community. It represents spill response contractors, manufacturers, distributors, consultants, instructors, government, training institutions, and corporations working in the industry. SCAA partners with the USCG and APICOM on marine safety and environmental protection, to improve the effectiveness of spill response and promote sound risk management among private and governmental response organizations.

3.3 Independent Research Interests

Several independent organizations conduct or manage oil pollution research programs. These include NGOs, non-profit organizations, and committees with a mix of memberships including citizens, industry, and government organizations.

3.3.1 Cook Inlet Regional Citizen's Advisory Committee (CIRCAC)

OPA 90 established CIRCAC to create an avenue for public participation in the oversight of the Cook Inlet, AK oil industry. Since its inception, CIRCAC has formed environmental monitoring and oil spill prevention programs to promote safe production and transportation of oil. These programs focus on the efficacy, fate, transport, and effects of oil response methods likely to be used Cook Inlet on oil spills. It monitors the biological and chemical environment in Cook Inlet and nearby areas to detect effects of oil extraction operations. CIRCAC also has a Coastal Habitat Mapping Program to assess coastal habitats with an oil spill prevention and response tool that incorporates habitat data.

3.3.2 Gulf of Mexico Alliance (GOMA)

The Gulf state governors established the GOMA in 2004 in response to the U.S. President's Ocean Action Plan. GOMA's mission is to enhance the ecological and economic health of the Gulf region by encouraging collaboration among government agencies, businesses, education providers, and NGOs. It is a state-led network of partners working together on projects related to the priority issues identified by the governors. GOMA's structure allows federal and state agency partners to focus funding priorities on the needs of the Gulf. It provides a forum to share knowledge, expertise, and collaborate to reduce duplication of efforts.

3.3.3 Gulf of Mexico Research Initiative (GoMRI)

On May 24, 2010, shortly after the *Deepwater Horizon* oil spill, BP announced a $500 million commitment to fund GoMRI, a 10-year independent research program designed to study the effects of the oil spill and its associated response on the environment and public health in the Gulf of Mexico. GoMRI concluded in 2020. During its operation, it awarded funds for scientists to investigate the impacts of the oil, dispersed oil, and dispersants on the ecosystems of the Gulf of Mexico and affected coastal states in a broad context of improving fundamental understanding of the dynamics of such events and their environmental stresses and public health implications.

As directed by an independent Research Board, GoMRI issued grants for independent scientific research conducted at academic institutions, primarily those located in U.S. Gulf Coast states. The funds were distributed, using a peer review process. Researchers were required to publish their results in peer- reviewed scientific journals with no requirement for BP approval. This work resulted in more than 1,400 peer-reviewed publications.

The goal of GoMRI was to improve society's ability to understand, respond to and mitigate the impacts of petroleum pollution and related stressors of the marine and coastal ecosystems, with an emphasis on conditions found in the Gulf of Mexico. To document and exploit scientific achievements and advances, GoMRI underwent a Synthesis and Legacy (S&L) effort with the idea that synthesis will lead to new understanding and improved practices. A S&L Committee was established and subsequently identified eight core areas of focus and a set of guiding principles to maintain consistently through the process. In total, it is anticipated that nearly 50 unique products will result from the GoMRI synthesis effort culminating in the GoMRI Special Issue in Oceanography anticipated Spring 2021.

3.3.4 National Fish and Wildlife Federation (NFWF)

Congress created NFWF in 1984. It serves as a non-profit to aid in the protection and restoration of fish and wildlife and their habitats. The BP and Transocean Settlement Agreements with the U.S. established NFWF’s GEBF to support projects that remedy harm to natural resources (e.g., habitats, species) where there has been injury to, or destruction or loss of use of resources resulting from the *Deepwater Horizon* oil spill. To date, the GEBF has supported 182 projects worth nearly $1.5 billion. These projects compliment other conservation investments worth more the $850 million, creating a total impact of more than $2.3 billion. Awards have been invested in projects that restore and maintain the ecological functions of landscape-scale coastal habitats, the ecological integrity of priority coastal bays and estuaries, ensure long term viability and resilience of habitats, and protect living resources.

3.3.5 The Native Village of Eyak

The Native Village of Eyak is a federally recognized self-governing Tribe in Alaska that provides services within the Tribe’s use area: Prince William Sound, the Copper River, and the Gulf of Alaska. The Native Village of Eyak’s Department of Environment & Natural Resources has capacity to mobilize and conduct research projects using imaging sonar, ground and ice penetrating radar, drone services, and environmental monitoring including analysis of contamination, resource assessments, water chemistry monitoring, and water quality monitoring.

3.3.6 Ocean Energy Safety Institute (OESI)

OESI was established under a BSEE sponsorship to facilitate research, development, and training of federal workers to remain current on state-of-the-art technology associated with oil and gas development. It provides recommendations and technical assistance on the determination of Best Available and Safest Technology (BAST), and implementation of operational improvements in the areas of offshore drilling safety and environmental protection, blowout containment and oil spill response. The OESI is a collaborative initiative involving government, academia, and scientific experts.

The Texas A&M Engineering Experiment Station's (TEES) Mary Kay O'Connor Process Safety Center manages the OESI, in partnership with the University of Texas at Austin and the University of Houston. The OESI provides a forum for dialogue, shared learning and cooperative research among academia, government, industry, and other NGOs, in offshore energy-related technologies and activities that ensure safe and environmentally responsible offshore operations.

OESI has developed a program of research, technical assistance, and education that serves as a center of expertise in offshore oil and gas exploration, development, and production technology, including technology specific to deep water and Arctic exploration and development.

It provides recommendations and technical assistance to BSEE and BOEM related to emerging technologies and the determination of BAST, and environmentally sound oil and gas development practices on the OCS. OESI provides assistance related to geological and geophysical sciences on the technical challenges of exploration and development, such as reservoir characteristics, geohazards, and worst-case discharge analyses.

OESI develops and maintains a domestic and international equipment failure reporting system and database of critical equipment failures related to control of wells that allows the institute to identify reliability issues and industry trends. This system engages users and manufacturers of the equipment. OESI engages employees of federal agencies to participate in research and training to remain current on state-of-the-art technology associated with offshore oil and gas development and promote collaboration among the agencies, industry, standards organizations, academia, and NAS.

3.3.7 Oil Spill Recovery Institute (OSRI)

OPA 90 established OSRI in response to the 1989 *Exxon Valdez* oil spill. The Prince William Sound Science Center, a non-profit research and education organization in Cordova, AK, administers and houses OSRI. Congress mandated that OSRI: 1) identify and develop the best available techniques, equipment and materials for dealing with oil spills in the Arctic and sub-Arctic marine environment; 2) complement federal and state damage assessment efforts and determine, document, assess and understand the long-range effects of Arctic and sub-Arctic oil spills on the natural resources of Prince William Sound; and 3) understand and document the effects to the environment, the economy and the lifestyle and well-being of the people who are dependent on those resources. Subsequent legislation has provided OSRI with a funding mechanism to assure the research continues as long as oil exploration and development occurs in Alaska.

OSRI's 2021-2025 Research Plan outlines its four main programs to categorize research efforts:

- The **Understand Program** seeks to attain an interdisciplinary understanding of Arctic and Subarctic marine environments as they pertain to: baseline data; the source, transport, fate and effects of spilled oil; damage assessment; and the recovery following a spill.
- The **Respond Program** enhances oil spill response and mitigation capabilities in Arctic and Subarctic marine environments.
- The **Inform Program's** goal is to share information and educate the public on the issues of oil spill prevention, response, and effects through workshops, conferences, education, and outreach.
- Through its **Partner Program** OSRI shares funding, facilities, knowledge, and experience with other organizations.

3.3.8 Pew Charitable Trusts (PCT) Arctic Science Program

The PCT Arctic Science Program engages in numerous scientific activities to support conservation campaigns throughout the Arctic. These efforts include original fieldwork, analyses of existing data, and the sharing of scientific findings with a range of audiences. Scientists provide expertise on marine conservation-related issues to the U.S., Canada, Greenland, and other Arctic nations.

3.3.9 Prince William Sound Regional Citizen's Advisory Committee (PWSRCAC)

OPA 90 established the PWSRCAC to promote partnership and cooperation among local citizens, industry, tribes, and government. PWSRCAC works to reduce pollution from crude oil transportation in Prince William Sounds and the Gulf of Alaska. It retains researchers to study oil transportation safety and the environmental effects of the Valdez Marine Terminal and tankers. PWSRCAC has five primary research areas: environmental monitoring, oil spill prevention planning, oil spill response operations, terminal operations, and maritime operations.

3.3.10 Ship Structure Committee

Since its inception in 1943, the Ship Structure Committee has sponsored and coordinated R&D projects to improve ship design, construction, operation, inspection, maintenance, and repair methodologies. The Committee's mission is to: enhance the safety of life at sea, promote technology and education advances in marine transportation, and protect the marine environment. This is done through advocating, participating in, and supporting cooperative R&D in structural design, life cycle risk management of marine structures, and production technologies. The committee includes representatives from the USCG, Navy, MARAD, American Bureau of Shipping, Transport Canada, Defense Research and Development Canada Atlantic, and the Society of Naval Architects and Engineers.

3.3.11 World Wildlife Foundation (WWF) Arctic Program

WWF is an NGO that focuses on conservation efforts on climate, food, forests, freshwater, oceans, and wildlife. WWF's Arctic Program was established in 1992 and has an office in every Arctic country other than Iceland. It is the only circumpolar environmental NGO present at the Arctic Council, where it holds observer status. The Arctic Program focuses on conservation efforts for critical Arctic species and their habitats, Arctic marine governance, climate research and communication, responsible industry, and developing a conservation strategy in the Arctic.

3.4 Academia

Extensive oil pollution research is conducted at academic institutions, either individually or as part of university consortia. These entities conduct and oversee basic and applied research to address oil pollution issues.

3.4.1 Arctic Domain Awareness Center (ADAC)

Hosted by the University of Alaska, ADAC is a USDHS Center of Excellence that develops and transitions technology solutions, innovative products, and educational programs to improve situational awareness and crisis response capabilities related to emerging maritime challenges posed by the Arctic environment. Launched in 2014, ADAC has expertise in marine robotics and unmanned vehicles, Arctic communication technologies, Arctic geophysical and maritime focused engineering, and environmental security. It has created unique long range autonomous underwater vehicles (AUVs) to aid in oil spill sensing and 3D mapping under the Arctic Ocean icepack. It has developed models for Arctic oil spills, ocean currents and sea ice that provide decision-support for Arctic disaster response, search and rescue, and humanitarian assistance. ADAC also created the Ice Conditions Index (ICECON), which forecasts up to 120 hours into the future using data from circulation and ice models developed by NOAA.

3.4.2 Florida RESTORE Act Center of Excellence Program (FLRACEP)

FLRACEP was established in 2010 as part of the RESTORE Act after the *Deepwater Horizon* oil spill, as a Florida Center of Excellence. Housed at the Florida Institute of Oceanography (FIO), FLRACEP focuses on coastal fisheries, wildlife, and ecosystem research/monitoring in the Gulf Coast region and comprehensive observation, monitoring, and mapping of the Gulf of Mexico. The program funds several projects through a state-overseen request for proposal (RFP) process.

3.4.3 Gulf of Mexico Research Consortia

Several university research consortia have been created to study the effects of the *Deepwater Horizon* oil spill. These consortia bring together researchers from universities, research institutes and other academic entities to collaborate on scientific studies in the Gulf of Mexico. Consortia activities combine research with scientific knowledge of the ecosystems of the Gulf of Mexico to advance the understanding of interactions that occurred and continue to occur among the marine and coastal ecosystems, and contaminants related to the spill.

GoMRI (see Section 3.3.3) provided funding for these consortia or their individual studies. GoMRI has funded multiple rounds of multi-year funding to 17 research consortia. These consortia played a critical role in addressing the GoMRI research themes. Consortia were comprised of four or more research institutions from the Gulf region, the U.S., and the international science community. GoMRI emphasized: interdisciplinary science and technology involving experts in physical, chemical, geological, and biological oceanography; marine biology; coastal and reef ecosystems, fisheries, and wildlife ecology; public health; and associated development of physical, chemical, and biological instrumentation, advanced modeling, and informatics. The activities combine research with scientific knowledge of the ecosystems of the Gulf of Mexico to advance the understanding of interactions that occurred and continue to occur among the marine and coastal ecosystems, oil, and dispersants produced by the oil spill.

The Alabama Center for Ecological Resilience (ACER) studies the role biological diversity (genetic, taxonomic, and functional) plays in determining the resilience of northern Gulf of Mexico ecosystems to impacts of oiling and dispersants. ACER investigates resilience across many groups of organisms and at several organizational scales to help predict the impacts of different forms of disturbance on critical coastal ecosystems.

The Aggregation and Degradation of Dispersants and Oil by Microbial Exopolymers consortium (ADDOMEx) investigates the impacts of spilled oil and dispersants on microbes that produce extracellular polymeric substances. When extracellular polymeric substances and oil combine, they ultimately sink back to the seafloor. As dispersants can enhance or impede microbial activity depending on environmental conditions, ADDOMEx research may inform clean-up efforts after future oil spills.

The Consortium for Advanced Research on Marine Mammal Health Assessment (CARMMHA) investigates the effects of oil exposure on Gulf of Mexico marine mammals, including dolphins. This is a new consortium funded by GoMRI started in 2018.

The Consortium for Advanced Research on Transport of Hydrocarbon in the Environment (CARTHE) focuses on the physical distribution, dispersion, and dilution of petroleum and associated contaminants subject to currents, air-sea interactions, and tropical storms. CARTHE's main goal is to predict the fate of oil released into the environment to guide response and minimize damage to human health, the economy, and the environment.

The Center for the Integrated Modeling and Analysis of the Gulf Ecosystem (C-IMAGE) explores the impacts of oil spills on the Gulf of Mexico by comparing two Gulf oil spills, the *Ixtoc* and the *Deepwater Horizon*, to advance understanding of the processes, mechanisms, and environmental consequences of marine oil blowouts.

The Consortium for the Molecular Engineering of Dispersant Systems (C-MEDS) studies dispersants, an essential aspect in the response to large oil releases in deep ocean environments.

The Consortium for Oil Spill Exposure Pathways in Coastal River-Dominated Ecosystems (CONCORDE) improves prediction of future oil spill impacts in shallow waters where freshwater flow and irregular coastlines complicate currents and associated plankton movements.

The Consortium for Resilient Gulf Communities (CRGC) focuses on helping the Gulf of Mexico region understand and overcome stress brought on by events such as the Deepwater Horizon oil spill. CRGC's goal is to increase community resilience by strategic planning and risk communication with local stakeholder groups and provide guidance to policymakers for future disasters.

The Consortium for Simulation of Oil-Microbial Interactions in the Ocean (CSOMIO) synthesizes model developments and results to advance understanding of how microbial biodegradation influences accumulation of oil in the water column, in marine sediments of the deep ocean, and on the shelf. CSOMIO also investigates the impacts of potential future oil spills under different conditions to understand how they will influence biodegradation. This is a new consortium funded by GoMRI that started in 2018.

The Coastal Waters Consortium (CWC) assesses how oil and dispersant change, break down, and impact Gulf of Mexico coastal ecosystems. Specifically, CWC studies food web structure, shifts in populations, individual and ecosystem function during recovery, and the interaction of oil with other stresses on the ecosystem.

The Deep Sea to Coast Connectivity in the Eastern Gulf of Mexico consortium (Deep-C) studies deep sea to coast connectivity in the northeastern Gulf of Mexico and investigates the environmental consequences of the release of oil and dispersants on living marine resources and ecosystem health in the deep Gulf.

The Deep Pelagic Nekton Dynamics of the Gulf of Mexico consortium (DEEPEND) investigates deep water communities on short-term and long-term timescales to assess their recovery following the *Deepwater Horizon* oil spill using an integrated net system to collect animals from the surface to 1500 meters deep.

The Dispersion Research on Oil: Physics and Plankton Studies consortium (DROPPS) investigates the breakup of oil patches into droplets in various physical conditions (e.g., breaking waves) when dispersant and bacteria are present. DROPPS also explores oil movement and its interaction with oil-degrading bacteria, phytoplankton, and zooplankton.

The Ecosystem Impacts of Oil and Gas Inputs to the Gulf consortium (ECOGIG) investigates the ecological impacts of natural and human-caused oil and gas inputs on deep water ecosystems in the Gulf of Mexico. ECOGIG quantifies the impacts, fates, and dynamics of hydrocarbons in the Gulf and evaluates specific biological responses and adaptations to hydrocarbon exposure, both natural and human-caused.

The Gulf of Mexico Integrated Spill Response consortium (GISR) conducts field and laboratory experiments to improve understanding of the physical, chemical, and biological behavior of petroleum fluids as they transit the Gulf from a deep oil spill to the beaches, marshes, estuaries, or atmosphere.

The Littoral Acoustic Demonstration Center - Gulf Ecological Monitoring and Modeling consortium (LADC-GEMM) conducts acoustic surveys to assess regional cetacean populations (sperm whales, beaked whales, and dolphins) and provide recommendations for actions to improve stock recovery for these species.

The Relationships of Effects of Cardiac Outcomes in Fish for Validation of Ecological Risk consortium (RECOVER) examines the effects of oil on two ecologically and economically important species of fish in the Gulf of Mexico: Mahi-Mahi and Red Drum.

3.4.4 Gulf of Mexico University Research Collaborative (GOMURC)

Universities across five U.S. Gulf of Mexico states initiated several marine research consortia over the past decades. GOMURC is a region-wide alliance of these consortia that promotes the large-scale, long-term research initiatives required to address Gulf ecosystem-wide stressors such as oil spills, hurricanes, and climate change. GOMURC's mission goals and objectives include advocating for science and education activities that support science-based policies to restore and sustain Gulf natural resources and economy. The following five university consortia members of GOMURC represent 80 universities in the Gulf States: Alabama Marine Environmental Sciences Consortium, led by Dauphin Island Sea Lab, FIO, led by University of South Florida, Louisiana Universities Gulf Research Collaborative, led by Louisiana State University, Mississippi Research Consortium, led by University of Southern Mississippi, and Texas Research Consortium, led by the Texas A&M University-Corpus Christi.

3.4.5 Harte Research Institute for Gulf of Mexico Studies (HRI)

HRI, an endowed research arm of Texas A&M University-Corpus Christi, is dedicated to advancing the long-term sustainable use and conservation of the Gulf of Mexico. The institute serves as a research center of excellence in generating and disseminating knowledge about the Gulf of Mexico ecosystem and its critical role in the economies of North America. The institute's ecosystems group focuses on environmental flows and the effects of deep-sea oil and gas activities. HRI houses the Gulf of Mexico Research Initiative Information and Data Cooperative (GRIIDC), which is a data management system that stores scientific data generated by Gulf of Mexico researchers. HRI created and maintains GulfBase, the only free, searchable database of people, places, projects, events, and organizations in the Gulf of Mexico.

3.4.6 Integrated Ocean Observing System (IOOS)

IOOS is a national-regional partnership providing new tools and forecasts to improve safety, enhance the economy, and protect the environment. The U.S. IOOS Program Office is organized into two divisions that implement policies, protocols, and standards to implement IOOS and oversee the daily operations and coordination of the System: (1) Operations Division, and (2) Regions, Budget, and Policy (RB&P).

The Operations Division coordinates the contributions of federally owned observing and modeling systems and develops and integrates non-federal observing and modeling capacity into the system in partnership with IOOS regions. It serves as the system architect for data processing, management, and communications, in accordance with standards and protocols established by the National Ocean Council, and leads nationwide program integration for modeling development, undersea glider operations, high frequency radar, and animal telemetry.

RB&P oversees several functions including management, budgeting, execution, policy, and regional and external affairs to further the advancement of U.S. IOOS. This division works to secure resources that help build the IOOS structure and the support ICOOS Act implementation in support of NOAA and other federal agency missions.

3.4.7 Louisiana State University (LSU) Center for Energy Studies

LSU's Center for Energy Studies conducts, encourages, and facilitates research and analysis to address energy-related problems or issues affecting Louisiana's economy, environment, or citizenry. The Center's research and policy analysis projects examine policies and trends affecting the energy industry, especially offshore developments. These projects aim to: measure the economic, safety, and environmental performance of the oil and gas industry; analyze the effects of deep-water development on the Gulf Coast economy; model the economics of the installation, removal and operation of offshore oil and gas platforms to forecast and evaluate regulatory and policy alternatives; and to identify trends and behavior important for planning, management, and regulation of the industry.

3.4.8 Mississippi Based RESTORE Act Center of Excellence (MBRACE)

MBRACE is Mississippi's Center of Excellence under the RESTORE Act. It is a consortium of four research universities (Jackson State University, Mississippi State University, The University of Mississippi, and The University of Southern Mississippi), with the University of Mississippi serving as the lead institution. MBRACE seeks sound comprehensive science and technology-based understanding of the chronic and acute stressors on the dynamic and productive waters and ecosystems of the northern Gulf of Mexico, and to facilitate sustainable use of the Gulf's important resources. MBRACE funded four projects in Fall 2017 that examine how ecological conditions relevant to oysters vary over time and between newly restored oyster reefs and adjacent unrestored oyster reefs in Mississippi Sound, Mississippi. In Spring 2020, MBRACE funded a second round supporting the original four projects for continued work. It also funded three projects through the Competitive Grants Program, also focused on water quality and oyster sustainability in Mississippi.

3.4.9 Monterey Bay Aquarium Research Institute (MBARI)

MBARI is a private, non-profit oceanographic research institute in Moss Landing, CA. Founded in 1987, MBARI is comprised of scientist and engineers that study the upper ocean systems, midwater, and seafloor processes and in addition to developing technologies. They have multiple remotely operated vehicles (ROVs), AUVs, and autonomous surface vehicles (ASVs). MBARI used an AUV during the *Deepwater Horizon* oil spill to better understand the nature and extent of any plume of oil that was beneath the ocean's surface. MBARI has also collaborated with USCG and Woods Hole Oceanographic Institute (WHOI) to use AUVs to detect and track oil spills.

3.4.10 NOAA's National Sea Grant College Program

NOAA's National Sea Grant College Program is a network of 34 individual programs located in universities in every coastal and Great Lakes state, Puerto Rico, Lake Champlain, and Guam. These programs serve as the core of a dynamic, university-based network of over 300 institutions involving more than 3,000 scientists, engineers, educators, students, and outreach experts. The network engages academia and a wide variety of partners to address issues such as coastal hazards, sustainable coastal development, and seafood safety.

3.4.11 National University Rail (NURail) Center

In January 2012, the U.S. Department of Transportation awarded a grant of $3.5 million to a multi-university consortium led by University of Illinois Urbana-Champaign (UIUC) to establish a rail transportation and engineering research center. Headquartered within the Department of Civil and Environmental Engineering, NURail was a consortium of seven partner colleges and universities with a combination of strengths in railway transportation engineering research and education in North America. NURail was the first University Transportation Center (UTC) focused solely on rail and concentrated on rail education and research to improve railroad safety, efficiency, and reliability. Some of NURail's research focused on strategies for crude oil transportation in the U.S. The center was funded for nine years ending in 2020.

3.4.12 Oil Spill Academic Task Force (OSATF)

OSATF is a consortium of scientists and scholars from institutions in Florida's State University System as well as from five of Florida's private universities and two marine laboratories working in collaboration with the Florida Department of Environmental Protection (DEP). The OSATF brings together expertise and resources to assist the state of Florida and the Gulf region in responding to and studying the Deepwater Horizon oil spill.

3.4.13 Poker Flat Research Range

Poker Flat Research Range is located northeast of Fairbanks, AK, and has a 10,000 square meter (100 x 100 m) shallow outdoor tank (less than 1 meter depth). It is operated by the University of Alaska's Geophysical Institute under contract to NASA's Wallops Flight Facility, which is part of the Goddard Space Flight Center. In addition to launching sounding rockets, Poker Flat is home to many scientific instruments designed to study the arctic atmosphere and ionosphere. For ISB operations, the facility can support aerial application of both the herding agent and igniter from helicopters and unmanned aerial systems (UAS). It has been used for testing UAS and chemical herders for use during in-situ burning in ice conditions.

3.4.14 RESTORE Act Center of Excellence for Louisiana (LA-COE)

Administered by the Water Institute of the Gulf since 2015, LA-COE was established under the RESTORE Act. It provides research directly relevant to the implementation of Louisiana's coastal mater plan though a competitive grant program and by providing coordination and oversight support to ensure that success metrics are tracked and achieved. LA-COE has an executive committee of senior research officials from Louisiana's universities and research organizations with a strong focus on coastal issues.

3.4.15 Subsea Systems Institute (SSI)

SSI is a collaboration between the University of Houston, Rice University, and the NASA's Johnson Space Center. SSI focuses on applied research to support engineering and technology development for offshore and deep-water exploration and production. SSI collaborations with the academic/research sector, the energy and space industries, and international organizations. It uses RESTORE Act and industry funding to support the collaborative development and validation of safe and efficient technologies for the exploration and production of hydrocarbons and deep-water resources.

3.4.16 Texas OneGulf

Texas OneGulf was established in 2015 as part of the RESTORE Act after *Deepwater Horizon* oil spill, as a Texas Center of Excellence. It advances research into oil spill impacts and long-term issues that threaten the health of the Gulf of Mexico. It is a nine-member consortium of research institution throughout Texas and has expertise in marine sciences, human health, sociology, economics, law, and policy. Texas OneGulf is forming the Texas OneGulf Agency Council to better inform OneGulf on decision-making needs and the development of projects. The council has representation from the Texas Commission on Environmental Quality, Texas Division on Energy Management, Texas General Land Office, Texas Parks and Wildlife Division, and Texas Water Development Board.

3.4.17 Scripps Institution of Oceanography (SIO)

Scripps Institution of Oceanography at the University of California San Diego is one of the oldest and largest centers for ocean, earth and atmospheric science research, education, and public service in the world. Scripps' research includes physical, chemical, biological, geological, and geophysical studies of the oceans as well as natural hazards, including tsunamis, storm waves, floods, erosion, hurricanes, and harmful algal blooms.

3.4.18 UAA/SIT Center of Excellence for Maritime Research (CMR)

The USDHS S&T Directorate selected the University of Alaska Anchorage (UAA) and the Stevens Institute of Technology (SIT) as co-leads for a Center of Excellence for Maritime Research (CMR). The CMR will provide research to identify better ways to create transparency in the maritime domain along coastal regions and inland waterways, while integrating information and intelligence among stakeholders. USDHS charged the CMR to develop new ideas to address these challenges, provide a scientific basis, and develop new approaches for USCG and other USDHS maritime missions.

3.4.19 U.S. Coast Guard Academy (USCGA) Center for Arctic Study & Policy (CASP)

The USCGA CASP is the USDHS's only institution of higher education. Academy cadets and faculty conduct academic research in oil spill science, policy in marine engineering. USCGA established CASP to promote academic research on Arctic policy and strategy by facilitating collaboration, partnerships, and dialogue among specialists from academia, government, tribal organizations, NGOs, industry, and the USCG. CASP, located in New London, CT, serves as an operationally focused think tank to promote research, broaden partnerships, and educate future leaders about the complexities of the Arctic. Through collaborative efforts, CASP promotes effective solutions to address present and future Arctic maritime challenges.

3.4.20 University of New Hampshire (UNH) Oil Spill Centers

UNH, in Durham, NH, administers two oil spill centers: The Coastal Response Research Center (CRRC) and the Center for Spills and Environmental Hazards (CSE). Both were established in 2004. CRRC is a partnership between the NOAA OR&R and UNH. CRRC partnership stimulates innovation in spills, and other environmental hazards, in preparedness, response, assessment, and recovery strategies. CRRC brings 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 to address environmental hazards occurring because of natural disasters, human error, or infrastructure failure. CRRC supports OR&R's Disaster Preparedness Program (DPP) through planning training exercises, informational workshops, and helping DPP engage its partners.

CSE expands the scope of interaction and cooperation with all non-NOAA entities, including governmental agencies, universities, NGOs, and industry. The CSE involves individuals and institutions, public and private, at local, regional, national, and international levels in identifying needs, evaluating, and demonstrating promising technologies, and fostering their use as part of new, integrative approaches to response and restoration.

3.4.21 Woods Hole Oceanographic Institution (WHOI)

WHOI is a non-profit oceanographic research organization with a mission to explore and understand the ocean and to educate scientists, students, decision-makers, and the public. WHOI scientists and engineers maintain expertise across a range of oceanographic research areas. They work collaboratively within and across six research departments to advance knowledge of the global ocean and its fundamental importance to other planetary systems. One focus of research is on AUVs. WHOI has seven active AUVs, each with a unique set of capabilities to operate in different conductions. Two of WHOI's newly designed robotic vehicles, Puma and Jaguar, are intended for deep-seafloor operations under Arctic icecaps, a key area of future oil pollution research. WHOI research provides information of value to a wide range of ICCOPR research areas including pre-spill baseline studies, injury assessment and restoration, and multiple response research areas.

3.5 International Efforts

Oil pollution is a global issue and requires international cooperation, including in research. ICCOPR and its members work cooperatively with other nations and international entities to conduct research to better respond to oil spills.

3.5.1 Arctic Council

The Ottawa Declaration of 1996 formally established the Arctic Council as a high-level intergovernmental forum to provide a means for promoting cooperation, coordination, and interaction among the Arctic States, with the involvement of the Arctic indigenous communities and other Arctic inhabitants on common issues, in particular issues of sustainable development and environmental protection. Arctic Council member states are: Canada, Denmark (including Greenland and the Faroe Islands), Finland, Iceland, Norway, the Russian Federation, Sweden, and the U.S.

The Council established a series of guidelines intended to define a set of recommended practices and outline strategic actions for consideration by those responsible for regulation of offshore oil and gas activities (including transportation and related onshore activities) in the Arctic. The goal is for regulators to identify the key aspects related to protection of human health and safety and protection of the environment for the management of offshore activities, remaining sufficiently flexible in the application of these regimes to permit alternative regulatory approaches. On three occasions, the Arctic States have negotiated legally binding agreements under the Arctic Council that aim to enhance international cooperation on issues related to maritime search and rescue, marine oil pollution, and Arctic scientific cooperation. The Emergency Prevention, Preparedness and Response Working Group (EPPR) of the Arctic Council addresses various aspects of prevention, preparedness, and response to environmental emergencies. The goal of EPPR is to contribute to the protection of the Arctic environment from threat or impact that may result from an accidental release of pollutants or radionuclides. In addition, EPPR considers questions related to the consequences of natural disasters.

3.5.2 Australia

The Commonwealth Scientific and Industrial Research Organization (CSIRO) focuses on the safe, efficient, and sustainable use of Australia's marine natural resources including offshore oil and gas resources. CSIRO works with industry, government agencies, and academia to provide scientific knowledge and advice. It also conducts research and provides advice on the environmental, economic, and social factors associated with the entire oil and gas value chain.

CSIRO's primary objective is to develop the knowledge and technology to prevent marine incidents and understand pre-spill ecosystems, so Australia is prepared to respond effectively. CSIRO has conducted a significant amount of research in a wide variety of areas that support a broad array of prevention and response initiatives. Recent research projects include:

- Bluelink reliable ocean forecasting for Australia and the world;
- Flow assurance systems to ensure uninterrupted flow of oil and gas in subsea pipelines and access to previously stranded gas;
- Hydrocarbon sensor array to monitor the movement of oil spills;
- Pipeassure to repair pipelines quickly and safely with minimal disruption and loss of operation down-time; and
- PressureDB data collection and analysis on subsurface formation pressure, temperature and salinity from oil and gas well.

The Australian Maritime Safety Authority (AMSA), a federal government self-funded maritime safety agency established in 1990, is responsible for providing a national response for marine pollution. AMSA administers the "National Plan to Combat Pollution of the Sea by Oil and Other Noxious and Hazardous Substances", a cooperative arrangement between the federal, state and northern territory (NT) governments and the shipping, oil exploration and chemical industries, emergency services, and fire brigades.

The oil industry maintains resources for spills occurring at their facilities. For incidents that may require resources beyond individual company capabilities, the Australian Institute of Petroleum (AIP) through its Australian Marine Oil Spill Centre (AMOSC) subsidiary has established a plan formalizing mutual aid arrangements among member companies.

3.5.3 Canada

Environment and Climate Change Canada (ECCC) is the Government of Canada's lead department for a wide range of environmental issues. The department addresses these issues through engaging with partners such as provinces, territories, and Indigenous peoples; monitoring environmental issues, conducting scientific research, developing policies and regulations and enforcing environmental laws. ECCC's Environmental Emergencies Program (EEP) was created in 1973, and carries out activities related to prevention, preparedness, response, recovery, and research. ECCC also is the host of the Arctic and Marine Oil spill Program (AMOP), an international forum on preventing, assessing, containing, and cleaning up spills of hazardous materials in every type of environment. The ECCC has worked with EPA, and now works with BSEE to conduct oil pollution research at the Ohmsett facility.

The National Environmental Emergencies Center (NEEC) provides ECCC technical and scientific environmental advice and assistance during an environmental emergency. NEEC has expertise in: spill and air trajectory and dispersion modelling to track the path and intensity of air, water and ground pollutants; behavior analysis of hazardous substances in the environment to understand the range of impacts; site-specific weather forecasts to coordinate response efforts; environmental sensitivity mapping to understand priority ecosystems and wildlife; and shoreline clean-up assessment and remediation advice to determine environmental recovery steps.

The Department of Fisheries and Oceans Canada (DFO) has a comprehensive science program on oil pollution research ecosystem effect and energy production and operational oceanography. DFO's research on ecosystem effects addresses expanded energy development in Canada, mainly offshore oil and gas, hydroelectricity, and oil sands. DFO's operational oceanography programs study oceanic processes and circulation patterns to predict the ocean's present and future state, and include ocean modeling, ecosystem modeling, and near- shore processes.

Canada's Multi-Partner Research Initiative (MPRI) is part of the national Oceans Protection Plan launched in 2016. The initiative has provided a total of $45.5 million from 2016-2021 to draw on the expertise of oil spill experts in Canada and abroad. It aims to: identify knowledge gaps and research priorities; improve the understanding of how oil spills behave in water and their impacts on aquatic organisms; develop new technologies and protocols to select the best methods for oil spill clean-up; and to support science-based decisions that minimize the environmental effects of oil spills and enhance habitat recovery.

The Center for Offshore Oil, Gas, and Energy Research (COOGER) is housed in the Bedford Institute of Oceanography (BIO) in Dartmouth, Nova Scotia. Established in 2002, COOGER is made up of experts in the fate and behavior of oil spills in aquatic environments. COOGER's main research areas are fate and behavior of diluted bitumen and refined oil products in the environment, improving response measures, and providing background information for the creation of localized response plans for high traffic shipping ports. Some of its research project include: *in-situ* monitoring and tracking of petroleum to model its dispersion in water; studying the weathering of products to understand their persistence and breakdown in the environment; and studying the interactions between microbes and petroleum in response to oil spills.

The National Research Council of Canada is the primary national research and technology organization of the Canadian government in science and technology research and development. It has 14 research centers across Canada and its research project span a broad spectrum of activities and industries. Under the National Research Council of Canada's Arctic program, researchers are developing tools and technologies to: improve the safety and efficiency of shipping operations in ice-covered waters; optimize ice management and investigate ice loads on offshore structures; develop solutions for oil spills in the Arctic; and improve the performance of life-saving appliances in extreme and remote environments.

3.5.4 Centre of Documentation, Research and Experimentation on Accidental Water Pollution (CEDRE)

CEDRE is a not-for-profit association created as part of the measures taken in the aftermath of the *Amoco Cadiz* oil spill. CEDRE's headquarters, technical facilities and most of its personnel are based in France. It has five main areas of focus: response support, contingency planning, training, analysis and testing, and research. CEDRE's advice and expertise is available to foreign authorities or private companies. CEDRE conducts its own research projects and contributes to French and international research programs. Their main research and development activities focus on themes of: dispersant and sorbent testing; equipment testing; pollutant analysis; product behavior; product ecotoxicity; and post-spill monitoring.

3.5.5 China

The China Maritime Safety Administration (MSA), part of the Ministry of Transport, has the mandate to investigate and respond to marine pollution incidents in Chinese waters. The China MSA headquarters in Beijing provides central control with 20 subordinate bureaus and about 97 local branches along the coast and Yangtze, Pearl, and Heilongjiang Rivers. The MSA has over 25,000 officials and a patrol force of 1,300 vessels. China currently has two polar-capable icebreakers, and in 2018, announced an intention to build a third icebreaker. Like several other nations, China has established a research station in the Svalbard archipelago and has another research station in Iceland. China has also made investments in Russia's Arctic oil and gas industry, specifically the Yamal natural gas project. China has shown interest in the opportunities in the Arctic seabed in Greenland and in the Canadian Arctic.

3.5.6 European Union (EU)

Since 1978, the EU has played a vital role in the response to marine pollution and its role has become even greater with the response coordination ensured by its European Response Coordination Center (ERRC) and with marine pollution preparedness and response services provided by the European Maritime Safety Agency (EMSA).

EMSA assumes the leading role in ensuring a uniform level of maritime safety, maritime security, prevention of and response to pollution caused by ships, as well as response to marine pollution caused by oil and gas installations. It provides technical and scientific assistance to the European Commission and member states. EMSA manages a network of standby at-sea oil spill recovery vessels based in all the regional seas. These normally commercial vessels cease their normal activities and quickly move to the scene of the oil spill, upon request. The agency also provides satellite imagery for detection and monitoring of oil spills, pollution response experts to give operational and technical assistance, and information service for chemical spills at sea.

In 2019, the European Commission published a hydrocarbon guidance document addressing 13 onshore and 10 offshore oil and gas activities that had potentially the highest impact on the environment and human health. The document was the result of four years of collaborative work of the member states, industry, and the commission to identify the best techniques and risk management approaches for the oil and gas industry. The guidance document supports the EU's energy security objectives by setting out a level, predictable and transparent guideline for oil and gas activities, helping to address public concerns on domestic oil and gas, and by facilitating dialogue with relevant stakeholders.

3.5.7 France

France is Europe's second largest consumer of energy after Germany. France relies on imports to meet most of its oil and gas needs since it does not produce a lot of oil. However, France's oil imports continue to decline each year. France imports crude oil through three major seaports (Marseille, Le Havre, Saint-Nazaire). France has very little domestic natural gas production, and since the French government banned the use of hydraulic fracturing, France imports natural gas through a variety of cross-border pipelines from the Netherlands, Norway, and Russia. France also imports liquefied natural gas (LNG) from countries around the world. In 2019, the La Mède oil refinery was converted to become the country’s first biorefinery to meet the growing demand for biodiesel.

Response arrangements are governed by the “at sea pollution response” section of ORSEC MARITIME (Organisation de la Réponse de SÉcurité Civile), France’s civil defense plan. Responsibility for preparing for and conducting clean-up operations at sea lies with one of three Maritime Préfets (one for the Mediterranean Sea, one for the Atlantic, and one for the North Sea/Channel). The Maritime Préfet will work in cooperation with the Secrétariat Général de la Mer who has the authority to access the various stockpiles of equipment. Coordination of sea and shoreline clean-up would be supervised locally by a permanent conference with representatives of the Maritime Préfet and the Préfet of the Department concerned.

3.5.8 International Maritime Organization (IMO)

The IMO is a specialized agency of the United Nations, which is responsible for measures to improve the safety and security of international shipping and prevent marine pollution from ships. It is also involved in legal matters, including liability and compensation issues and the facilitation of international maritime traffic. IMO's governing body is the assembly, made up of all 170 Member States, which meets once every two years. The IMO’s Maritime Safety, Marine Environment Protection, Legal, Technical Co-operation and Facilitation Committees, and several sub-committees carry out the main technical work. Since 1967, the IMO has adopted a series of conventions covering marine pollution prevention by ships, preparedness and response to incidents involving oil and hazardous and noxious substances, prevention of use of harmful anti-fouling systems and the international convention on ballast water management to prevent the spread of harmful aquatic organisms in ballast water.

The IMO has multiple international Centers for oil spill response and prevention called Regional Activity Centers (RACs); the Marine Environmental Emergency Preparedness and Response RAC of NOWPAP (NOWPAP MERRAC), the Regional Marine Pollution Emergency Information and Training Center for the Wider Caribbean (REMPEITC-Caribe), Marine Emergency Mutual Aid Center (MEMAC), Regional Organization for the Protection of the Marine Environment (ROPME), the Regional Marine Pollution Emergency Response Center for the Mediterranean Sea (REMPEC), Partnerships in Environmental Management for the Seas of East Asia (PEMSEA), the PERSGA Marine Emergency Mutual Aide Center (PERSGA/MEMAC), and the Indian Ocean Commission. Each RAC assists with the prevention, preparedness, and response to marine pollution events in specific regions.

In 2017, the IMO’s International Code for Ships Operating in Polar Waters (Polar Code) was established. The Polar Code covers the full range of shipping-related matters relevant to navigation surrounding the two poles: ship design, construction, and equipment; operational and training concerns; search and rescue; and the protection of the environment and ecosystems of the polar regions.

3.5.9 Kill-Spill

Kill-Spill was an EU-funded research program with the mission to develop highly efficient, economically, and environmentally viable biotechnological solutions for the clean-up of oil spills caused by maritime transport or offshore oil exploration and related processes. The program concluded in 2016 and resulted in the development of bio-based products that detected, monitored, and detoxified marine oil spills in an eco-friendly way. The final products were intended for longer-term actions, such as the hydrocarbon detecting biosensors that were developed to monitor the efficiency of oil-degrading bacterial communities. They also created bio-based dispersants and microbial-chemical combinations for use as integration bioremediation agents in addition to other tools. Kill Spills versatile range of tools helped to fill in the gaps in current oil spill cleanup approaches with applications for the initial response, follow-up, and long-term monitoring. This project provided sustainable, industry driven strategies for mitigating oil spills through increased understanding of the degradation of petroleum hydrocarbons released in the marine environment.

3.5.10 Mexico

A National Contingency Plan was developed in 1981 by a sub-committee of the Mexican Inter- Departmental Commission for Environmental Health. It aims to establish a national response network and provide overall coordination of resources in the event of a spill. The Mexican navy maintains a regional and local organizational structure to implement the National Plan at these levels. Under the General Law of Ecological Equilibrium and Environmental Protection (LEGEEPA), overall responsibility for oil pollution matters in Mexican ports and territorial waters rests with the Mexican navy. Response to a spill is likely to be initiated through the Navy's Marine Environment Protection Division (PROMAM). Assistance is also likely to be sought from the national oil company, Petróleos Mexicanos (PEMEX).

The Mexico-United States Joint Contingencies and Emergencies Plan for Preparedness and Response to Events Associated with Chemical Hazardous Substance in the Inland Border Area (Inland Border Plan), provides a mechanism for cooperation between Mexico and the United States to provide response to a hazardous substance spill that would affect both countries. Another Joint Contingency Plan was established between the U.S. and Mexico for the maritime border, which covers oil spills in the Mexico border region that could impact both countries. The U.S.-Mexico Border 2020 Program (Border 2020) is an eight year (2013-2020) binational effort designed to protect the environmental and public health in the U.S.-Mexico border region. The five main goals of Border 2020 are to: reduce air pollution; improve access to clean and safe water; promote materials management, waste management, and clean sites; enhance joint preparedness for environmental response; and enhanced compliance assurance and environmental stewardship.

3.5.11 Norway

As a major energy nation, Norway has significant expertise in petroleum and hydropower science and engineering. In addition, Norway is conducting important research efforts in the field of environment and climate research. The Norwegian Government's goal is to be a pioneer in developing an integrated, ecosystem- based management regime for marine areas. The purpose of this management plan is to provide a framework for the sustainable use of natural resources and ecosystem services derived from the North Sea and Skagerrak and at the same time maintain the structure, functioning, productivity and diversity of the area's ecosystems. Norway uses its major universities to conduct major research programs with respect to oil and gas. Norway also conducts research using intentional releases of oil on the sea.

SINTEF operates in partnership with the Norwegian University of Science and Technology (NTNU) in Trondheim. NTNU personnel work on SINTEF projects, and many SINTEF staff members teach at NTNU. SINTEF is known for its work on oil spills, dispersants, and is one of the world's largest independent research organizations within the oil spill research community and offers expertise in many areas, including: oil weathering studies; oil slick characterization; oil spill response technology; surface chemistry; fluid chemistry; oil spill contingency and response analysis; oil spill contingency in Arctic areas; and sub-sea releases.

Norway's Oil and Gas for the 21st Century (OG21) developed a national technology strategy for Norway that sets direction for public funded petroleum research in Norway, and influences R&D plans and activities in the petroleum industry, in research institutes and in universities. OG21 was established by the Ministry of Petroleum and Energy in 2001 and its strategy is revised every 5 years with the last revision in 2016. A similar program, Maritim21, was established in 2015 by the Ministry of Trade, Industry, and Fisheries to develop a unified, stakeholder-inclusive strategy for research, development, and innovation for the maritime industry. The Maritim21 and the OG21 strategy revisions are expected by the end of 2021.

3.5.12 Russia

The Arctic is a top strategic priority for Russia. Russia has adopted multiple strategy documents, most recently in 2020, outlining plans to bolster its Arctic military capabilities, strengthen territorially sovereignty, and develop the region's resources and infrastructure. In May 2021, Russia assumed the chairmanship of the Arctic council and officials have stated that national security concerns will be a priority for Russia during its two-year chairmanship of the council.

The Federal Agency of Maritime and River Transport, part of the Ministry of Transport, is the federal executive body with responsibility for preparedness and response for oil spill incidents in Russia. The Marine Rescue Service (MRS) is involved in ensuring the safety of offshore projects, including oil spill preparedness and response; ocean and sea towage of watercrafts and structures, including offshore drilling platforms; emergency salvage operations and other marine related activities. On February 1, 2021, the MRS and the USCG signed the 2020 update to the Joint Contingency Plan (JCP), which is a bilateral agreement focused on preparing for and responding to transboundary maritime pollution incidents. The updated JCP prompted a coordinated system for planning, preparing and responding to pollutant releases in the waters between the U.S. and Russia. Both countries plan to hold a joint training exercise to prepare for pollution response within the next few years.

3.5.13 United Kingdom (UK)

The Department of Energy and Climate Change (DECC) works to ensure that the UK has secure, clean, affordable energy supplies and promotes international action to mitigate climate change. DECC is a ministerial department, supported by nine agencies and public bodies. The Oil and Gas Authority, an executive office of the DECC, works with government and industry to make sure that the UK gets the maximum economic benefit from its oil and gas resources, whilst also supporting the move to net zero carbon by 2050. The current priorities of the Oil and Gas Authority are to: revitalize offshore exploration; improve asset stewardship; drive regional development and protect critical infrastructure; improve decommissioning efficiency; support the adoption and adaption of available technologies; support the energy transition to a low carbon economy; and achieve regulatory excellence in all oil and gas activities.

The Maritime and Coastguard Agency (MCA) is the UK's authority responsible for the provision of response procedures designed to deal with any emergency at sea that threatens or causes actual pollution. The National Contingency Plan for Marine Pollution from Shipping and Offshore Installations, published in 2014 with revisions in 2017, is a strategic overview for response to marine pollution from shipping and offshore installations. MCA develops and participates in maritime exercises designed to maintain the operational readiness of its staff and equipment. The Counter Pollution and Response Branch also organizes training courses for local authorities to prepare their staff when responding to shoreline pollution.

3.6 Non-Federal Oil Pollution Testing Facilities

Several non-federal facilities provide opportunities for oil pollution testing.

3.6.1 COOGER Testing Facilities

COOGER's testing facility is in Dartmouth, Nova Scotia, maintains a wave tank facility for oil pollution research. Each tank measures 32 m long, 0.6 m wide, and 2 m high (1.5 m water depth; 28,800 L volume). Water from the Bedford Basin of Halifax Harbor is pumped into the tanks through a coarse (25 µm pore size) and fine (5 µm pore size) serial filtration system. The tanks can generate various types of wave energies in either static or flow-through mode. Breaking and non-breaking waves (computer-controlled flat-type wave maker) provide mixing energies to achieve dispersant effectiveness like that of field conditions. The tanks are equipped with subsea injection systems from pressurized, heated canisters. Experiments benefit from the ability of the tanks to be drained and cleaned (tank walls, bottom, wave maker and absorbers) after each experiment to remove all oil and surfactants.

3.6.2 CEDRE Technical Facilities

CEDRE has an outdoor tank designed to run practical spill response training courses, pilot-scale experiments, and outdoor equipment trails with real oil releases. The sweater tank has a surface area of about 1,900 m^2 and is about 2-3 m deep. There is also a 2,500 m^2 man-made beach and a 3,500 m^2 water body. These two areas allow full-scale simulation of oil pollution on various shore types during experiments and training courses. The facilities also include a 15 m- deep well that can be used to measure the suction and discharge capacities of pumping systems on different types of oil. Other facilities include a showroom of various response equipment, a road surface area, a port area, and a laboratory.

3.6.3 Churchill Marine Observatory (CMO)

In 2020, construction of the Churchill Marine Observatory was completed. Lead by the University of Manitoba, the CMO is an innovative and multidisciplinary research facility located in Churchill, Manitoba, Canada. CMO is a research facility where researchers study the detection, impact, and mitigation of oil spills in sea ice and investigate issues facing Arctic marine transportation. CMO has three science priorities: oil and other transportation related contaminant spills in sea ice; climate change, extreme weather, and teleconnections; and freshwater-marine coupling. The core CMO infrastructure comprises of:

- The Ocean-Sea Ice Mesocosm (OSIM) consists of two outdoor pools located in Churchill, which are designed to simultaneously accommodate contaminated and control experiments on various scenarios of oil spills in sea ice and/or to examine processing controlling how freshwater mixes with and affects marine systems.
- The Environmental Observing (EO) system is a series of taut-line moorings located in the Churchill estuary and along the main shipping channel across the Hudson Bay and Strait. The EO system provides a state-of-the-art monitoring system and can be used to scale process studies conducted in OSIM to Hudson Bay and the larger Arctic environment.
- The Research Vessel (RV) William Kennedy is a 65-ft. former fishing vessel that has been retrofitted for Arctic science expeditions.

3.6.4 International Institute for Sustainable Development (IISD) Experimental Lakes Area (ELA)

The IISD-ELA is a laboratory consisting of 58 small lakes and their watershed reserved for scientific research to understand the how climate change, agricultural runoff, water management, and contaminants such as oil impact fresh water. Located in Northwestern Ontario, Canada, the facility studies how oil spills impact freshwater and what response methods are need for freshwater spills by simulating oil releases into enclosures in lakes.

3.6.5 Ocean, Coastal and River Engineering Research Center

The National Research Council of Canada's Ocean, Coastal and River Engineering Research Center assists industry and government to develop solutions to engineering challenges within ocean, coastal and river environments with a particular focus on harsh and extreme conditions. The approach includes physical and numerical modeling, engineering analysis, technology development, as well as full scale experiments and field work conducted with the support of a comprehensive suite of world-class model test basins and tanks capable of reproducing a wide range of ice, wave, current and wind conditions. It provides technology and facilities to support problems related to: the Arctic; marine infrastructure, and; marine vehicles. It maintains several testing facilities that provide real world conditions:

- Refrigerated material test laboratory (cold test labs);
- Towing tank (200 m × 12 m);
- Offshore engineering basin (75 m × 32 m);

- Ice tank – 90 m (90 m × 12 m);
- Cavitation tunnel;
- Design and fabrication facilities for models and precision instrumentation;
- Thermal lab and manikin;
- Coastal wave basin (63 m × 14.2 m);
- Multidirectional wave basin (26 m × 36 m);
- Large area basin (47 m × 30 m);
- Ice tank – 21 m (21 m × 7 m);
- Large wave flume (97 m × 2 m);
- Steel wave flume (63 m × 1.4 m);
- High-discharge flume; and
- Hydraulics laboratories.

3.6.6 PRCI Technology Development Center (TDC)

PRCI opened the TDC, in Houston, Texas, in 2015. The TDC covers 8 acres, including a state-of- the-art pull test facility, an over 20,000 sq. ft. workshop, and an additional 9,000 sq. ft. of office and meeting space. The TDC is used by the energy pipeline industry as it provides an independent third-party site to fully understand the capabilities of current tools and to guide the development of new technologies needed to push toward the goal of zero failures. The TDC pull test facility contains various size pipe strings containing real and manufactured defects. The TDC also has a liquid test loop and a large warehouse that has access to over 1,300 pipe samples with various defect types and dimensions.

3.6.7 SINTEF Sealab

SINTEF Sealab is a cooperative effort of SINTEF Fisheries and Aquaculture and NTNU and offers a variety of experimental facilities covering the key elements of marine food webs. The emphasis is on developing experimental systems that simulate natural processes and mimic the fate, behavior, and effects of pollutants in the recipient.

The SINTEF Sealab provides laboratory testing on dispersibility, emulsification, photo-oxidation, shoreline cleaning agents, simulated shoreline systems, sediment columns, and ignitability testing for ISB. At the meso-scale level, there is a flume with wave generation, currents, and light exposure; shoreline basin with tidal variation, wave exposure, and seawater exchange; and a high-pressure exposure system (30 bar, 1400 L). At the large – scale level, there is a basin (4 x 10 x 2 m, waves 0.5 m, current 5 knots) and a tank.

3.6.8 Texas A&M Corpus Christi Center for Coastal Studies (CCS)

The Texas A&M Corpus Christi CCS comprises 10,000 sq. ft. of office and laboratory space within the Carlos F. Truan Natural Resources Center. The CCS facilities include: plankton laboratory, marine ecotoxicology laboratory, marine invertebrate environmental physiology laboratory, and benthic ecology laboratory.

3.6.9 Texas A&M Corpus Christi National Spill Control School (NSCS)

NSCS, part of Texas A&M Corpus Christi, was established in 1977 and was named as a consulting, training, and research resource for the National Response Team in OPA 90. NSCS offers specialized hands-on Occupational Safety and Health Administration (OSHA) mandated training for professionals and workers in the oil spill, hazardous material, and emergency management industries, as well as others in exploration, production, and transportation who deal with spill prevention, planning, and response.

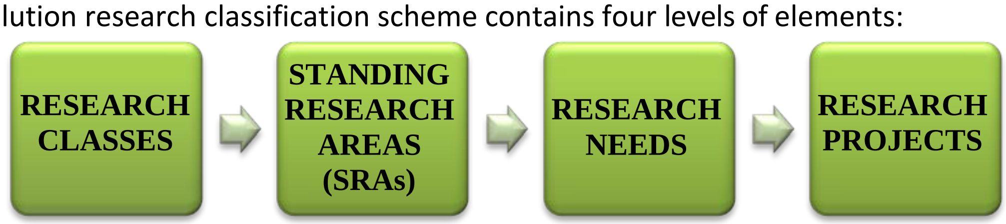
4. Structuring Oil Pollution Research

The field of oil pollution research covers an array of subjects depending on the interests and needs of the researcher or funding source. The focus of oil pollution research extends well beyond removing or mitigating spilled oil from the environment, involving other themes such as developing new methods for preventing oil discharges, assessing impacts on the natural and human environment, and restoring an affected ecosystem as best as possible to pre- spill conditions. Each of these areas includes a broad spectrum of subjects and topics, which creates challenges for tracking research activities.

In 2015, ICCOPR established a categorization framework to provide a common language and planning approach that would enable interested parties to identify and track research. This new approach is used by ICCOPR to facilitate communications with Congress, Federal partners, industry, academia, and the general public. It provides a basis for the 16 member organizations to translate their research needs and perspectives into one federal voice through ICCOPR.

4.1 Introduction to the Oil Spill Research Framework

The Categorization Framework provides a hierarchy of terms to classify, discuss, and prioritize oil pollution research. It is analogous to the taxonomic classification of organisms (i.e., Kingdom, Phylum, Class, Order, Family, Genus, and Species). ICCOPR's oil pollution research classification scheme contains four levels of elements:



Research Classes and Standing Research Areas (SRAs) are generally fixed, while Research Needs and Projects assigned to the SRAs vary over time. When SRAs contain many Research Needs, they may be divided into Subcategories, each having its own set of priority Research Needs (**Appendix A**). Each of the categorization terms is defined later in this chapter. The following example shows how the classification scheme works for one project:

Class: Prevention
SRA: Pipeline Systems
Subcategory: Leak Detection
Need: Develop advanced pipeline break sensing technologies
Project: Smart Pipeline Network – Seal Sensor System

Chapter 9 of this OPRTP provides a prioritized list of current Research Needs suggested for 2022-2027. To address the progress of the priority Research Needs, ICCOPR monitors relevant projects and publications from government, NGOs, industry, and academia. ICCOPR uses this information to provide updates on research progress in its Biennial Reports to Congress. ICCOPR will revise the OPRTP for the next cycle to include a summary of the previous version's accomplishments and a new set of prioritized Research Needs in Chapter 9.

4.2 Classes

The categorization framework includes four Classes that represent the general groupings of oil spill research: Preparedness, Prevention, Response, and Injury Assessment and Restoration (Figure 4-1). It shows that the research in each Class can inform and support the research from other Classes and that the Preparedness Class plays a central role in supporting the others. ICCOPR's member organizations may conduct or support research across one or multiple Classes depending on their specific mission, regulatory responsibilities, and/or expertise.

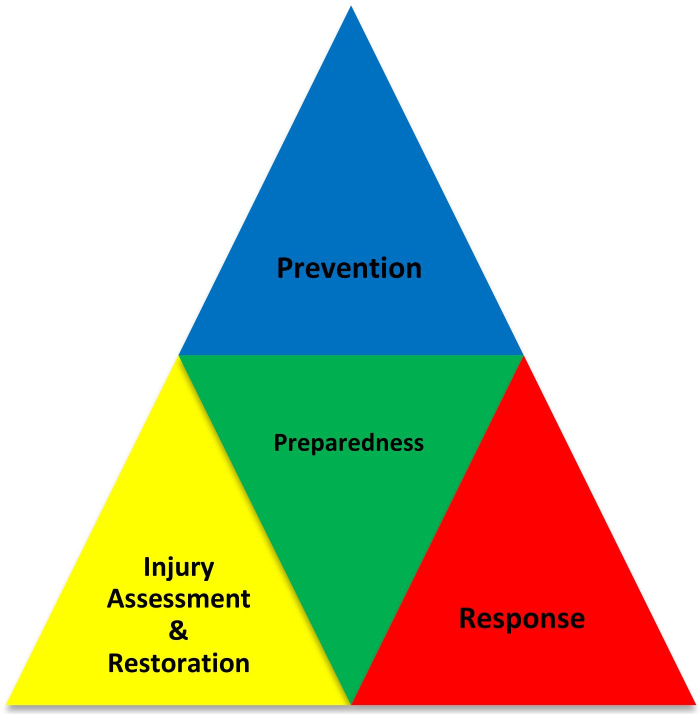


Figure 4- 1 The Oil Pollution Research Categorization Framework Classes

Prevention Class

The Prevention Class includes research that supports the development of practices and technologies designed to predict, reduce, or eliminate the likelihood of discharges, or, if a discharge occurs, minimize the volume discharged into the environment.

Preparedness Class

The Preparedness Class includes research that supports the activities, programs, and systems developed prior to an oil spill to improve the planning, decision-making and management processes needed for responding to and recovering from oil spills.

Response Class

The Response Class includes research that supports techniques and technologies that address the immediate and short-term effects of an oil spill and encompasses all activities involved in containing, cleaning up, treating, and disposing of oil. The goal of response research is to: 1) maintain the safety of human life; 2) stabilize a situation to preclude further damage; and 3) minimize adverse environmental and socioeconomic effects.

Injury Assessment and Restoration Class

The Injury Assessment and Restoration Class includes research that involves the collection and analysis of information to: 1) evaluate the nature and extent of environmental, human health, and socioeconomic injuries resulting from an incident; 2) determine the actions needed to restore natural resources and their services to pre-spill conditions; and 3) make the environment and public whole after the intervening losses.

4.3 Standing Research Areas (SRAs)

The backbone of ICCOPR's categorization framework is the SRAs that exist within the four Classes. The SRAs represent the most common research themes encountered for oil spills, many of which have been studied over several decades. Their topical content supports the themes of the Classes to which they are assigned. ICCOPR identified three additional SRAs for this OPRTP, resulting in 28 SRAs within the four Classes. The number of SRAs remains, for the most part, consistent; however, changes may occur based on emerging research themes. Table 4-1 lists the current SRAs by Research Class.

Table 4- 1 SRAs assigned within the four research Classes

Prevention	Preparedness	Response	Injury Assessment & Restoration
• Human Error Factors • Offshore Facilities and Systems • Onshore Facilities and Systems • Waterways Management • Vessel Design • Drilling • Rail & Truck Transportation • Pipeline Systems • Geohazards • Subsea Systems Automation and Reliability	• Pre-spill Baseline Studies • Response Management Systems • Renewable Energy Systems	• Structural Damage Assessment and Salvage • At Source Control and Containment • Chemical and Physical Behavior Modeling • Oil Spill Detection and Surveillance • In- and On-water Containment and Recovery • Shore Containment and Recovery • Dispersants • *In-situ* Burning • Alternative Chemical Countermeasures • Oily and Oil Waste Disposal • Bioremediation	• Environmental Effects and Ecosystem Recovery • Environmental Restoration Methods and Technologies • Human Safety and Health • Sociological and Economic Effects

ICCOPR uses a numbering scheme to facilitate the tracking of research within each SRA, Subcategory, and Research Need. The numbering scheme consists of five digits to identify the Research Class, SRA, and SRA Subcategory (if applicable). Two decimal points are included to identify specific Research Needs. The following example shows how this numbering scheme is applied.

Class: Prevention (10000 Series)
SRA: Pipeline Systems (07)
Subcategory: Leak Detection (02)
Need: Develop advanced pipeline break sensing technologies (10702.01)

Research Classes are identified by the first number. The Prevention Class is the 10000 Series, so all SRAs, Subcategories, and Research Needs in this Class will start with a 1. Likewise, the Preparedness Class is the 20000 Series, so all SRAs, Subcategories, and Research Needs in the Preparedness Class will start with a 2. SRAs are identified by the second and third numbers. In this example, Pipeline Systems is the seventh SRA, so it is numbered as 07. If an SRA has Subcategories, they are numbered by the fourth and fifth digits. Leak Detection is the second Subcategory for Pipeline Systems, so it is numbered as 02. Research Needs are labeled as two decimal places. In this example, the Research Need is the first one listed for Leak Detection, so it is labeled as .01.

4.3.1 Prevention SRAs

There are 10 SRAs within the Prevention Class.

4.3.1.1 Human Error Factors [10000 series]

Description: This SRA focuses on how human performance and factors contribute to accidents in the oil production/transportation system. It includes the development of advanced methods and systems for training operational personnel, basic research on personnel performance in preventing oil spills (i.e., safe navigation on vessels, proper oil transfer practices, analysis/evaluation of equipment monitoring systems, decision-making processes). It also includes the development of methods and technologies to evaluate the ability and knowledge of personnel in performing their duties. This extends to the overall management culture and its ability to foster the appropriate organizational safety, preparedness, and response operating environment.

Importance: Human error factors are a primary cause of oil spills (Ye et al., 2020). They are typically related to communication, task assignments, mental and physical fatigue, training levels, knowledge or understanding, and lack of experience (Ye et al., 2020). A Coast Guard analysis of oil spill causes found that human error factors were responsible for more than one third of non-casualty discharges from ships (USCG, 2012). Non-casualty spills typically include those resulting from actions such as overfilling of tanks or equipment failures not related to a vessel accident. More than half of these human errors were due to inattention, others resulted from inadequate training, and management and organizational culture. Identifying and solving various human error factors can significantly reduce oil spills at a far less cost than more expensive technology-based solutions once the oil is discharged into the environment.

4.3.1.2 Offshore Facilities and Systems [10100 series]

Description: This SRA includes: offshore exploration and development wells, platforms, and well control systems; the methods, techniques, and equipment for system reliability inspections; measures to ensure well bore integrity; systems to detect and prevent oil and gas discharges; and equipment to regain control of a well blowout or any other unplanned discharge. It also includes equipment, storage units, and piping used to transfer oil within the offshore system and connect the system to transfer pipelines. This technology is relevant for the multiple operating environments of exploration and production activities (e.g., Arctic, shallow, deep and ultra-deep waters). The term "well bore stability and integrity" recognizes that offshore wells include an engineered system reaching from the ocean floor to surface facilities, supported by the drilling platform that undergoes continual stresses and corrosion. It also includes production platforms (after drilling) that undergo stress and corrosions over the 30–40-year lifetime of the well, and the plugged and permanently decommissioned wellbore. To ensure wellbore stability and integrity throughout the well's lifecycle, cumulative fatigue must be addressed in design and maintenance.

Key needs for risk reduction associated with connecting the well to the surface facilities include analysis of cumulative fatigue in the wellbore system to inform design and maintenance of equipment and facilities. As industry moves into more challenging environments at the same time as the under corresponding intensity of meteorological and oceanographic ("met-ocean") conditions increases, the capability of offshore systems to deal with extreme conditions will likely need to increase. Improved understanding of these factors (e.g., the effects of cumulative fatigue, extreme environments) reduces the risk of oil spill incidents.

Importance: Offshore oil and gas facilities are responsible for a significant percentage of oil and natural gas production in the U.S. Globally, three of the ten largest oil spills came from offshore facilities, including the *Deepwater Horizon* oil spill, the largest marine oil spill in U.S. history. Important new and potential offshore discoveries will continue to be made in frontier environments in increasingly deeper water and Arctic conditions, creating new technical challenges. Research is needed to determine the effects of deep water conditions, ice forces, and increasingly severe weather conditions (e.g., hurricanes, blizzards) on offshore structures built in these environments. Research is also needed to address issues due to aging of existing offshore facility infrastructure. Older well spills result from internal (e.g., chemical/mechanical corrosion) and external damage (e.g., electrochemical corrosion, mechanical damage, structural failures). Advanced system designs and the effective application of improved inspection technologies have the potential to detect problems before failures occur. Improved leak detection and well control systems have the ability to identify leaks when they are still small and can be quickly isolated and mitigated to minimize spillage.

4.3.1.3 Onshore Facilities and Systems [10200 series]

Description: This SRA includes designs, techniques, operational procedures and equipment for fixed onshore facilities, including wells. It covers inspections and systems to detect, prevent, and mitigate oil and gas discharges from the facilities and their systems, including transfer equipment, storage, and piping.

Importance: Oil spill discharges can occur from onshore infrastructure, coastal bunkering facilities, and cargo transfer operations. Studies conducted by industry estimate almost a third of oil discharges between 1998 and 2007 occurred at inland facilities subject to USEPA's Spill Prevention, Control, and Countermeasures (SPCC) program (API, 2009). As of 2019, there were 540,000 SPCC facilities, including 4,600 Facility Response Plan (FRP) facilities identified as high risk due to their size and location (USEPA, 2019). USEPA inspects approximately 0.08% of SPCC facilities per year (USEPA, 2019). In 2017, USEPA found that 82% of FRP facilities and 77% of SPCC facilities inspected had inadequate prevention and response plans. Advanced system designs and the effective application of improved inspection technology have the potential to detect or predict the likelihood of potential failures before they occur. Improved detection systems can identify leaks quickly, potentially reducing the size and impacts of the discharge. It is also important to understand the ability of onshore structures to withstand changes in soil bearing capacity caused by alterations in the climate and other factors such as melting permafrost.

4.3.1.4 Waterways Management [10300 series]

Description: This SRA includes methods, equipment, and integrated systems designed to improve navigation at sea and in ports, rivers, and inland waterways. It includes on-board navigation systems, such as integrated navigation and bridge systems and collision avoidance systems. It also includes systems external to the vessel, such as vessel traffic and tracking systems, navigational aids and piloting systems, and general research into navigation risks, the effects of navigational safety programs, and the development of decision support tools for waterways management. This SRA includes development of navigational channel maintenance programs and analysis of voyage pre-planning processes.

Importance: The most frequent causes of oil spills from tankers are allisions, collisions, and groundings (ITOPF, 2019). Collisions occur when two moving vessels run into each other. Allisions occur when a moving vessel strikes a stationary object such as a bridge abutment or an anchored ship. Groundings occur when a vessel runs ashore or strikes the bottom. According to ITOPF (2019), 50% of large oil spills occurred while vessels were underway in open water, 58% of these spills were due to allisions, collisions, or groundings. These same causes account for 99% of spills when the vessels navigating in inland or restricted waters (ITOPF, 2019). Improving navigation and waterways management, particularly in congested port areas and the approaches to ports, can prevent many of these accidents. In addition, improved waterways management can facilitate safe navigation through the Arctic and other ice-infested waterways as shipping increases in these areas.

4.3.1.5 Vessel Design [10400 series]

Description: This SRA includes the development, physical and numerical modeling, and testing of advanced tanker and barge designs to make these vessels less susceptible to damage and less likely to discharge cargoes into the waterways when a grounding, collision or structural failure occurs. This SRA also includes research on non-tank vessel designs (e.g., double-hulled fuel and lube oil tanks) to minimize the possibility of spillage from a wide range of vessels.

Importance: OPA 90 required a phased in double-hull program for all tank vessels entering U.S. ports with all remaining tank barges having double hulls by January 1, 2015. IMO Regulation 12A established double-hull fuel tank construction for certain vessels. It also includes requirements for the location of fuel tanks and standards for accidental oil fuel outflow. In addition, the anticipated increase in shipping in the Arctic seas has created a need to evaluate and develop new vessel designs to ensure safe operations where ice filled waters and icing conditions around ships and structures create additional structural stresses and corrosion hazards.

4.3.1.6 Drilling [10500 series]

Description: This SRA focuses on: the design, construction, and placement of wells (shallow, deep water, ultra-deep water, onshore); materials, sensors, and systems needed for offshore drilling and production platforms, and well heads/risers; and techniques and equipment for well and facility monitoring and inspection under extreme pressure and temperature environments. Also included are efforts aimed at understanding the chemical and physical characteristics for the full range of petroleum oils under varying conditions of pressure and temperature; predicting their phase/state, behavior, and their physical interaction with other materials in the environment (e.g., rock, sediments); and their impact on engineered systems. Examples include: early kick detection; systems for communicating and responding to changes in downhole parameters; strategies and methods for training operational personnel on the use of advanced technology; systems to detect and prevent oil and gas discharges; and well-head systems and equipment to control wild wells and cap well blowouts.

Importance: Increased exploration and production in extreme environments (e.g., Arctic) increases the difficulty in responding to well blowouts and oil spills. Systems to improve safe drilling operations and prevent loss of well control are needed as drilling operations advance into deeper waters and the Arctic. Of key importance is the ability to detect changes in rock and fluid properties at the bit-rock interface or even in the rock and fluids ahead of the bit so that measures can be taken to bring the well under control. Advanced system designs and materials, and the effective application of improved sensors, monitoring systems, and more in-depth inspection technology have the potential to detect and measure well integrity and prevent failures, while improved detection and other systems can identify leaks when they are still small and can be quickly isolated and mitigated to prevent or minimize spillage. A fundamental understanding of the chemical and phase behavior, especially under extreme conditions of pressure and temperature and their effects on engineered systems is critical to effective well construction planning, long-term monitoring, and long-term well integrity.

4.3.1.7 Rail & Truck Transportation [10600 series]

Description: This SRA includes the development and testing of rail and truck transport system designs, operations, and infrastructure to make oil tank cars less susceptible to damage and loss of cargo during normal operations, and train and truck accidents. This SRA includes evaluation of vehicle designs, construction materials, spill prevention devices, and loading/unloading systems and equipment. It also includes evaluations of: the physical and chemical characteristics and behavior of crude oils being shipped, the effects of those characteristics on the tanks during operations and accidents, and systems to control these characteristics. This SRA also includes evaluations of safety systems and processes to: manage the movement and composition of trains and trucks carrying crude oil, prevent accidents and derailments, select preferred shipping routes, and respond safely to an oil spill.

Importance: The amount of crude oil transported by rail depends on many variables such as the source of oil, the type of tank car used, and the season of the year. At the peak in 2014, railroads transported over 35 million barrels of crude oil per month (EIA 2020d) due to increased oil production activities in Canada and the Bakken fields in North Dakota and Montana. Since then, rail transportation of crude oil has decreased to about 8,000 million barrels per month (EIA, 2020d). Several factors contribute to this decline, including the narrowing price difference between domestic and imported crude oil, the development of new crude oil pipelines, and declining domestic production in the Midwest and Gulf Coast onshore regions. While railroad transport is declining, need for safe rail transport of crude oil remains a priority. In May 2015, the USDOT issued a final rule to strengthen safety of tank cars transporting flammable liquids. There was a series of deadlines for specific tank cars to be retrofitted in accordance with the regulations starting on January 1, 2017.

4.3.1.8 Pipeline Systems [10700 series]

Description: This SRA includes the development of technology, models, and knowledge-based solutions to prevent and mitigate spills from offshore and onshore pipeline systems used to transport oil between facilities. It includes solutions to prevent damage from corrosion, outside forces, and other threats to pipeline integrity, and considers methods to detect and locate leaks and to mitigate volumes released. It also includes solutions to detect and characterize defects to repair or replace them before failure.

Importance: From 2001 to 2020, there were 6,232 pipeline incidents involving crude oil and/or refined petroleum products, 98% of which were onshore releases (PHMSA, 2020). These incidents accounted for the discharge of about 1.1 million barrels of crude oil and/or refined petroleum products and more than 3.5 billion dollars in property damages cumulatively from 2001 to 2020 (PHMSA, 2020). Subsurface pipeline discharges can be especially challenging to respond to. The number of pipeline spills has decreased from 399 spills in 2014 to 261 spills in 2020 (PHMSA, 2020). However, several major pipeline spills have occurred causing significant damage to aquatic environments and residential areas. Other pipeline spills in remote areas have gone undetected for long periods of time. Advanced system designs and the effective application of improved inspection technology have the potential to detect potential failures before they occur, while improved detection systems can identify leaks quickly, potentially reducing the volume and impacts of the discharge.

4.3.1.9 Geohazards [10800 series]

Description: This area consists of studies to identify and understand geohazards and conditions that are potential “precursors” to drilling and production incidents potentially resulting in oil spills or loss of life. Research in this area enhances the understanding of the geological formations and their rock properties, enabling operators to reduce the risk of encountering unexpected hazards (e.g., pressure anomalies, salt formations, faults), thereby increasing safety of drilling activity. Resources for profiling the geologic environment include remote sensing surveys that provide information for determining “precursors” to potential drilling and production incidents that could result in oil spills or loss of life. Examples of geologic precursors include: weak formations that have an unusually low fracture gradient, which indicates a tendency for the formation to destabilize wellbore integrity by losing drilling mud to the formation. Research opportunities include activities such as regional geologic studies (especially geohazards), advanced pre-drill seismic/sensing technology (especially “look ahead”), and combined reservoir and geologic studies to minimize geologic and operational exposure associated with exploration wells.

Importance: Geohazards are a significant risk-driver in deep water oil and gas developments. Even with recent advances, there remains a need to develop technologies that identify geologic precursors quickly so the risk of future incidents can be assessed and mitigated.

4.3.1.10 Subsea Systems Automation and Reliability [10900 series]

Description: This area includes analysis and improvement of the reliability of components within complex production systems operating autonomously on the ocean floor. These efforts serve the purpose of reducing the risk of spills by identifying issues earlier, with greater accuracy, and with a faster response time and lessening the environmental impact should a failure occur. Topics include: advanced equipment packaging; improved sensor and system reliability for ROV maintenance and intervention; ROV interface standardization; and advanced flow assurance understanding, especially under high pressure/high temperature (HPHT) conditions (USDOE, 2015).

Importance: The Subsea Systems Automation and Reliability SRA is focused on subsea completions. Multi-well completions over tens of square miles often come to a single subsea processing point. Industry has coined the term "subsea factory" to incorporate all the design, reliability, automation, and power requirements that are needed to make such a system functional, and reliable over a 20-year life cycle (USDOE, 2015). The risk of significant undetected subsea oil and gas leaks increases with each mile of pipeline and each umbilical connection that is made (USDOE, 2015).

4.3.2 Preparedness SRAs

The three SRAs under the Preparedness Class cover research that: 1) supports the collection of baseline data needed to assess the effects of oil spills under the Injury Assessment and Restoration Class, 2) develops management tools and systems to improve the ability of response organizations and responders to collect and analyze information during an incident, and 3) studies the expanding development of renewable energy facilities and their use of fluids that meet the regulatory definition of oils under the OPA 90 and other laws, but are not crude oils/fuels traditionally considered in spill response plans.

4.3.2.1 Pre-spill Baseline Studies [20000 series]

Description: This SRA includes research to acquire, characterize and analyze baseline data on the natural environment, human health, and socio-economic conditions in areas at risk for oil spills. Risk factors include (but are not limited to) extensive exploration and/or production, busy transportation routes, remote areas, and fragile ecosystems. Baseline information and studies may include: location and population data on species and their habitats, especially ecologically sensitive species; the epidemiology/human health characteristics of people in potential impact areas; and potential community and economic impacts in these areas (e.g., tourism, commercial/recreational fishing, seafood industry).

Importance: Baseline studies provide scientists a point of reference to monitor the environment in spill prone areas and detect changes that may indicate a spill has occurred. Should a spill occur, the baseline studies provide the information and data needed to compare pre-and post- oil spill changes in natural, human health, and socio-economic systems to support response decision-making and post-spill damage assessments and restoration activities. It is often necessary to conduct a credible post-spill environmental and economic damage assessment without pre-spill baseline information, using reference sites not contaminated by the spill for comparative studies. The availability of pre-spill baseline information makes the post-spill natural and socio-economic damage assessment task much easier, accurate, and more defensible. Essentially, the better environmental and economic systems are understood before a pollution event, the easier it is to assess changes to them, estimate damage and develop appropriate restoration strategies.

4.3.2.2 Response Management Systems [20100 series]

Description: This SRA includes development of systems to manage how data and information are collected, analyzed, documented, and shared between and among, the planning/preparedness and response communities, the National Incident Management System (NIMS), and the public. These systems are used to integrate diverse sets of narrative, graphic, and video information and many sets and types of raw and analyzed data. Examples of oil spill information systems include: ICS forms; computer systems; data management software and databases; GIS; spill and incident management tracking systems; electronic mail and web content; documents, photographs, and video management and archiving systems; communication systems; public information messages and protocols; remote sensing; and graphical displays.

Importance: Management and decision-making tools are critical to successfully planning for and managing a response and meeting external demands for information about an incident. These systems provide the tools to obtain a common operating picture of an incident, support making resource management decisions, and share appropriate information with all relevant parties. Improving the accuracy and timeliness of the data increases the ability of the incident command (IC) to stay abreast of changing situations and keep the IC best informed in order to execute often difficult decisions. Efficient systems also provide public affairs officers and personnel with timely information to disseminate as appropriate to the public and media in support of the 24-hour news cycle.

4.3.2.3 *Renewable Energy Systems [20200 series]*

Description: This SRA focuses on the challenges posed by the development of renewable energy facilities and their use of OPA regulated products that may behave differently than products traditionally considered in spill response plans. This SRA seeks to determine the extent and nature of the fluids used, or planned for use, in renewable energy systems. It also covers research to better understand how the fluids are used, the associated sources and risks of releases, their potential health and environmental consequences, and the ability of current response systems to recover these materials.

Importance: Renewable energy accounts for 11% of the U.S. total energy consumption (EIA, 2020e). Over 40% of this is from biomass (wood, biofuels, and biomass waste), 24% is from wind energy, and 22% is from hydroelectric energy. Solar and geothermal make up the remaining sources (EIA, 2020e). Since 2016, renewable energy consumption in the U.S. has continued to grow (EIA, 2020f). Wind energy has continued to increase within the U.S. and most of the nation's wind capacity is produced by onshore wind farms. In 2019, 41 states had at least one onshore wind turbine with a cumulative wind capacity exceeding 100 gigawatts (GW). In 2020, the U.S. had one operational offshore wind project located off Block Island, RI (Block Island Wind Farm), which became operational in 2016 (AWEA, 2020). Offshore locations are increasingly being considered as high-quality locations for wind farms. There are several projects in various stages of development across 15 offshore energy lease sites issued by BOEM along the East Coast (AWEA, 2020). Additional lease sites are being planned off the coast of California, Hawaii, New York, and South Carolina. Many of these facilities will beginning operating during the 6 years (AWEA, 2020). Many East Coast states aim to have a total of 25,400 megawatts (MW) of offshore wind by 2035, which is driving demand for the expansion of renewable energy (State of New Jersey, 2020). Many renewable energy sites use fluids for lubrication, cooling, transformers, and other components to keep the system functioning. It is important to understand how these fluids behave when released into the environment to select appropriate response methods and tactics.

4.3.3 Response SRAs

The Response Class of research includes 11 SRAs that support improvements to the activities, technologies, techniques, and equipment used during response operations. These SRAs cover all areas from oil detection, behavior modeling, cleanup, to waste disposal.

4.3.3.1 *Structural Damage Assessment and Salvage [30000 series]*

Description: This SRA includes the development of methodologies and equipment for assessing the extent of damage to a vessel resulting from collision, allision, grounding, explosion, or improper hull stresses during cargo transfers. This area also includes development of methods and technology to graphically present the implications of various measures that can be implemented to stabilize a vessel's condition, reduce the potential for further pollution, and allow it to be moved safely for repairs or disposal.

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

4.3.3.2 At Source Control and Containment [30100 series]

Description: This SRA includes the development of methods, systems, and equipment for containing and recovering oil at or from the source and for mitigating flow from a damaged vessel, onshore/offshore pipeline, exploration or production platform, temporarily abandoned (plugged) well, or well-head once a spill has begun. Such technologies include wellhead capping systems, unmanned systems for subsea containment activities, and patching, plugging and sealing systems. This technology is applicable to all geographic/environmental areas (Arctic, terrestrial, water surface, subsurface shallow, and deep and ultra-deep water).

Importance: The logistical difficulties, enormous costs, and limited success experienced during on-water and shoreline cleanup operations make clear the advantages of containing or recovering oil within, near, the source of the flow. Technological breakthroughs arose from experiences acquired during the 2010 *Deepwater Horizon* oil spill incident. Additional advances in this area could provide substantial return on R&D investment to contain/recover oil at the source and thereby reduce the extent of contamination and resulting ecological and socio-economic effects if a spill occurs.

4.3.3.3 Chemical and Physical Behavior Modeling [30200 series]

Description: This SRA includes laboratory research, theoretical research, and field studies aimed at understanding the behavior and characteristics of the full range of petroleum oils. Topics cover behavior and transport in the environment, partitioning of hydrocarbon constituents, and physical interaction with other materials (e.g., rock, sediments, ice). It includes studies of oil behavior and changes throughout the water column in different systems (e.g., riverine, marine). There is particular interest in non-conventional oils such as those produced from the Bakken and Canadian tar sands (diluted bitumen (dilbit) and synthetic bitumen (synbit)). It also incorporates the development and verification of numerical models to predict surface and subsurface movement and weathering (i.e., spreading, evaporation, dispersion, dissolution) of oil spills. This SRA includes methods to provide accurate input data to verify model outputs and development of user-friendly programs to enhance contingency planning and serve as training aides for spill response teams. Models should be available for various spill scenarios at specific locations for different flow and weather conditions to pre-plan potential boom deployment strategies and estimate response resource needs.

Importance: Predicting the trajectory (movement) and the weathering of spilled oil, its resultant physical properties and behavior in the water, and the extent of contamination are all critical to identifying the appropriate mix of spill response equipment and countermeasures. A fundamental understanding of the fate (chemical behavior and transport) and effects of oil in the environment is critical to effective contingency planning, response operations management, long-term monitoring, and restoration. In addition, knowledge of longer-term fractionation and transport of hydrocarbons, coupled with potential effects on aquatic resources, provides valuable information to help focus monitoring efforts and develop environmentally relevant restoration plans.

4.3.3.4 *Oil Spill Detection and Surveillance [30300 series]*

Description: This SRA refers to methods and equipment for characterizing and monitoring oil spills pre- and post-implementation of response options, and the detection of unknown discharges. This SRA includes surface and subsurface oil spill surveillance including devices, sensors, and systems for detecting and tracking spills, determining the area and thickness of a slick, and measuring the physical properties of the oil. Examples of equipment considered in this area are: surface spill tracking buoys; airborne remote sensors and data analysis systems; fluorometers and light-scattering sensors; and satellite remote sensing data and on/in-water detection devices with the ability to conduct nighttime and low light recovery operations. It includes research supporting development of monitoring protocols for subsea and surface responses or improvements to existing ones such as the NRT Atypical Use guidance or the Special Monitoring of Applied Response Technologies (SMART) guidance, as applicable. Evaluation of techniques for autonomous sensing operations and reporting from remote locations where logistical challenges limit human accessibility is included.

Importance: Finding and characterizing areas of subsurface or submerged oil in onshore (inland) and offshore waters is a key input to effective oil spill response efforts. Surveillance technologies provide opportunities to locate spills and their source, determine their extent and volume, provide important data to support response operations, and determine the effectiveness of response. The ability to determine concentrations of oil and track slick movements for countermeasures and cleanup planning supports response operations. Measurement of thickness and physical properties allow responders to determine the feasibility of mechanical recovery, ISB, and dispersant use. The data obtained from surveillance can facilitate the efficient deployment of resources for response operations and improve and validate spill behavior models.

4.3.3.5 In- and On-water Containment and Recovery [30400 series]

Description: This SRA includes the development of methods, equipment, and materials for physically containing and removing oil from the surface, in the water column, or on the bottom of the sea/lake/riverbed. This SRA focuses on improving traditional equipment such as booms, skimmers, and sorbent materials, as well as developing new approaches to surface containment, and equipment and systems specific to containment and recovery of subsurface oils.

Importance: Mechanical recovery is often the preferred option because it physically removes oil from the environment, so it does not pose the potential for additional harm. Containment booms are subject to entrainment and splash over when they encounter certain current velocities or wave heights, thereby reducing their effectiveness. Developing new boom designs could improve oil containment across a wider range of environmental conditions, including ice-infested and brash-ice infested waters. Mechanical recovery is often the most viable recovery option since it is not subject to agency pre-approval requirements (as are the use of dispersant and ISB). The total average on-water recovery effectiveness for larger spills depends upon the type of oil spilled, ambient conditions, and available equipment. Improvements in the speed of skimmer advance and encounter rates, onboard separation/decanting, enhanced abilities in waves, and rapid systems for temporary oil storage of skimmers could significantly improve mechanical recovery efficiencies. Technology advances are also needed for recovery of oil suspended in the water column or located on the sea or riverbeds.

4.3.3.6 Shoreline Containment and Recovery [30500 series]

Description: This SRA covers new methods, treating agents, and equipment for removing oil from shorelines, as well as mitigating the environmental impact of oil that remains. Specifically, it includes water washing and flooding techniques, the use of chemical treating agents, and novel applications of mechanical removal techniques and equipment. It also includes analysis, evaluation, and decision-making (risk, benefits) for the use of active shoreline oil removal techniques versus passive naturally occurring processes.

Importance: Oil spills that impact shorelines often result in oiling of natural resources (e.g., beaches, marshes, coral reefs, mangroves) and man-made structures (e.g., breakwaters, seawalls, piers, vessels). Removing the oil or mitigating the impacts of the oil requires a range of technologies that minimize environmental damage. Implementing technologies also requires knowledge of the relative benefits of foregoing cleanup activities and allowing natural processes to remove the oil.

4.3.3.7 Dispersants [30600 series]

Description: This SRA addresses the deployment and use of chemical products designed to interact with marine oil slicks by reducing the oil/water interfacial tension and creating tiny droplets with the aid of waves or other energy sources. Research areas for dispersants include: developing appropriate dispersant applications for cold weather and deep sea environments; increasing dispersant effectiveness for water surface and subsurface applications (e.g., effective on a wider viscosity and emulsification range, calm sea conditions); reducing ecological effects of individual components and the overall dispersant in the water column; refining vessel, aircraft, and subsea application methods and equipment; developing enhanced monitoring methods and systems for determining the effectiveness of surface and subsea application of dispersants; distinguishing physically versus chemically dispersed oil; studying the distribution and impact of chemically dispersed oil in the environment; and understanding regional variations in dispersant performance and potential environmental impacts. This SRA includes research that enhances the ability to predict dispersant effectiveness on various oil types and at varying application rates, including weathered/emulsified oils and a range of water salinities. This SRA also encompasses studies to determine the suitability of subsea application of dispel rsants in the Arctic region where the unique conditions (e.g., shallow depths, water salinity, ice-infested water, under-ice discharges) could influence their fate and effects. An important supporting activity is the development of an information database on dispersant product effectiveness, application procedures, and effects. Also included in this SRA is research on the potential acute and chronic effects of dispersants on organisms and populations at various depths.

Importance: Dispersants are an important tool in spill response when it is critical to mitigate oil slicks, especially those that are large and offshore. Refinements in dispersant formulations to improve their effectiveness, reduce environmental effects, and/or increase understanding about their potential benefits and risks, can allow dispersants to remain a viable option. This is especially important for large offshore spills and other areas where mechanical techniques fall short in reaching desired levels of effectiveness to remediate spilled oil. Research is needed to address environmental tradeoffs, worker and public health exposures and provide the conditions under which they may be used appropriately. Research is needed to address questions about the potential acute and chronic effects of dispersants on organisms and populations at various depths since dispersants shift the risk from the surface to the water column.

4.3.3.8 [In-situ Burning [30700 series]]

Description: This SRA addresses equipment and techniques required to ignite and sustain combustion of oil spills on the water, along shorelines, and on land. Also considered is research on intentional wellhead ignition (IWI) as a source control measure. A source of ignition must be present as well as the necessary mix of fuel (e.g., oil) and oxidant (e.g., oxygen) to burn. Because slick thickness is a key variable determining whether the oil will burn, this research area includes development of equipment such as fire-resistant booms and herders to concentrate the slick thickness, and improved ignition devices. This SRA also covers developing knowledge of the conditions under which equipment and techniques can be applied effectively, including evaluation of use in frigid (i.e., Arctic) environments, where cold conditions and ice limit operational effectiveness of mechanical containment and recovery of spilled oil. This SRA also includes research to develop new methods to enhance efficiency and burn weathered, emulsified, and more viscous oils. Research into the production of residuals including soot and other ISB byproducts, and the techniques and equipment to recover them is also included in this SRA.

Importance: The *Deepwater Horizon* demonstrated that ISB can remove large amounts of oil from the surface of the water. For example, on a single day (June 18, 2010), 16 on-water ISBs removed approximately 60,000 barrels of oil from the Gulf of Mexico (USCG, 2011). This technology also reduces the extent of onshore disposal of recovered oil. It can be an effective method of mitigating spills on land and in coastal areas by removing the spilled oil from the surface to prevent damage caused by certain mechanical removal techniques or longer-term, passive natural degradation processes. In Arctic regions, operators are proposing IWI as a source control measure. Studies are needed on the viability of this technique and the resulting effects of soot deposition on the thickness of snow and ice.

4.3.3.9 [Alternative Chemical Countermeasures [30800 series]]

Description: This SRA includes the development and use of various spill response chemicals to treat slicks on the surface of the water making oil more amenable to mechanical recovery, ISB, and other techniques. These chemicals include solidifiers, herding agents, elasticity modifiers, shoreline pre-treatment agents, and emulsion treating agents (demulsifiers). Research includes improving chemical formulations, refining application techniques, and conducting studies of effectiveness and environmental effects.

Importance: Alternative chemical countermeasures are not frequently used but, in certain cases, can be very effective in improving oil recovery and mitigating impacts. At present, the countermeasures included in this SRA are typically used on smaller spills close to shore due to the logistics involved. However, new formulations of these agents have the potential to increase their utility. Emulsion breakers used on recovered oil could decrease the amount of material for disposal.

4.3.3.10 Oily and Oil Waste Disposal [30900 series]

Description: This SRA includes study and development of analytical methods, procedures, equipment, and techniques to manage and dispose of oil, oily water, oiled soils, and oiled debris recovered on-water and on land during pollution responses. Specific technologies include waste segregation, temporary storage, solidification and stabilization prior to landfill disposal or recycling, oil reclamation, incineration, and biological treatment (i.e., land farming, composting). It also includes techniques and equipment for onsite oil-water separation, filtration, and decanting operations that reduce the volumes of material to be handled, transported, and disposed.

Importance: Disposal of oil and oiled debris can be a significant problem during major spills, particularly in remote areas. Oil can emulsify (wave action results in water becoming incorporated into the oil, so that it occupies a larger volume, making waste treatment and disposal an even more significant issue. Waste is also generated by decontamination activities, such as cleaning of oiled vessels, booms and skimmers, and mechanical shoreline cleanup equipment. Sorbents are used extensively during oil spill response, and many are not biodegradable. Disposal of decontamination waste includes the oil, water, and cleaning agents, which further complicates waste disposal options. Research is needed to advance recycling opportunities, develop treatment technologies for recovered oil waste, and reduce overall waste.

4.3.3.11 Bioremediation [31000 series]

Description: This SRA includes research and technology to exploit the capabilities of microorganisms and plants to accelerate the rate of degradation of oil in soil and water. Bioremediation is largely an *in-situ* technology as *ex-situ* use requires removal and further manipulations that may have a greater potential for environmental harm. Research methods are needed for nutrient and/or microbial enrichment to accelerate the biodegradation process on land (bio-augmentation). Research is also needed on bioremediation in the presence of dispersants, herders, and other chemical agents in water. In areas such as coastal wetlands, where stranded oil may have penetrated the anaerobic subsurface, topics include wicking oil to aerobic conditions and nutrient enrichment. This SRA also includes the application of bioremediation for more effective response and restoration including phytoremediation (remediation using plants), as longer-term restoration technique.

Importance: Bioremediation may be is used as a polishing step to follow mechanical recovery or other *ex-situ* treatment strategies. It is less intrusive than mechanical recovery, which is especially important in environmental habitats and sensitive areas that could be seriously damaged by equipment.

4.3.4 Injury Assessment and Restoration SRAs

The four SRAs in the Injury Assessment and Restoration Class address the development of strategies for environmental recovery from oil spills by determining the level of effects and their implications on the environmental and sociological resources. These SRAs primarily support the NRDA process as well as the need to improve restoration techniques and determine ways to minimize the adverse effects of response activities.

4.3.4.1 *Environmental Effects and Ecosystem Recovery [40000 series]*

Description: This SRA includes laboratory research, field studies, and modeling efforts to understand and predict the short- and long-term effects of oil spills at the ecosystem level. It includes research into the short- and long-term recovery of various types of environments and the chronic effects of oil spills on habitats, species, recovery and rehabilitation of wildlife, and communities. This SRA includes the effects of the oil and the countermeasures and cleanup techniques used to remove it. It also includes research to determine the rate of ecosystem recovery with and without countermeasures and cleanup.

Importance: This research provides important feedback on the effectiveness of past responses, forms the basis for future decision-making during spill response, and provides input for damage assessment, restoration planning, and development of decision support tools. Knowledge of the environmental and ecosystem effects of different response measures provides decision-makers the opportunity to identify and select methods that maximize recovery and reduce the adverse effects of response. OPA 90 Title VII was amended in 2021 to emphasize the need for research on sublethal and acute impacts as well as long-term effects of oil spills, which are addressed by this SRA.

4.3.4.2 *Environmental Restoration Methods and Technologies [40200 series]*

Description: This SRA includes development of methods and technologies to facilitate and accelerate the recovery of resources following an oil spill. It includes research into the effectiveness of approaches for environmental restoration. It also includes evaluations and comparisons of the factors affecting success of the restoration methods and technologies and studies of previous restoration efforts and natural recovery.

Importance: OPA 90 mandated restoration activities and required that funds obtained through damage assessment and compensation litigation be spent on restoration. However, few proven methods, technologies, or monitoring protocols exist to support restoration activities. Knowing the conditions affecting the success of the methods and technologies provides decision-makers with tools for selecting the approaches that would enhance the chance for successful restoration. OPA 90 Title VII was amended in 2021 to emphasize the need for research on long-term recovery from oil spills, which is addressed by this SRA.

4.3.4.3 Human Safety and Health [40300 series]

Description: This SRA includes studies on the effects of spilled oil and response activities on human health and safety for workers and the public. It includes the study of oil weathering throughout the water column and the potential concerns relative to worker health and safety. It focuses on the development of monitoring instruments, procedures, and processes to inform personnel engaged in response activities, as well as the general public, who could be affected by the spill and response options. It also includes studies of the safety of seafood that can impact commercial and recreational fishing and subsistence seafood use. in a spill area to determine if they are safe to market and consume. Research on seafood safety may include petrochemical toxicology and profiling, risk analysis, sampling and testing methodology development, and risk communications.

Importance: Protecting the health and safety of responders and the public is the highest priority during a response. Potential hazards include fire and explosion, vapor toxicity, and dermal exposure. Physical health hazards can be acute or chronic. There are processes and procedures that can be implemented to reduce these potential hazards. Some hazards require a greater understanding of how oil behaves to inform the potential concerns relative to worker health and safety. Benzene, for example, can present a potential for chronic health hazards such as leukemia, hence understanding oil weathering would inform the needed levels of protection. Response operations conducted on water or shoreline present inherent dangers such as: trips, falls, and cuts; equipment accidents; working in extreme weather conditions (e.g., heat stroke, freezing); and environmental hazards. Some response options present additional health concerns such as: the chemicals in dispersants and oil and ISB fires. An additional aspect of human health and safety is seafood safety (both fresh and marine waters), which is a complex topic involving sampling and analytical plans, equipment and methods, and data interpretation to assess the potential effects on consumers. Recreational and subsistence use harvesters are a greater concern than the general population when estimating health risks following a spill due to their increased seafood consumption and reliance on local seafood resources. Development of health and safety techniques and equipment to mitigate these hazards helps the incident command meet its fundamental responsibility to safeguard responders and the public.

4.3.4.4 Sociological and Economic Effects [40400 series]

Description: This SRA includes studies on how oil spills and response affect the sociological fabric of communities and their economies. Disciplines encompassed in this research area include sociology, economics, behavioral sciences, political science, and law. It also involves studies on risk communication and community resilience.

Importance: Research is needed to improve communication of risk, decrease scientific uncertainty, and address socioeconomic concerns associated with oil spills. Oil spills and response may cause high levels of stress and psychological trauma, including post-traumatic stress. These effects may begin at the individual level and frequently spread to families, and communities whose culture and livelihood are dependent upon the waters and shorelines near a spill. Unemployment and loss of income are additional stressors on peoples' lives. Oil spills can also adversely affect social relationships and have disastrous effects on specific individuals and communities in areas where livelihoods depend on use of resources. Research that supplies a broad understanding of the human dimensions of oil spill hazards and identifies better ways to engage and share information using risk communication principles enhances future decisions concerning sociological and economic effects on community stakeholders and assist them in successfully overcoming these obstacles.

4.4 Research Needs

ICCOPR identifies Research Needs during the OPRTP planning cycle through an analysis of several sources, including:

- Reports on research programs and results;
- Analyses of lessons learned from recent oil spill incidents;
- Data and information shared at various workshops, conferences, and technical and policy meetings;
- Development or enactment of new laws or regulations;
- Input shared and collected from correspondence, quarterly meetings, or scheduled public meetings;
- Data calls and public listening sessions to elicit recent publications and research needs from government experts, industry, academia, NRDA Trustees, and other appropriate parties;
- Research projects conducted/managed by industry, academia, and non-governmental organizations; and
- Forecasts of issues or problems associated with changes or expansion in any aspect of the energy distribution system.

ICCOPR's compiled master list of 570 Research Needs from the FY2015-2021 OPRTP was used as a baseline list for the FY2022-2027 OPRTP. The Research Needs on the list were evaluated and were removed if they were resolved or newly identified needs were added. For the FY2022-2027 OPRTP, ICCOPR removed 14 resolved priority Research Needs through the process described above. Part Two of this OPRTP describes the process used to review the resulting master list of 737 Research Needs to establish 171 priorities.

4.5 Projects

Projects are the specific research experiments and studies conducted by a primary investigator that address a Research Need. Projects involve a methodological study or technology development with assigned budgets, resources, and personnel. ICCOPR tracks projects conducted by any entity, not just those conducted specifically by ICCOPR member organizations. ICCOPR recognizes the value of research projects by other entities and welcomes the research efforts of partners from industry, NGOs, state research programs, research institutions, academia, Indian tribes, and international organizations.

ICCOPR monitors oil pollution research projects from any identified source and classifies identified needs within the Research Categorization Framework by SRA. ICCOPR uses the lists of projects and information on the research results as a basis for assessing how well the Research Needs from the previous OPRTP were addressed.

5. Knowledge Transfer and Advancement

ICCOPR's goal for the R&T program is to advance information, technologies and regulations that increase the effectiveness of oil spill prevention, preparedness, response, and injury assessment and restoration efforts. The R&T planning process emphasizes and strengthens member agencies' roles and responsibilities to ensure that research advances the capabilities to reduce oil pollution. The degree to which practitioners implement the results of the R&T program depends upon the success of the research and how the results are communicated to the oil spill response community. As part of the program, ICCOPR promotes continuous improvement by monitoring the state of knowledge and adjusting the program to meet changing needs.

5.1 Factors Affecting Research and Technology Program Success

The success of the federal oil pollution R&T program depends on: 1) funding; 2) continuity of research; 3) field testing; 4) regional issues; 5) including new researchers; and 6) public perception. The importance of these factors to the success of the federal program is discussed below.

5.1.1 Funding

A steady funding stream at appropriate levels is a primary factor to support a successful R&T program. In their review of the 1992 OPRTP, the NAS Marine Board (1993) acknowledged the need for steady funding:

> "An important unresolved issue is funding. The continued evolution and effectiveness of the plan is in doubt because the additional funding authorized by Congress has not been appropriated. Moreover, little funding under OPA 90 is expected. This short-term funding approach poses a significant barrier to most multi-year research. For example, scientists cannot undertake basic research dealing with the nature of oil and seawater mixtures and their response to mechanical and chemical treatment, oceanic environments, and time, because several years of laboratory work and additional time for field testing would be required."

The Marine Board also noted the problems caused by the boom-and-bust cycle of research and funding efforts for oil spill cleanup technology:

> "Research and development related to oil spills follows a boom-and-bust cycle. After catastrophic spills, when the acute effects of oiled beaches, polluted waterways, and dying wildlife are featured in all the media, there is public outcry and political interest, accompanied by calls for action, for more research, and for better prevention and control measures. Later, as acute effects fade, but longer term and less obvious problems may continue, public interest-and with it political interest-fade. By the time the calls for action are translated into R&D plans, the interest is gone, and the plans typically are neither supported nor funded..."

Similarly, the National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling (2011) discussed the continued need for funding at an appropriate level:

> "The technology available for cleaning up oil spills has improved only incrementally since 1990. Federal research and development programs in this area are underfunded: In fact, Congress has never appropriated even half the full amount authorized by the Oil Pollution Act of 1990 for oil spill research and development. In addition, the major oil companies have committed minimal resources to in-house research and development related to spill response technology. Oil spill response organizations are underfunded in general and dedicate few if any resources to research and development …"

> "Recommendation: Congress should provide mandatory funding for oil spill response research and development and provide incentives for private-sector research and development."

The U.S. Department of the Interior (2021) describes the need for research to support inland oil spill preparedness:

> "The objective for the Inland Oil Spill Preparedness Program (IOSPP) is to improve overall preparedness and the ability to respond to inland oil spills in ways that better protect the Nation’s natural and cultural resources, historic properties, and public lands. When an inland oil spill occurs, personnel from the Department’s bureaus are often among the first responders, along with State and local responders and the Environmental Protection Agency (EPA) on-scene coordinators. Pre-incident preparation requires contingency planning, including response teams efforts, planning, and inland oil spill drills.
>
> The IOSPP funds are used for a variety of research projects that support the Administration’s priorities. For example, the program is working with several USGS Environmental Centers to evaluate the flow, trajectory, and potential impacts of inland oil spills. This information will be used by federal, state, and local responders to inform and prioritize their response actions and to protect sensitive, unique, and publicly-owned land, furthering the goal of protecting land and habitat so as to not lose these habitats to the impacts of spills and releases."

The trends in the oil production and distribution systems are constantly changing, posing new challenges to managing pollution. The ability of R&T efforts to keep pace with the challenges will be affected by long-term funding levels.

ICCOPR does not receive funding for research. Instead, its members fund research using their agency’s annual budget appropriations or OSLTF R&T funds. The ICCOPR agencies with access to the OSLTF R&T funds are: the USCG, USEPA, BSEE, and PHMSA, Department of the Treasury, Prince William Sound OSRI, and the Denali Commission.

However, federal budgetary rules count any funds withdrawn from the OSLTF for research purposes against an agency’s overall budget, which means that oil pollution research initiatives still must compete against other agency missions to obtain funding. The National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling (2011) made the following comment on the funding levels for oil pollution research:

> “Specifically, Congress should provide mandatory funding (i.e., funding not subject to the annual appropriations process) at a level equal to or greater than the amount authorized by the Oil Pollution Act of 1990 to increase federal funding for oil spill response research by agencies such as Interior, the Coast Guard, USEPA, and NOAA— including NOAA’s Office of Response and Restoration.”

While mandatory funding, not subject to appropriations, may be impractical, Federal funding for coordinated research, presumably through ICCOPR, is generally recognized as beneficial to improving prevention of and response to oil spills.

ICCOPR initially used Regional Research Grants authorized by Section 7001(c)(8) of OPA 90 to address oil spill issues. The objective of the Regional Research Program was to "coordinate a program of competitive grants to universities or other research institutions, or groups of universities or research institutions, for the purposes of conducting a coordinated research program related to the regional aspects of oil pollution, such as prevention, removal, mitigation, and the effects of discharged oil on regional environments." Congress authorized funding for the program for the FYs 1991 through 1995, but never again. ICCOPR will consider additional Regional Research Grants if Congress authorizes funding in the future.

5.1.2 Continuity of Research

The ability of research programs or projects to continue is an important factor in successfully addressing oil pollution research needs. Changing agency missions, funding priorities, staffing, or site access may interrupt research programs. Breaks in research continuity, if long enough, can result in a "hiatus effect" where key knowledge or learning opportunities are lost. Studies that measure trends over time (e.g., baseline and impact assessment biological studies, oil fate and effects studies, ocean current monitoring) are particularly vulnerable. The institutional knowledge resulting from research efforts can also be lost when program lapses or changes prompt employees to leave their federal positions.

5.1.3 Field Testing

ICCOPR recognizes that field testing is a valuable tool to validate laboratory results and to study techniques, treatments, and equipment *in-situ*. In 1993, the NAS Marine Board recommended that the Federal R&T program include controlled field experiments that involve a deliberate, limited discharge of oil to advance research areas (e.g., oil dispersants, ISB, incineration, bioremediation). The NAS Marine Board noted that laboratory experiments cannot replicate real-world process interactions and variables, and accidental spills provide limited learning opportunities because data on pre-spill conditions and/or spill volume usually are lacking. An independent report, "Responding to Oil Spill in the U.S. Arctic Marine Environment", also highlighted the need for field testing (NRC, 2014). The report noted that countries such as Norway have consistently supported this type of research by permitting controlled spills when clear research needs, methods, and goals have been identified, and responsible cleanup and monitoring plans have been established.

Field tests may be justified when laboratory or other simulated settings (e.g., test tanks) cannot address specific Research Needs and no other open water research projects have addressed them. Experiments in large test tanks (i.e., Ohmsett) provide opportunities to simulate environmental conditions and bridge the gap between laboratory and *in-situ* experiments; however, they cannot completely replicate actual field conditions. ICCOPR will continue working with policy makers and permitting authorities to explore field testing opportunities.

5.1.4 Building the Next Generation of Researchers

The federal oil pollution R&T program needs an adequate pool of researchers and policy makers interested in research to replace those that are retiring or leaving for other opportunities. College students need to view the oil pollution management and research fields as a viable career path. Interest in pursuing these areas is strongest in the years following a major spill (i.e., *Exxon Valdez*, *Deepwater Horizon*) and decreases as events fade from national consciousness. Thus, generating and maintaining interest by college students about to enter the workforce in oil spill R&T careers is an important element of ICCOPR's efforts.

Several of the ICCOPR member agencies have programs to encourage students to become interested in oil pollution research or management. NOAA and the UNH CRRC educate students on issues related to oil spills and response and work with other university programs to encourage academic interest in the field. Additionally, NOAA administers the RESTORE Act that funded the Gulf Coast Restoration Initiative (GulfCorps) in 2017. From 2017 to 2020, the funds were distributed evenly to the five Gulf Coast states to support existing local Corps hiring of young adults to conduct restoration and conservation activities to both restore valuable coastal habitats and train young adults in marketable job skills for the growing restoration economy.

The U.S. Coast Guard Academy includes environmental protection and marine safety topics across its curriculum in many forms ranging from drilling technology and petroleum chemistry to the history of spills of national significance. The Marine and Environmental Science major includes specific courses in geochemistry, analytical chemistry, and petroleum and oil spill science. The Engineering Department offers courses focused on the needs of the prevention community. Cadet research projects, which are part of their curriculum, often address oil spill issues.

NASA's DEVELOP National Program fosters an interdisciplinary research environment for students, where applied science research projects are conducted under the guidance of the agency and its partner science advisors. DEVELOP is unique in that young professionals lead projects that use NASA Earth observations to address community concerns and public policy issues, including oil pollution research.

The triannual International Oil Spill Conference (IOSC) Executive Committee, which includes several ICCOPR members, offers a scholarship program, conference mentoring, and student awards to promote interest in oil pollution research.

The American Association for the Advancement of Science (AAAS) offers Diversity, Equity, and Inclusion (DEI) Programs to leverage a diverse and inclusive foundation for science, technology, engineering, and mathematics (STEM) communities and the public to build a nation that values the inclusion of diversity in STEM. The DEI Program provides tools that expand access to STEM education, strengthen and diversify the science and technology workforce, and amplify underrepresented and marginalizes voices within STEM.

ICCOPR also provides annual advice to the NAS GRP on the direction of the GRP program, which includes education and training. A key program objective of the GRP is to support the development of future professionals and leaders in science, industry, health, policy, and education who can apply cross-boundary approaches to critical issues that span oil system safety, human health, and environmental resources.

The DOI's Youth Initiative includes outreach to students at the Ohmsett facility and at the annual Clean Gulf Conference. At the 2014 and 2016 Clean Gulf Conference, several ICCOPR members participated in a day-long outreach session with a local high school's Advanced Placement environmental science class.

Over its 10-year program, GoMRI funded more than 1,200 graduate students, with over 300 of them being recognized as GoMRI Scholars. The GoMRI Scholars Program recognized graduate students and their research to improve the understanding the damage, response, and recovery following the *Deepwater Horizon* oil spill. This program built a community for the next generation of ocean science professionals. However, the 10-year funding for the GoMRI program expired in 2021 and the program was disbanded.

5.1.5 Public Perceptions

The NAS Marine Board observed that public reactions and perceptions can play a significant part in oil spill response decisions, regardless of their scientific validity. Adverse reactions to the use of a technology can lead to political pressures to limit its use. For example, public concerns in 2010 about the use of dispersants during the *Deepwater Horizon* oil spill response prompted interest groups and state agencies to oppose their use. Such opposition increases the need for research to provide additional validation of dispersant safety and efficacy before approval of dispersant applications as a response option.

5.2 Communicating Research and Technology Efforts

Researchers must effectively communicate their results to the broader oil spill research and response communities to provide the greatest benefit from their efforts. ICCOPR uses a variety of mechanisms, discussed below, to transfer research knowledge to stakeholders and to learn of advances by non-federal researchers.

5.2.1 ICCOPR OPRTP

OPA 90 established the ICCOPR OPRTP as the mechanism to inform Congress and the public on the status of oil pollution technologies, research needs and priorities, and agency roles and responsibilities. The 1992, 1997, and 2015 versions of the OPRTP provided ICCOPR's assessments of the state of knowledge at that time. The 2021 version updates the assessment of oil pollution R&T to reflect recent research advancements and changes in oil spill risks. ICCOPR intends for future versions of the OPRTP to continue serving as information sharing documents that provide the current Federal perspective on oil pollution research. ICCOPR plans to update the OPRTP every six years to maintain timely information and perspective on research needs. ICCOPR may publish supplements, if warranted.

5.2.2 ICCOPR Biennial Reports to Congress

Section 7001(e) of OPA 90 requires that ICCOPR submit a report biennially on its activities and those of its members during the previous two FYs and the anticipated activities for the next two FYs. The ICCOPR Biennial Reports to Congress serve as a reference document on ICCOPR activities, member initiatives, and planned activities. Appendices to the reports provide listings of publications by ICCOPR member agencies and descriptions of their research projects. As of the writing of this report the current Biennial Report to Congress is being completed (2020-2021) and the next Report will be drafted for 2022-2023.

5.2.3 ICCOPR Meetings

ICCOPR's standard practice since 2012 is to conduct quarterly membership meetings and special meetings with interested stakeholders. These meetings provide an opportunity for members and outside parties to share information and ideas. Quarterly meetings are mandated by the Elijah E. Cummings Coast Guard Authorization Act of 2020.

The quarterly meetings are conducted in two parts: 1) an open public session, and 2) an internal business meeting session. The public session includes presentations by invited speakers or ICCOPR members about research results and topics of interest to the members and the public. Agenda topics and presentations are selected based on timeliness of the research advancements, meeting themes, and relevance to the member's research programs. The internal business sessions focus on Committee administration and opportunities for members to present agency updates and coordinate and collaborate on their research initiatives. Business meetings may contain information that is pre-decisional and deliberative for agencies. Meeting minutes are published on the ICCOPR webpage maintained by the USCG.

ICCOPR devotes at least one quarterly meeting a year to presentations and discussion of restoration and recovery topics. ICCOPR member agencies such as NOAA, USEPA, and USFWS, have served as members of NRDA Trustee Councils on many major U.S. oil spills, including the *Exxon Valdez* oil spill and/or the *Deepwater Horizon* oil spill, as well as numerous smaller marine and inland spills such as the Enbridge Kalamazoo River incident. The representatives of those agencies provide updates and/or presentations on their agency's NRDA activities as appropriate.

The annual restoration-themed meeting includes an update on the NAS GRP. These updates are consistent with the BP/Transocean settlement agreement that established the GRP and called for annual coordination with ICCOPR. These meetings also include presentations from other restoration entities such as GoMRI (now disbanded), the NOAA RESTORE program, or State recovery and restoration programs. ICCOPR also conducts an annual special meeting with the PWSRCAC during their annual visit to Capitol Hill, which provides an opportunity to discuss recovery issues from the *Exxon Valdez* oil spill. ICCOPR may conduct special meetings with outside organizations to discuss their issues and share oil pollution related information as well as special public meetings when needed to identify areas of concern for future oil pollution research.

5.2.4 Meetings with Other Entities

ICCOPR representatives participate in meetings with industry, state governments, NGOs, associations, academia, and other nations to exchange information and promote collaboration and cooperation. Stakeholders frequently ask ICCOPR to present federal research priorities and initiatives. ICCOPR will continue participating in these meetings and encourage the entities to address the ICCOPR OPRTP Research Needs.

5.2.5 Demonstration Projects

Section 7001(c)(6) of OPA 90 directed ICCOPR to conduct Port Oil Pollution Minimization Demonstration Projects in New York, New Orleans, and Los Angeles/Long Beach. The Great Lakes Oil Pollution Research and Development Act of 1990 amended OPA 90 to include a fourth demonstration in ports of the Great Lakes. ICCOPR conducted two demonstration projects in New Orleans (December 1994) and New York (October 1995). After these first two projects were completed, the USCG determined that they were cost prohibitive and ICCOPR agreed that these objectives could be met through other means. Since 1995, ICCOPR has addressed the objectives through interagency participation in, and support for, regularly scheduled domestic and international oil spill conferences (i.e., IOSC, Interspill, Spillcon, Clean Gulf, Clean Pacific).

In 2017, ICCOPR member agencies participated in an all-day series of technical demonstrations of oil spill response capabilities at the 2017 IOSC in Long Beach, California, led by BSEE. The theme of the program was "The Evolution of Oil Spill Response." The demonstrations provided an interactive tour of the evolution of response technologies over the previous 25+ years. The tour consisted of six stations; each station had a presentation by engineers, scientists, and spill responders. Participants were able to view live and simulated demonstrations, video footage, and photos of equipment. ICCOPR members organized a similar technical demonstration for the planned 2020 IOSC, but the demonstration was cancelled when the conference was postponed to 2021 and changed to a virtual format due to the COVID pandemic.

ICCOPR and its member agencies will consider future demonstrations of response technologies within budgetary considerations.

5.2.6 Conferences

Participation in conferences is an important way to communicate research results, showcase technology, and provide opportunities for researchers and response professionals to interact. ICCOPR and its member agencies sponsor, support, and participate in several oil spill-related conferences domestically and internationally. Primary conferences promoted by ICCOPR include:

- International Oil Spill Conference (triennial in U.S.),
- Interspill (triennial in Europe),
- Spillcon (triennial in Asia Pacific),
- Clean Pacific (biennial) and Clean Gulf Conferences (annual),
- Offshore Technology Conference (annual),
- Arctic Marine Oil Spill Program Technical Seminars (annual),
- Society of Environmental Toxicology and Chemistry (annual),
- Gulf of Mexico Conference (being established in 2022).

The domestic and international conferences include technical programs and equipment tradeshows that present the latest issues, products, and technologies available for oil spill and hazardous materials response, spill prevention, marine salvage, cleanup and remediation, professional services, and regulatory compliance.

API and the IOSC Executive Committee, which includes several of the ICCOPR agency representatives, worked to make all papers presented at the IOSC since its inception in 1969 available free of charge on the internet (https://meridian.allenpress.com/iosc).

This service provides a wealth of information specific to the oil spill research community.

GoMRI founded and sponsored the Gulf of Mexico Oil Spill and Ecosystem Science (GoMOSES) conference starting in 2013. Starting in 2022, the annual GOMA All Hands Meeting, the annual GoMOSES Conference, and the triannual State of the Gulf Summit will be combined to form the Gulf of Mexico Conference.

5.2.7 Workshops and Seminars

Workshops and seminars are widely used by the oil pollution control community to bring together professionals to discuss specific topics and challenges. ICCOPR member agencies sponsor workshops on a wide variety of topics that address priority research issues.

5.2.8 Publications

Researchers funded by ICCOPR member agencies are encouraged to publish in peer reviewed journals, conference proceedings, books, and special reports. Literature from researchers within the oil spill community, NGOs, and academic scientists and engineers are particularly valuable. Research published in peer-review journals, especially ones with high impact factors, also have value in oil spill litigation cases. Examples of high impact factor peer-review journals and publications that address marine pollution topics include, but are not limited to:

- *Applied and Environmental Microbiology,*
- *Environmental Science & Technology,*
- *Environmental Toxicology and Chemistry (SETAC),*
- *Human and Environmental Risk Assessment,*
- *Journal of Toxicology and Environmental Health,*
- *Marine Pollution Bulletin,*
- *Journal of Environmental Monitoring,*
- *Nature,*
- *Journal of Marine Science and Engineering,*
- *Science, and*
- *Water Research.*

5.2.9 Newsletters

ICCOPR monitors newsletters published by many organizations that present their activities, highlight specific programs or initiatives, and summarize advancements in R&T. In addition, several of the ICCOPR member agencies publish newsletters addressing elements of their oil pollution research missions.

5.2.10 Internet and Social Media

ICCOPR and its member agencies use the individual websites, blogs, and social media on the internet as tools to provide oil spill research results and news to stakeholders and other users. ICCOPR maintains an internet site (https://www.dco.uscg.mil/ICCOPR/) to: share documents, provide links to other programs and resources, distribute research reports, announce conferences and other events, and provide news about research developments.

5.3 Monitoring the Status of Oil Pollution Technologies

The 2015-2021 version of the OPRTP marked a new baseline in ICCOPR's oil pollution research planning efforts, documenting the status of oil pollution Research Needs at the start of the planning process. Throughout each planning cycle, ICCOPR tracks research projects and publications conducted by members, federal and state partners, NGOs, academia, international contributions, and industry. ICCOPR uses the Oil Pollution Research Characterization Framework and research protocol described in Chapter 6 of this OPRTP to compile information on studies that address current and future priority Research Needs.

ICCOPR assesses the compiled information to determine the degree to which the priority Research Needs from the previous plan were addressed and then develops a new set of research priorities for the subsequent planning period. ICCOPR may also issue supplements to the OPRTP during a planning cycle to address emerging Research Needs that increase in priority. ICCOPR may periodically review after action reports, Government Accountability Office (GAO) reports, and other sources of identified gaps to inform the Oil Pollution Research Characterization Framework for future research needs.

PART TWO – ESTABLISHING RESEARCH PRIORITIES

6. Oil Pollution Research Needs Identification and Prioritization Process

During the development of the FY 2015-2021 OPRTP, ICCOPR established a Research and Technology (R&T) Workgroup with representatives from BSEE, USDOE, USEPA, NOAA, and USCG overseen by the ICCOPR Executive Director. The R&T Workgroup developed a process to identify and prioritize Research Needs, which included defining the Research Classes, SRAs, and developing the final language of each Research Need. This effort led to the development of a proposed list of priority Research Needs to be reviewed and approved by the larger ICCOPR membership.

For this OPRTP update, a similar R&T Workgroup was formed with representation from the same federal agencies. Subject Matter Experts (SMEs) from PHMSA, USDOE, and BSEE were included to address specialized topics. The R&T Workgroup used the identification and prioritization process to guide the OPRTP update. They updated the process to include an evaluation of the priority Research Needs published in the previous OPRTP and engaged the public through listening sessions and a data call. This chapter describes the systematic process used by the R&T Workgroup to identify and prioritize the nation’s oil pollution Research Needs for 2022 - 2027. Sections 6.1 and 6.2 describe the elements of the process (Figure 6-1).

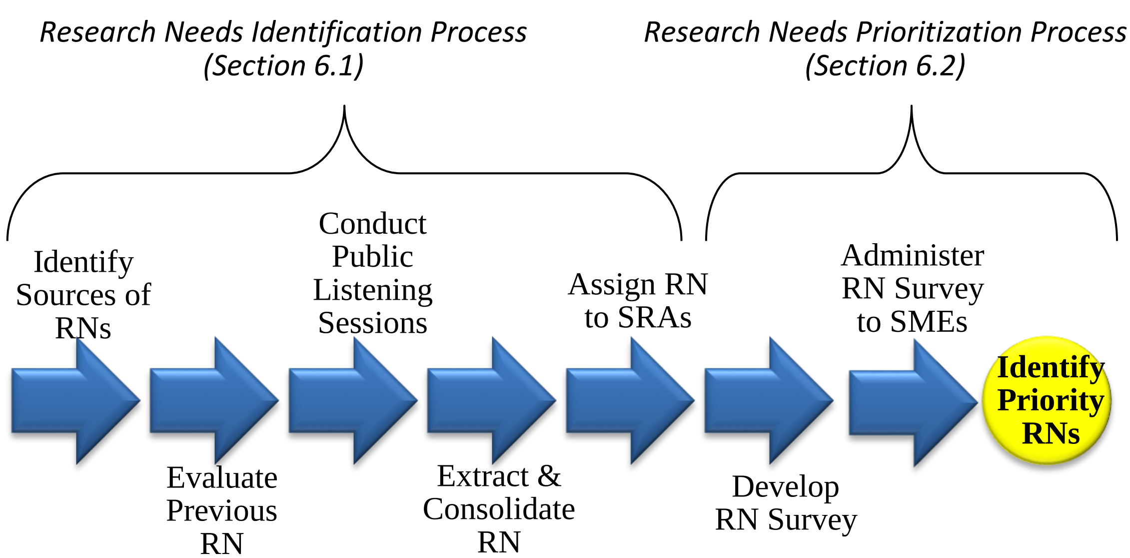


Figure 6- 1 Major Steps in the Research Needs (RN) Identification and Prioritization Processes

6.1 Research Needs Identification Process

The Research Needs identification process consisted of five steps: 1) identification of research needs sources; 2) SME Research Needs evaluation; 3) public listening sessions; 4) extraction and consolidation of Research Needs; and 5) assignment of Research Needs to SRAs and SRA Subcategories (Figure 6-1).

6.1.1 Identification of Sources for Research Needs

The R&T Workgroup conducted an extensive literature review and a public data call to identify any updates to the list of sources used to identify Research Needs for the 2015 OPRTP, which included sources prior to 2013. The current data call and literature review were focused on identifying sources published between 2013 and 2020. Sources identified after 2020 will be evaluated in the next planning cycle. For the purposes of this plan, ICCOPR defined sources as: incident case studies; published papers; research reports; workshop or meeting proceedings; white papers; lessons learned; and agency or organizational opinions.

The 2020 data call was initiated with NRDA Trustees, government, industry, tribal and academic experts to collect Research Needs. An extensive literature search was conducted in which sources were reviewed and cataloged into an Excel database if they included research recommendations. Examples of new sources reviewed included: oil spill incident after-action reports; the previous versions of the OPRTP; CRRC workshop reports; ICCOPR public meeting transcripts; interagency reports; research solicitations and publications.

A searchable database recorded source title, abstract/summary and applicable web link. Within the database, each source was sorted under the applicable SRAs and Subcategories.

Although it was not possible to review every source of oil pollution Research Needs since 2013, ICCOPR views the sources used in this plan as representing a comprehensive list. The original list of potential Research Needs and associated sources is included in **Appendix B**. It is important to note that the Research Needs presented in this database have not been processed or reviewed by ICCOPR and are considered source/raw data. The final list of Research Needs can be found in Chapter 9 of this OPRTP.

6.1.2 Subject Matter Expert (SME) Research Needs Evaluation

There were 150 priority Research Needs identified in the 2015 OPRTP across 25 SRAs. The R&T Workgroup identified federal SMEs to evaluate each Research Need listed in the previous OPRTP to determine if the need was still relevant or if research published during the plan's cycle filled the identified gap. Each SME was supplied a list of literature specific to their assigned SRA or Subcategory (Section 6.1.1) and scored the 2015 – 2021 Research Needs using a uniform rubric (Table 6-1).

Table 6- 1 Uniform Research Need Evaluation Rubric

	Score 1	Score 2	Score 3
Status	Little to no progress	Some progress, but more is needed	Sufficient research has beendone and is no longer a Research Need
Next Steps	Still an active Research Need and will be included in the newest survey	Only specific research gaps within the Research Need will be included inthe newest survey – not the entire Research Need	This Research Need will be deemed complete and will not be included in future evaluations
Feedback	None	**Required** – what specific research gaps still exist within the Research Need	None

If a Research Need was scored 1, it was active and included in the prioritization process. If a Research Need was scored 2, it was updated to identify the continuing gaps and included in the prioritization process. If the Research Need was scored 3, it was not included in the prioritization process. Forty-six Research Needs scored 1, 90 Research Needs scored 2, and 14 Research Needs scored 3 (Table 6-2).

Table 6- 2 Research Needs Completed from 2015 - 2021 OPRTP

SRA	Subcategory	Research Need
Vessel Design	N/A	Develop improved analytical tools (procedures, computer models, and software) to evaluate performance of structures in collisions, allisions, and groundings, so that estimates of damage extent and loss of oil-tight boundaries are available.
Rail & Truck Transportation	N/A	Analyze hazards and develop corresponding mitigation methods/technologies for head space gases in tank cars.
Pipeline Systems	Materials*	Evaluate the performance, reliability, and failure mechanisms of the use of composites technology for pipelines.
Pipeline Systems	Integrity*	Improve and develop in-line inspection to locate and size defects in girth welds and long seam defects including cracks in electric resistance welded pipe.
Pipeline Systems	Integrity*	Assess the remaining integrity of pipelines that have multiple different anomalies in proximity.

Pre-spill Baseline Studies	Oceanographic and Geological Baselines	Develop methodologies for using baseline flow characteristic data (such as tidal energy mapping and other energy sources) to support shallow water inlet protection strategies during oil spills.
Chemical and Physical Modeling and Behavior	Oceanographic Models	Link ocean circulation models to observations (e.g., ocean observing systems) to better incorporate real-time data.
Dispersants	Impacts	Collect existing dispersed oil toxicity data and studies to aid in risk-based decision-making regarding use of dispersants at spills.
Dispersants	Fate	Develop studies to quantify the weathering rates and final fate of chemically dispersed vs. physically dispersed oil droplets under different scenarios.
Dispersants	Subsurface	Develop conditions of operability for dispersant use in the subsea, including the characteristics of the most effective dispersant, application methods, and dispersant to oil ratios.
Dispersants	Subsurface	Conduct research involving the application of dispersants at high pressure and low temperatures including quantifying the mixing energy at the wellhead
Bioremediation	N/A	Develop an improved understanding of bioremediation processes with a wider range of conditions/environments (e.g., cold water), multiple types of oil, nutrient enrichment, toxicity, and eutrophication.
*Sociological and Economic Impacts	Human Impacts	Study the resilience of social-ecological systems to environmental disasters, including the degree of impact on human well-being from ecosystem services losses.
*Sociological and Economic Impacts	Human Impacts	Study the effects of media and community groups in shaping individual and public perceptions of a spill's impact.

* The Subcategories for the Pipeline Systems SRA have been updated. Materials and Integrity are the previous names of two Subcategories under Pipeline Systems in the 2015 OPRTP. The three new Subcategories are Threat/Damage Prevention, Leak Detection, and Anomaly Detection/Characterization. Additionally, the SRAs Environmental Impacts and Ecosystem Recovery, and Sociological and Economic Impacts have been updated to Environmental Effects and Ecosystem Recovery, and Sociological and Economic Effects.

6.1.3 Data Call

The R&T Workgroup initiated a public data call in October 2020 with government experts, industry, academia, NRDA Trustees, and other appropriate parties to elicit research publications since 2013. Participants in the data call received an excel workbook made up of four separate worksheets to document publications (one for each Research Class). Users inputted the published report/paper title, agency affiliation, collaborative agency (if applicable), weblink to publication, citation, and a three-sentence synopsis description. For each publication submitted, users selected the appropriate SRA, Subcategory (if applicable), and indicated if the publication addressed one or more of the 2015 OPRTP Research Need priorities. Over 60 agencies, organizations, and researchers participated in the data call resulting in 1,344 submitted publications and reports.

6.1.4 Public Listening Sessions

The R&T Workgroup hosted two public listening sessions in December 2020 to provide an opportunity for participants to directly submit Research Needs rather than only sources of Research Needs that were being collected under the data call. To initiate the sessions, input forms were sent to NRDA Trustees and government, industry, tribal and academic experts. Each submitted proposed Research Need on the input form had to be supported by literature and a detailed explanation as to why it should be considered as a priority Research Need.

Submitters could present their proposed Research Need(s) to the R&T Workgroup at an optional public listening session. Out of 63 submitters, 24 presented a brief overview of their Research Needs(s). To limit bias, the presenters could not observe the other presentations and each presenter had to adhere to strict constraints during their presentation. The R&T Workgroup did not ask questions of the presenters during the sessions. As the presentations were optional, there was no advantage to those who gave a presentation over those who did not. All proposed Research Needs that were supported by relevant literature sources were included in the prioritization process.

6.1.5 Extraction and Consolidation of Research Needs

Every source from the data call and literature review was analyzed to determine if it contained Research Needs. Over 2,000 Research Needs were identified from these two efforts. An additional 136 Research Needs were identified from the SME evaluations of the 2015 OPRTP as needing additional research. There were 214 proposed Research Needs submitted via the public listening sessions. The over 2,350 Research Needs were consolidated by eliminating duplicates. The final list consisted of 737 separate proposed Research Needs for inclusion in this plan, almost 200 more than the 2015 OPRTP.

6.1.6 Assignment of Research Needs to an SRA

The last step in the identification process involved assigning each of the proposed 737 Research Needs to one of the SRAs or Subcategories described in Chapter 4. The decision to use this approach was based on the experience of UNH Survey Center experts (managers of the survey) who indicated that “survey fatigue” often occurs if a participant is asked to answer a large number of questions, thus affecting the validity of the results.

6.2 Research Need Prioritization Process

The Research Needs prioritization process followed the process used in developing the 2015 OPRTP. The process included development of a survey (Figure 6-1) that could be distributed to SMEs (e.g., scientists, policy makers) familiar with current oil spill research. The survey results helped ICCOPR identify and prioritize the proposed Research Needs within each SRA. The majority of SMEs were federal. However, in some SRAs, there were not enough federal SMEs so state agency, academic, or industry experts were included. There was no SRA or Subcategory in which the number of non-federal SMEs exceeded the number of federal SMEs.

Appendix C provide the survey technical report. The R&T Workgroup compiled a set of proposed priority Research Needs for the SRAs and Subcategories and presented them to the whole ICCOPR for approval. The ICCOPR members approved the SRAs and Subcategories at the June 2021 Quarterly meeting.

6.2.1 Development of Research Needs Survey

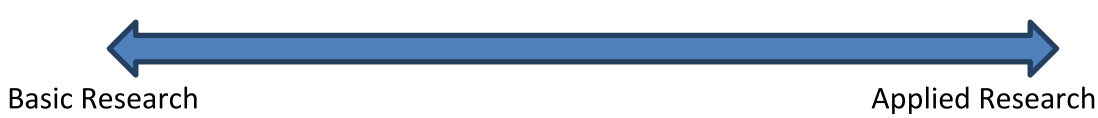
The R&T Workgroup developed a series of key questions that reflected the various aspects of the research process and selected the following questions for the survey:

Question 1: How important is it that we solve this Research Need to the advancement of {applicable Research Class}? (Via sliding scale)

Question 2: Using the definitions below, please estimate where this Research Need fits in this spectrum of basic to applied research? (Via sliding scale)

Applied Research seeks to answer specific questions to solve practical, real-world problems. The knowledge acquired may have commercial objectives (e.g., products, procedures, services).

Basic Research seeks to answer why, what, or how questions to increase the understanding of fundamental principles. The goal is to expand knowledge and the research may not result in a solution to a practical problem.



Question 3: How likely is it that this Research Need can be completely addressed within the next six years? (Via sliding scale)

Not At All Likely Very Likely

Question 4: Are there any research needs related to this subject area that you feel need to be addressed, but were not on this list? (Answers via text box)

Fill in blank text box

The UNH Survey Center built and designed the survey instrument, in conjunction with the CRRC, who worked closely with the R&T Workgroup (**Appendix C**). A total of 58 separate surveys were developed, one for each SRA or Subcategory.

6.2.2 Administration of Survey to SMEs

The R&T Workgroup recruited 410 SMEs to provide at least four SMEs with knowledge and expertise in each of the SRAs and Subcategories. The SMEs include 213 federal and 97 non-federal employees to avoid Federal Advisory Committee Act (FACA) issues. Responses were received from 212 of these experts resulting in a 55% response rate. The UNH Survey Center administered the confidential survey, tabulated the scores, and provided the results to the R&T Workgroup.

6.2.3 Processing of Survey Results

A mean and standard deviation were calculated from the SMEs' responses for each of the questions (i.e., raw data). In addition, a weighted mean and standard deviation were calculated for each Research Need. The scheme placed higher weights on the questions the R&T Workgroup believed were more relevant to the overall importance of the Research Need.

1. How important is it that we solve this Research Need to the advancement of {applicable Research Class}? Weighting **60%**

2. Using the definitions below, please estimate where this Research Need fits in this spectrum of basic to applied research? Weighting **30%**

3. How likely is it that this Research Need can be complete addressed within the next six years? Weighting **10%**

6.2.4 Identification of Top Priority Research Needs for Each SRA

The R&T Workgroup's iterative process to select the recommended priorities consisted of the following steps:

- Review statistical ranking and analysis of survey results (i.e., the raw and weighted means and the standard deviations). The R&T Workgroup used these initial rankings to start their discussions.
- Review missing Research Needs. Several SMEs identified potentially missing Research Needs in their responses to Question 4. The R&T Workgroup reviewed the suggestions and determined whether a different SRA or Subcategory already included the Research Need. The R&T Workgroup added newly identified Research Needs to the appropriate SRA or Subcategory and assigned an appropriate rank based on the members' expert opinions.
- Consolidate Research Needs. In many cases, an SRA or Subcategory listed similar Research Needs. The R&T Workgroup reviewed these similarities and consolidated them, where appropriate. The draft ranking was adjusted to reflect the importance of the consolidated Research Need.
- Determine top three recommended priority Research Needs. The R&T Workgroup agreed upon the top three suggested priority Research Needs for each SRA and Subcategory.
- Develop the final description of each recommended priority Research Need. The R&T Workgroup reviewed the language of each SRA, and the associated priority Research Needs to ensure they were clearly articulated and consistent with the definition.
- Obtain ICCOPR member feedback. The R&T Workgroup sent its draft list of priorities to all ICCOPR members for review and comment. The R&T Workgroup adjudicated the comments through discussions with commenting and dissenting members and a meeting of the R&T Workgroup.
- Complete the recommended priorities. The R&T Workgroup made its final edits to the recommendations based on the comment adjudication process in September 2021. ICCOPR adopted the top three priority Needs for each SRA and SRA subcategory as presented in Chapter 9.

7. Assessment of Oil Spill Technologies and Noteworthy Oil Spills

This chapter provides an assessment of oil spill technology advances since the 2015 OPRTP. It also reviews noteworthy oil spills describing the incident, significant causal factors, response operations, and identified Research Needs.

7.1 Oil Groups

Title 33 of the Code of Federal Regulations groups oil types into five categories (33 CFR § 155.1020). Non-persistent oils, or Group I, are petroleum-based oils that consist of hydrocarbon fractions: "at least 50% of which by volume, distill at a temperature of 340 C (645 F); and at least 95% of which by volume, distill at a temperature of 370 C (700 F)" (Navigation and Navigable Waters, 2016). The oil groups have different levels of acute and long-term toxicity to species and ecosystems and require different response and mitigation strategies after a spill. Group I oils are highly volatile, evaporating in 1-2 days, and include gasoline and condensate. All petroleum-based oils that do not meet the criteria for non-persistent oils are classified as persistent oils (i.e., Group II – V oils).

- Group II oils have a specific gravity of less than 0.85 and are moderately volatile, leaving a residue of up to one-third of the spill amount after a few days (e.g., diesel, No.2 fuel oil, light crudes) (NOAA, 2020a).
- Group III oils have a specific gravity equal to or greater than 0.85 and less than 0.95 and are moderately volatile (e.g., most crude oils and intermediate fuel oil (IFO) 180) (Navigation and Navigable Waters, 2016).
- Group IV oils have a specific gravity equal to or greater than 0.95 and less than or equal to 1.0 (e.g., heavy crude oils, No. 6 fuel oil, Bunker C) and exhibit no evaporation or dissolution and weather slowly (NOAA, 2020a).
- Group V oils include slurry oils, residual oils, and non-floating oils that have a specific gravity greater than 1.0 and sink quickly in water (i.e., little evaporation) (Navigation and Navigable Waters, 2016).

7.2 Assessment of Current and Emerging Technologies

7.2.1 Bioremediation

Bioremediation can treat oil-contaminated soils by using oil-degrading microorganisms. A study by Brown et al (2016) examined how bioremediation methods can be employed to encourage natural biodegradation processes (biostimulation), supplement natural processes with oil-degrading bacteria (bioaugmentation) and monitor natural processes (natural attenuation). Bioremediation's effectiveness is dependent on the site characteristics. It can be applied in place (*in-situ*) or to excavated soil off-site (*ex-situ*). *In-situ* technologies are more cost-effective, but delivery of supplements uniformly is often difficult. *Ex-situ* technologies provide more control, but soil excavation can be costly and may increase exposure to contaminants.

Recent bioremediation technology advances include:

- **Genome Repository of Oil Systems: An Interactive and Searchable Database that Expands the Catalogued Diversity of Crude Oil-Associated Microbes (Non-Federal):** This study developed a searchable genomic database of documented microbial populations in natural oil ecosystems and oil spills including underlying physicochemical data and geographic distribution patterns.
- **"*Candidatus* Macondimonas diazotrophica", a Novel Gammaproteobacterial Genus Dominating Crude-Oil-Contaminated Coastal Sediments (Non-Federal):** This project studied the metagenome-guided isolation of a novel organism that represents a phylogenetically narrow group of previously uncharacterized, crude oil degraders, which could be used as a model organism when studying ecophysiology responses to oil spills.
- **Diverse, Rare Microbial Taxa Responded to the *Deepwater Horizon* Deep-Sea Hydrocarbon Plume (Non-Federal):** This project documented previously unrecognized diversity of related hydrocarbon degrader taxa to describe their spatio-temporal distribution in the Gulf of Mexico, near the *Deepwater Horizon* discharge site to determine how environmental factors shape the ecologically relevant dynamics of microbes.

7.2.2 Skimmers

A skimmer is used to mechanically recover oil from the water's surface. Skimmers can be self-propelled, used from shore, or operated from vessels. There are three main types of skimmers: weirs, oleophilic (oil-attracting), and suction. Each skimmer has advantages and disadvantages depending on the type of oil being recovered, sea conditions, and presence of ice or debris in the water (USEPA, 2020a). To recover oil: weir skimmers use a dam or enclosure positioned at the oil/water interface; oleophilic skimmers use belts, disks, or continuous chains of oleophilic materials to blot the oil from the water surface; and suction skimmers suck oil through floating devices and pump it into storage tanks (USEPA, 2020a).

Recent skimmer technology advances include:

- **Evaluation of Skimmer Performance in Diminishing Oil Slick Thicknesses (BSEE)**: This project tested different skimming systems with varying oil slick thicknesses to better understand the relationship between oil recovery rates and efficiencies as a function of oil slick thickness.
- **ASTM F2709-08 Testing of Skimmer Systems at Ohmsett Facility (BSEE):** This project conducted performance tests of different skimming systems to better understand the relationship between manufactures' published capacity rates those obtained using testing to a prescribed standard.

- **Oil Skimmer Test during 2017 Arctic Technology Evaluations aboard the CGC HEALY (USCG):** The evaluations tested different skimmers' performances in open and ice infested waters. The evaluations focused on: 1) testing the efficiency of a user controlled self-propelled skimmer in ice vs. a skimmer dipped into icy water by a crane, and 2) determining if maneuvering a vessel was improved with new skimmers technology, when compared to conventional skimmers.

7.2.3 Sorbents

Sorbents are insoluble materials used to recover liquids through absorption and/or adsorption. In oil spill response, sorbents need to be oleophilic (oil-attracting) and hydrophobic (water-repellent). Sorbents are used to remove small amounts of oil in places where other equipment, such as skimmers, cannot access. Sorbents are divided into three categories: natural organic (e.g., peat moss, hay, sawdust); natural inorganic (e.g., clay, perlite, vermiculite, sand); and synthetic (e.g., polyurethane, polyethylene, polypropylene). Their effectiveness depends on the characteristics of the sorbent, oil type, rate of absorption/adsorption, oil retention, and ease of application (EPA, 2016).

Recent sorbent technology advances include:

- **Assessment of Innovative Sorbents (BSEE):** This project compiled data on commercially available sorbents, conducted a comprehensive review of research and development, and identified new and emerging technologies. The assessment included organic, inorganic, and synthetic sorbent materials.
- **Practical Oil Spill Recovery by a Combination of Polyolefin Absorbent and Mechanical Skimmer (BSEE):** This project explored the use of a recently developed polyolefin oil superabsorbent (i-Petrogel) that can effectively stop crude oil weathering processes in open water.

7.2.4 Solidifying Agents

Solidifying agents are chemicals that react with oil to form rubber-like solids (EPA, 2020b). These agents can be applied by hand and left to mix on their own, or mixed using high pressured water streams (EPA, 2020b). The solidified oil is removed from the water using nets, suction equipment, or skimmers. An advantage of solidifying agents is that they can be used in moderately rough sea conditions, where the wave energy increases the mixing and results in greater solidification (EPA, 2020b). A disadvantage is that a large quantity (up to three times the volume of oil) needs to be applied to the spill area (EPA, 2020b). For larger spills, it may not be practical to store, move, and apply such large quantities of material (EPA, 2020b).

Recent solidifying agent technology advances include:

- **Development of a Testing Protocol for Oil Solidifier Effectiveness Evaluation (USEPA):** This project tested the oil removal efficiency of solidifiers using three testing protocols to determine the protocol with the least amount of free oil remaining in the water after treatment.
- **Characterization of Solidifiers Used for Oil Spill Remediation (USEPA):** This project studied the physical and chemical composition of oil spill solidifiers and correlated their properties with product effectiveness to determine the desirable characteristics in a good solidifier.

7.2.5 Dispersants

Dispersants are chemicals that contain surfactants and/or solvent compounds that create into small droplets so the oil can be more readily biodegraded (EPA, 2020c). Dispersants move the oil from the water's surface into the water column, making it less likely that shorelines and coastal ecosystems will be impacted (EPA, 2020c). Dispersants are most effective when applied directly following an oil spill, before the oil has started to evaporate and when there is sufficient mixing energy (e.g., wind, waves) (EPA, 2020c). The effectiveness of dispersants also depends on the type of oil and environmental conditions (e.g., salinity, temperature).

Recent dispersant technology advances include:

- **Validating and Expanding the Dispersant Spray Drift Decision Support Tool (BSEE):** This project validated assumptions associated with the Dispersant Spray Drift (DSD) tool, which is intended to help decision-makers identify operational windows and setback distances based on weather conditions, aircraft type, dispersant spray system and release rate. The project also expanded the DSD to include different oil spill response aircraft and add concentration contours to the output display to improve the user interface.
- **Oil Composition vs. Dispersant Effectiveness (BSEE):** This project investigated how oil composition (e.g., concentration of saturates, aromatics, resins, and asphaltenes) and viscosity affect dispersant effectiveness.
- **Assessment of Dispersant Effectiveness using Ultrasound to Measure Oil Droplet Particle Size Distributions (BSEE):** This project developed acoustic techniques to measure dispersed oil droplet size *in-situ* and monitor the efficacy of subsea dispersant application.
- **Determine the Relative Efficiency of Various Surface Dispersant Delivery Techniques/Systems (BSEE):** This project developed a technology selection guide to help decision-makers determine the relative effectiveness of dispersant delivery techniques/systems based on various spill characteristics and delivery system capabilities.

- **Characterizing Dispersant Effectiveness of Crude Oil at High Salinities: Implications for Subsea Spill Preparedness (USEPA & BSEE):** This project evaluated the influence of salinity on dispersant effectiveness for different oils and dispersants. It also characterized dispersant effectiveness during simulations of high-velocity subsea releases of oil injected with dispersants.

7.2.6 *In*-Situ Burning (ISB)

ISB is the controlled burning of spilled oil on water and land. When conducted properly, ISB can reduce the amount of spilled oil and eliminate the need to collect, store, transport, and dispose of recovered material (Brown, 2016). There are many environmental factors that may prevent the use of ISB including its oil thickness, waves, winds, currents, and emulsification (NOAA, 1997). Other operational factors, such as risks to human health and natural resources (e.g., from smoke), can also prevent insufficient use (NOAA, 1997).

Recent ISB technology advances include:

- **Low Emission Combustor System for Emulsified Crude Oil (BSEE & US Navy):** This project advanced the technology readiness level of a low emission, low pressure atomization, and combustor system for emulsified crude oil by developing and refining a flow blurring atomizer spray burner.
- **Efficient Remediation of Oil Spills Over Water Using Fire Whirls (BSEE):** This project tested the burning of liquid fuels on water in a traditional pool fire and a controlled fire whirl to better understand the role of fire whirls to develop faster, cleaner, and more efficient ISB.
- **Interface Insulation Systems for Enhancing *In-Situ* Burning (BSEE):** This project investigated concepts that change the oil/water interface beneath a burning oil slick, reduce the amount of burn residue, and prevent residue from sinking.
- **Analysis of Emissions and Residue from Methods to Improve Combustion Efficiency of *In-Situ* Oil Burns (USEPA & BSEE):** This project conducted real-time air emissions and residue testing to characterize combustion efficiency.
- **Freshwater In-Situ Oil Burning (USCG & US Navy & USEPA):** This project conducted a series of tests using crude, residual fuel, and “bunker” oil to understand the physical and chemical processes involved in freshwater ISB.

7.2.7 Remote Sensing

Remote sensing is the process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation from a distance (USGS, n.d.). It is an essential part of oil spill response operations to determine the spill extent, location, and emulate the suitability of response countermeasures. General applications of oil spill remote sensing data include: oil spill mapping, slick detection, and surveillance, gathering legal evidence, and slick trajectory determination (Fingas, 2018).

Recent remote sensing technology advances include:

- **Development of an Oil Thickness Sensor (BSEE):** This project developed two sensors designed to measure the thickness of different oil slicks on water and wirelessly communicate information in near real-time.
- ***Deepwater Horizon* Lessons Learned – Methodology and Operational Tools to Assess Future Oil Spills (BSEE & NOAA & NASA & USEPA):** This project compared the ability of different remote sensing platforms to detect and quantify surface oil and verify that anomalies in images corresponded with observable oil slick features.
- **Optical Monitoring of Subsea Blowout Droplets and Subsea Dispersant Efficacy (BSEE):** This project analyzed data from an optical *in-situ* imaging system (SilCam) for use in subsea blowouts. The project used data obtained during a series of large-scale tests releasing mixed oil and gas.
- **Estimating Oil Slick Thickness with LiDAR (Light Detection and Ranging) Remote Sensing Technology (BSEE & USEPA & US Navy):** This project conducted controlled surface and subsurface oil release experiments to assess and evaluate the capabilities and limitations of LiDAR to detect and characterize oil thickness and oil/water emulsions. The project also developed and validated protocols and algorithms using LiDAR, optical, and acoustic data sets to differentiate oil types and estimate oil thickness.

7.2.8 Autonomous Underwater Vehicles (AUVs)

AUVs are unmanned, untethered, programable vehicles that can be used to: map the ocean floor; identify environmental data, navigation hazards, and geologic formations; explore shipwrecks; and inspect offshore infrastructure. The data collected by the AUV is downloaded and processed when the vehicle is retrieved. AUVs do not rely on human operators; some can communicate with the operators via satellite signals or underwater acoustic beacons (WHOI, n.d.).

Recent AUV technology advances include:

- **Three-Dimensional Mapping of Dissolved Hydrocarbons and Oil Droplets using a REMUS-600 (Remote Environmental Monitoring Unit) AUV (BSEE & NOAA & USEPA):** This project integrated a suite of sensors on a REMUS AUV to quantify, characterize, and determine oil droplet size. It also demonstrated the ability of the REMUS to detect oil and develop a schema for real-time data transfer into response data management and visualization tools.
- **Advancing UAS and AUV Capabilities to Characterize Water Column and Surface Oil in Ice Environments (USCG & NOAA & USEPA):** This project

conducted lab and field tests to better understand aerial and underwater sensor capabilities to characterize oil on the surface or in the water column in ice conditions.

- **Development of Propeller Driven Long Range AUV (LRAUV) for Under-Ice Mapping of Oil Spills and Environmental Hazards (ADAC & WHOI & MBARI & USEPA & USCG & NOAA & BSEE):** This project is developing an Arctic-capable LRAUV that is helicopter portable and has environmental mapping capabilities to provide rapid response and situational awareness for responders.

7.2.9 Remotely Operated Vehicles (ROVs)

ROVs are unmanned vehicles that are connected to a platform (e.g., vessel) with cables that are operated by humans. ROVs can be equipped with cameras, lights, water samplers, manipulator arms, and water quality sensors (NOAA, n.d.). The tether allows the ROV to send and receive signals in real-time, collect samples wherever desired, conduct experiments, and observe environmental conditions (WHOI, n.d.).

Recent ROV technology advances include:

- **Utilizing 3D Optical and Acoustic Scanning Systems to Investigate Impacts from the Oil Spill on Historic Shipwrecks (BSEE & BOEM):** This project assessed deep water shipwrecks to determine oil spill effects and the status of ship preservation using 3D laser data from an AUV and 3D sonar data from an ROV. This project informed resource managers about site stability, formation processes (e.g., sedimentation), and the long-term effects of oil on submerged resources.
- **Observations of Bubbles in Natural Seep Flares at MC 118 and GC 600 Using *In Situ* Quantitative Imaging (Non-Federal):** This project collected quantitative images using a stereoscopic, high-speed camera system at two natural gas seep sites in the Gulf of Mexico. The observations of the seeps were used as surrogates for the behavior of hydrocarbon bubbles in subsea blowouts.
- **Influence of Ice Thickness and Surface Properties on Light Transmission through Arctic Sea Ice (Non-Federal):** This project used Nereid Under-Ice (NUI), a hybrid ROV (HROV), to investigate the spatially varying ice thickness and surface properties on the spatial variability of light transmittance.
- **Determining the Discharge Rate from a Submerged Oil Leak Jet Using ROV Video (USDOE):** This project studied a technique that used ROV video to measure discharge rate more quickly and accurately from a submerged oil leak jet.

7.2.10 Unmanned Aerial Systems (UAS)

UAS (e.g., drones) are sensor equipped vehicles that operate autonomously or remotely. UAS can be used for many purposes including assessments of oil slicks, shoreline damage, abandoned or sunken vessels, and environmental applications. UAS offer a cost-effective method for surveillance.

Recent UAS technology advances include:

- **Classification of Oil Spill Thicknesses Using Multispectral UAS and Satellite Remote Sensing for Oil Spill Response (NOAA & BSEE):** This project developed methods for rapid classification of oil types (e.g., emulsified vs. non-emulsified) and thickness to deliver real-time information to responders.
- **Measuring Oil Residence Time with GPS-Drifters, Satellites, and Unmanned Aerial Systems (NOAA):** This project used remote sensing platforms (e.g., UAS, GPS tracked drifters) to investigate the residence time of oil slicks from an ongoing crude oil release.
- **System and Algorithm Development to Estimate Oil Thickness and Emulsification Through an UAS Platform (BSEE):** This project developed a near real-time sensor system that could be mounted to a UAS and collect data on floating oil and emulsions to derive slick thickness.

7.2.11 Booms

Containment booms are used to control the spread of oil and reduce the possibility of polluting natural resources (EPA, 2020d). Booms concentrate oil in thicker surface layers and may be used to channel it along desired paths, making it easier to remove from the water's surface (EPA, 2020d). Most booms have four elements: an above-water "freeboard" to contain oil and prevent it from overflowing; a flotation device; a below-water "skirt" to contain the oil and reduce the amount lost under the boom; and a "longitudinal support" (usually a chain or cable running along the bottom of the skirt to strengthen the boom against wind and wave action) (EPA, 2020d). There are three basic types of booms: fence, round (curtain), and non-rigid (e.g., inflatable) booms (EPA, 2020d). Fence booms have a high freeboard and a flat flotation device, making them least effective in rough water (EPA, 2020d). Round booms have a circular flotation device and a continuous skirt, making them more difficult to clean, but they perform better in rough water (EPA, 2020d). Non-rigid booms come in many shapes, are the easiest to store and clean, and perform well in rough seas (EPA, 2020d). However, they are also the most expensive and complicated to use. In the absence of other response equipment, booms can be made from common materials (e.g., wood, plastic pipes, tires).

Recent boom technology advances include:

- **Investigation of Design Enhancements to Current Boom Technologies (BSEE):** This project studied alternative designs to allow booms to collect and contain oil when towed at higher speeds greater than 0.7 knots.
- **Research and Develop a Linear Augmented Fire Boom Configuration to Increase Burn Efficiency and Reduce Emissions of the Outer Continental Shelf (BSEE & USACE & USEPA):** This study tested fire boom technology to increase burn and combustion efficiencies for ISB by changing the geometry of the slick and supplementing the burn with compressed air.
- **Mitigation of Oil Moving Along the Waterway Bottom (USCG & USEPA):** This project developed and tested three boom prototypes with the potential to respond to non-floating oil spills.

7.2.12 Herding Agents

Herding agents (herders) are surfactant mixtures or singular surfactants, used to push thin oil slicks to a desired location or to merge slicks together to yield a thicker oil spread to be collected or burned (Fingas, 2013). Herders are typically used in conjunction with ISB, which requires ~ 3mm slick to ignite (Gupta, 2015). Over time, the surfactants in herders dissolve or adhere to objects in the water, reducing their effectiveness (Fingas, 2013).

Recent herder technology advances include:

- **Operational Limits of Chemical Herders (BSEE):** This study measured the relationship of oil characteristics and temperature on herder efficacy in a laboratory.
- **Multifunctional Herding-Sorbent Agents for Use in Icy Water (BSEE & USDOE):** This project evaluated three novel oil herding approaches. The material developed was tested for oil sorption in frazil sea ice and underwent performance evaluations in large scale ISBs.
- **Aerial Application of Herding Agents to Advance *In-Situ* Burning for Oil Spill Response in the Arctic: A Pilot Study (Non-Federal):** This project evaluated a proof-of-concept application of aerial herders and igniters for ISB operations in the Arctic and identified challenges.

7.2.13 Models/Common Operating Pictures (COPs)

Operational oil spill models use computer simulations of ocean circulation, wind, and waves to forecast oil behavior, fate, and transport to guide response actions (Barker, 2020). Model outputs are displayed in COPs to aid in contingency planning, resource deployment, and trajectory analysis. Models can also be used to inform the potential fate and biological effects of oil on different resources; assist responders in selecting response methods; and advise decision makers on short- and long-term environmental parameters (Barker, 2020).

Recent model/COP technology advances include:

- **Progress in Operational Modeling in Support of Oil Spill Response (NOAA & US Navy & BOEM):** This study synthesized scientific advances, remaining challenges, and future opportunities in operational oil spill modeling and forecasting.
- **NOAA WebGNOME Additions for Trajectories and Oil Libraries (NOAA & BSEE):** This project expanded NOAA's oil spill response modeling tool, WebGNOME, by expanding the display options for the model outputs to include trajectory visualizations that show changes in oil concentration and allow the user to enter properties into an oil library where it can be extracted for spill models.
- **Trajectory Analysis Planner (TAP) (NOAA):** TAP is a software tool that produces graphical outputs on shoreline impacts, response time, site oiling, threat zones, and natural resources.

7.2.14 Pipeline System Technology

Pipeline system technologies focus on preventing spills from offshore and onshore pipelines used to transport oil between facilities. This includes: preventing damage from corrosion, outside forces, and other threats to pipeline integrity; detecting and locating leaks to mitigate releases; and characterizing defects to allow repair and prevent failure.

Recent pipeline technology advances include:

- **In-Ditch Validation Methodology for Determination of Defect Sizing (PHMSA):** This project improved existing technology to more accurately and reliably detect and size defects in pipeline girth welds during new construction.
- **Improve and Develop In-Line Inspection Tools to Locate, Size, and Quantify Complex/Interacting Metal Loss Features (PHMSA):** This project used excavation measurements of anomalies encountered by in-line inspection tests to improve the interpretation of data allowing operators to distinguish between anomalies that require remediation and those that can be monitored.
- **Comprehensive Study to Understand Longitudinal Electric Resistance Welded (ERW) Seam Failures (PHMSA):** This project studied the characteristics of ERW seams that make them susceptible to failure and identified factors to enhance pipeline safety by enabling evidence-based repair and replacement decisions.
- **Definition of Geotechnical and Operational Load Effects on Pipeline Anomalies (PHMSA):** This project developed a tool that looks at the effects of operational and geotechnical loads on pipeline systems to define the local nominal strain state. To supports design and maintenance decisions.

7.2.15 Rail Transportation Technology

Rail transportation technology includes the development and validation of system designs, operations, and infrastructure to make oil tank cars less susceptible to damage and loss of cargo (e.g., new rail designs, construction materials, spill prevention devices, loading/unloading equipment/systems).

Recent rail transportation technology advances include:

- **Pool Fire and Fireball Experiments in Support of the US DOE/USDOT/TC Crude Oil Characterization Research Study (USDOE & USDOT):** This project studied the physical, chemical, and combustion characteristics of crude oils transported by rail and their influence on thermal hazard distances.
- **Evaluation of Risk Reduction from Tank Car Design and Operations Improvements: An Extended Study (USFRA):** This project developed a method that accounts for elements that are relevant to tank car derailment performance and combined them into a probabilistic framework to estimate the merit of mitigation strategies.
- **Validation of Methodology to Evaluate Risk Reduction in Tank Car Derailments (USFRA):** This project developed verification and validation methods to enhance the confidence in the method developed in the project entitled "Evaluation of Risk Reduction from Tank Car Design and Operations Improvements: An Extended Study."

7.2.16 Geohazard Identification

Geohazard identification technology enhances the understanding of geological formations and their rock properties, enabling operators to reduce the risk of encountering unexpected hazards (e.g., pressure anomalies, salt formations, faults). This increases safety of offshore drilling. Geohazards and metocean conditions can also affect the integrity and longevity of offshore infrastructure.

Recent geohazard identification technology advances include:

- **A Systematic, Science-Driven Approach for Predicting Subsurface Properties (USDOE):** This project developed a hybrid spatiotemporal statistical-geologic framework for guiding future science-based machine learning and natural processing to optimize subsurface analyses and predictions.
- **Extracting Quasi-Steady Lagrangian Transport Patterns from the Ocean Circulation: An Application to the Gulf of Mexico (USDOE):** This project analyzed a 12-year record of surface currents in the Gulf of Mexico from a simulation using methods from the theory of nonlinear dynamical systems to better understand Lagrangian transport patterns.
- **Persistent Meanders and Eddies Lead to Quasi-Steady Lagrangian Transport Patterns in a Weak Western Boundary Current (USDOE):** This project examined the persistent Lagrangian transport patterns in a boundary current with persistent meanders and eddies to improve future oil spill responses.

7.2.17 Well Control Technologies

Well control technologies are applicable to drilling and production operations, including materials, sensors, and systems, needed for offshore drilling, platforms, and equipment for well and facility monitoring and inspection under extreme pressure and temperature. Examples include: early kick detection; systems for communicating and responding to changes in downhole parameters; strategies and methods for training operational personnel on the use of advanced technology; systems to detect and prevent oil and gas discharges; and wellhead systems and equipment to control wild wells and cap well blowouts.

Recent well control technology advances include:

- **Kick Detection at the Bit: Early Detection via Low-Cost Monitoring (USDOE):** This project validated a method for using data from standard and cost effective technologies that are typically implemented during well drilling to support early kick detection.
- **Visualizing Well System Breakdown: Experimental and Numerical Analyses (USDOE):** This project developed an approach to increase understanding of cement failure within well systems. The method combined a scaled experimental technique with a model to simulate conditions that could lead to well system failure.
- **Effects of CO_2 and H_2S on Corrosion of Martensitic Steels in Brines at Low Temperature (USDOE):** This project conducted corrosion studies on carbon steels in brine solutions to stimulate different Arctic subsurface drilling environments.
- **Early Kick Detection from Downhole Measurements: A Novel Method for Reducing the Frequency and Magnitude of Loss-of-Well-Control Events (USDOE):** This project evaluated an alternative, lower cost, early kick detection method and compared it to conventional ones. The proposed method used measurements from devices deployed on the drillstring to provide real-time information on the wellbore.
- **High Pressure/High Temperature Sensor for Real-Time Downhole Density Measurements of Wellbore Drilling Mud (USDOE):** This project developed a low-differential pressure range sensor cell with higher sensitivity to density change in wellbore drilling mud. This would improve early warning and control of high-pressure flow in the wellbore.

7.2.18 Subsea Automation and Reliability

Technology that enhances subsea automation and reliability reduces the risk of spills by identifying problems sooner, with greater accuracy, leading to a faster response time and reduced environment effects of a failure. Technology includes advanced equipment packaging and improved sensor and system reliability for maintenance and intervention.

Recent subsea automation and reliability technology advances include:

- **A New Subsea Large Load Deployment System (USDOE):** This project was part of a larger study designing a subsea 3,000+ barrel chemical storage and injection system that required manufacturing a subsea facilities deployment and recovery technique for large and heavy loads. The Anchor Handling Tug Supply method provided safe and cost-effective subsea placement of a wide range of subsea systems and components.

- **Subsea Produced Water Sensor Development (USDOE):** This project developed a subsea monitoring sensor to measure the quality of produced water separated at the sea floor. The sensor provided an improved failsafe system and controls for subsea production equipment.
- **Blowout Preventer Control System Reliability (USDOE & BSEE):** This project examined control system failures and provided recommendations to improve reliability, especially blowout preventers.

7.3 Influence of Environmental Conditions on Response Equipment

Every oil spill is unique in its location, time of year, depth, environmental conditions, affected resources, and available response options. The most used open-water response methods are mechanical recovery (booms and skimmers), dispersants applied subsea or at the surface, and ISB (Wilkinson, 2017). The specific limitations and advantages of mechanical recovery, ISB, and dispersants under different environmental conditions are outlined in **Appendix D**, which is adapted from Table 5-1 Typical Arctic Conditions and Potential Impacts on Spill Response Options (Nuka Research and Planning Group, 2010).

In high wind and sea states, surface applied dispersants can be the most effective response option as they rely on mixing energy (NAS, 2020). Dispersants can treat large volumes of oil over great distances, but their use requires special approval and is dependent on current environmental conditions at the spill site (daylight hours, sea state, miles of visibility, minimum cloud ceiling, wind speeds) (NAS, 2020). Subsea dispersant injection (SSDI) was first used during the Deepwater Horizon oil spill and has many potential benefits, including a high encounter rate and minimal resources (i.e., personnel, vessels) when compared to other response methods. However, SSDI also requires special approval and its efficacy and environmental effects under different conditions is still being evaluated (NAS, 2020).

In contrast, mechanical recovery is the most well understood and most readily available of these types of response methods. However, mechanical recovery often has a low encounter rate, and its efficacy is largely dependent on environmental conditions such as high winds, waves, and ice coverage (NAS, 2020). Recent research has improved mechanical recovery equipment, particularly booms, skimmers, and sorbents, for separating oil from ice, operating under higher wind speeds, and recovering oil at faster rates (NAS, 2020).

ISB can be an effective tool to permanently remove oil from the environment, therefore reducing the amount to be recovered and stored. A successful burn is dependent on oil slick thickness, in addition to environmental factors. If the slick is too thin, it will be harder to ignite and sustain a burn. Fire booms specifically designed for ISB, called fire boom, can collect oil forming thicker slicks. In locations where boom is not as effective (e.g., Arctic), chemical herders can be used to prevent oil from spreading into thin slicks (NAS, 2020).

7.4 Noteworthy Oil Spill Incident

The following noteworthy oil spill incidents occurred during the period since the previous OPRTP. Spills are categorized chronologically by the incident type: vessel (e.g., barges, fishing vessels, freighters), offshore drilling operations, offshore and onshore pipelines, and facilities. Research Needs applicable to each incident are identified. The following noteworthy incidents are not intended to be an exhaustive list of significant spills, but a focused list aligned with Research Needs.

7.4.1 Vessel Spills

Texas City Y

In March 2014, the cargo ship *M/V SUMMER WIND* collided with *MISS SUSAN*, a vessel towing two tank barges loaded with fuel oil, in Lower Galveston Bay near the junction know as Texas City Y (NTSB, 2015a). The collision punctured a barge's tank releasing ~168,000 gallons of IFO 380 (bunker fuel) affecting Galveston Bay and the Gulf of Mexico (USCG, 2015a). Two crew members suffered inhalation injuries when responding to the spill. The NTSB identified the probable cause of the incident as "the *MISS SUSAN* captain's attempt to cross the Houston Ship Channel ahead of the *SUMMER WIND*, thereby impeding the passage of the bulk carrier, which could transit only within the confines of the channel" (NTSB, 2015a).

Most of the discharge impacted the shorelines between Galveston and Matagorda Islands (NOAA, 2021). Response actions included deploying over 165,000 feet of boom, 10 skimming vessels, 88 response and support vessels, and creating temporary storage facilities (NRC 2021). Additional response actions included trajectory forecasts of the floating oil movement, shoreline assessment, data management, overflight tracking of the oil, weather forecasts, and assessment of the natural resources at risk (NOAA, 2021). A NRDA was conducted for the shoreline habitats, birds, bottlenose dolphins, and recreational use.

This incident underscores the need for research on human error, waterways management, and human safety and health because of the potential to prevent this incident. The following Research Needs were derived from the recommendations listed in NTSB's investigation report (NTSB, 2015a).

- **Human Safety and Health (40200):** Improve training methods on hazardous materials to ensure the safety and health of vessel crews responding to hazardous material releases.
- **Waterways Management (10300):** Identify high density vessel traffic areas with diverse types of vessels and develop vessel separation policies to avoid collisions.
- **Waterways Management (10300):** Improve technology used to monitor vessel traffic and communicate with vessel crews.

***Nalani* Towing Vessel**

In January 2015, the Panama towing vessel *Nalani* took on water and sank off the west coast of Barbers Point Harbor, Oahu, Hawaii with 75,000 gallons of diesel fuel on board (NTSB, 2015b). The National Transportation Safety Board (NTSB) concluded that "the probable cause of the flooding and eventual sinking of the *Nalani* was the captain's decision to get under way without sufficient freeboard at the stern and without ensuring proper watertight integrity" (NTSB, 2015b). Response operations included shoreline, near-shore and overflight assessments. Non-recoverable diesel sheens were observed at the sinking location but dissipated after three days (Pacific States/British Columbia Oil Spill Task Force, 2016). The Hawaii Department of Health conducted air monitoring and determined that there was no threat to humans. NOAA moved monk seals from the Wai'anae coastline to NOAA's monk seal facility on Ford Island (Bennington-Castro, 2018).

This incident is an example of the importance of decision-making and the consequences of human error on an otherwise preventable release. There were no specific research recommendations following the spills; however, this incident highlighted the need for research in key SRAs:

- **Human Error Factors (10000):** Evaluate and improve methods that increase safe work culture on vessels.
- **Human Error Factors (10000):** Improve and develop training methods to enhance decision-making.
- **Human Error Factors (10000):** Design methods that evaluate an operator's (e.g., vessel captain) ability to deal with unexpected or high stress situations.

***ALAKSKA JURIS* Fishing Vessel**

In July 2016, the *F/V ALASKA JURIS* fishing vessel took on water in the Bering Sea about 41 miles northeast of Segula Island in the Aleutian Islands (ADEC, 2016). It sank due to flooding in the main engine with ~ 87,000 gallons of diesel and other miscellaneous lubricant oils on board (NTSB, 2016). The NTSB determined that the "probable cause of the sinking of the fishing vessel ALASKA JURIS was a lack of watertight integrity, which failed to contain flooding in the engine room" (NTSB, 2016). Aircraft and vessel searches were conducted where *ALASKA JURIS* was last seen, but nothing was not found (NTSB, 2016). There were no reports of affected fish or wildlife in the area and NOAA trajectories showed a low potential for shoreline impacts (NTSB, 2016). A sheen of unrecoverable diesel fuel dissipated and reformed in the area. No other response actions were conducted.

This sinking and subsequent oil release was caused by failed watertight integrity on the vessel, despite it being a fundamental safety priority for operating on the water. The following Research Needs were developed using the lessons learned from the 2017 NTSB Safer Seas Digest: Lessons Learned from Marine Accident Investigations, which discussed the *ALASKA JURIS:*

- **Vessel Design (10400):** Further understand and develop methods to improve vessel watertight integrity and prevent flooding.
- **Vessel Design (10400):** Develop procedures for testing bilge alarms regularly and maintaining records of these tests.
- **Human Error Factors (10000):** Improve training exercises on dewatering and lifesaving survival gear (e.g., ladders, life rafts, and lines).

***Buster Bouchard, B. No. 255* Fire and Explosion**

In October 2017, an explosion and subsequent fire occurred on the barge of the articulated tug and barge *Buster Bouchard/B. No. 255,* located off Port Aransas, TX (NTSB, 2017). The incident resulted in two casualties and released ~ 84,000 gallons of crude oil (NTSB, 2017). The NTSB concluded that the cause of the explosion was likely due to a "lack of effective maintenance and safety management of the barge…which resulted in crude oil cargo leaking through a corroded bulkhead…forming vapor, and igniting" (NTSB, 2017). A helicopter, response vessel, and fireboat were deployed to the scene immediately. Due to the fire and reports of a sheen on the water's surface, air monitoring was conducted, in addition to deploying an estimated 8,000 feet of boom around the oil slick to protect environmentally sensitive areas (USCG, 2017). Other response activities included aerial flights, skimmers, beach cleanup, and wildlife response assessments.

A significant contributing factor in this casualty was the failure of the operator to properly implement and maintain safety management, which resulted in decreased structural integrity of the vessel. The NTSB recommendations showed the importance of continued research in the following SRAs:

- **Vessel Design (10400):** Establish joint procedures to share information, including findings from audits, surveys, examinations, inspections, and other activities related to vessel safety.

- **Human Error Factors (10000):** Develop management strategies to promote and ensure a safety culture to ensure the wellbeing of vessels and crews.

***Ex-USS PRINZ EUGEN* Oil Recovery**

In December 1946, World War II German heavy cruiser *ex-USS PRINZ EUGEN* sank in the Kawajalein Atoll, Republic of the Marshall Islands with oil in many of its storage tanks (NOAA, 2018a). The cruiser was used in the Able and Baker Atomic Tests and sustained unrepairable damage leading to its eventual sinking (NAVSEA, 2018). As the ship aged, there had been increasing signs of oil leakage. In August 2018, after two years of planning, a team led by the NAVSEA's SUPSALV and sponsored by the U.S. Army Space and Missile Defense Command/Army Forces Strategic Command (USASMDC/ARSTRAT) started salvage operations to remove oil from 173 tanks onboard *ex-USS PRINZ EUGEN* (NAVSEA, 2018).

Response equipment, including boom tow boats, inflatable boom, oil skimmers, and sorbent booms were set up as a precaution for potential releases (NAVSEA, 2018). Of the 173 tanks, 159 of them were tested and 92 contained recoverable oil. Fourteen tanks were inaccessible; however, they pose little risk of a significant release due to their protected location inside the ship (NAVSEA, 2018). An estimated 228,900 gallons of oil was recovered.

This operation highlights the current technology available for salvage operations and additional advances needed to conduct future vessel and infrastructure assessment and removal operations. The following Research Needs were identified at an ICCOPR quarterly meeting in December 2018 (ICCOPR, 2019).

- **Structural Damage Assessment and Salvage (30000):** Improve non-invasive technologies to determine vessel storage contents and minimize potential for a release.
- **Structural Damage Assessment and Salvage (30000):** Advance closed system thru-hull sampling/testing technologies to minimize the potential for a release.
- **Structural Damage Assessment and Salvage (30000):** Develop and improve methods to recover/eliminate clingage of heavy oils to render tanks free of residual petroleum product.
- **Structural Damage Assessment and Salvage (30000):** Improve diver locator and audio/visual systems.
- **Vessel Design (10400):** Develop more accurate aids for hull navigation, especially for low visibility situations.

***MV Wakashio* Bulk Carrier**

In July 2020, the bulk carrier M/V Wakashio grounded on a coral reef on the coast of Mauritius, an island in the Indian Ocean, carrying ~2.9 million gallons of low sulfur fuel oil, ~154,846 gallons of diesel, and ~67,324 gallons of lubricant oil (Seveso, 2021). Days after the grounding, the vessel split apart and released ~748,052 gallons of fuel into the surrounding environment polluting coral reefs, mangroves, beaches, and lagoons (Seveso, 2021). Local volunteers manufactured improvised boom with readily available materials in the early response phases that did contain some oil, but also produced large quantities of contaminated waste. Traditional booms and skimmers were deployed by responders. Most of the released oil affected the shoreline focusing response efforts on shoreline cleanup and natural resource assessments (e.g., coral reefs, sea turtles, subsistence fisheries) (NOAA, 2020b). The U.S. provided satellite imagery, natural resource guides, trajectories, and other expertise remotely. The overall response was complicated by the restrictions from the COVID-19 pandemic, limiting travel and available personnel. Current restoration proposals include mangrove and coral farming to restore the ecosystems (Seveso, 2021). The natural resource assessments and restoration activities are anticipated to continue for years.

This was the first recorded spill of low-sulfur fuel oil and emphasized the need for more specialized training, response, and recovery methods focused on type of release. It was the first major oil spill in Mauritius and the first during a pandemic. Although there were no specific recommendations for future research, the response highlighted the need for research in the following SRAs:

- **In-and On-Water Containment and Recovery (30400):** Develop and update response equipment to be more effective for low-sulfur fuel oil.
- **Human Error Factors (10000):** Update oil spill response and planning exercises to train personnel on how to respond to low-sulfur fuel oil spills.
- **Chemical and Physical Modeling and Behavior (30200):** Evaluate the physical and chemical properties of low-sulfur fuel oil to determine how it weathers once released.

7.4.2 Offshore Drilling Operations

Australia Montara

In August 2009, an uncontrolled discharge of oil occurred at the Montara wellhead platform in Australia during drilling activities releasing 6.2 million gallons of light crude oil (Spies, 2017). The spill affected one sea snake and 29 birds (21 killed) (AMSA, 2010).
Immediate response actions included deploying aircraft, response personnel, and response equipment and increasing dispersant at stockpile locations (AMSA, 2010). During the response, over 130 surveillance flights were conducted to: collect

environmental data, inform dispersant spraying aircraft and vessels, and collect information to guide offshore containment and recovery operations (AMSA, 2010). A total of 247 response personnel were involved in the cleanup from multiple countries and organizations (AMSA, 2010). Two vessels were used to deploy a 300-meter boom with a skimmer operating in the boom that recovered 222,961 gallons of product (AMSA, 2010). Six types of dispersants were used during the response (Slickgone NS, Slickgone LTSW, Ardrox 6120, Tergo R40, Corexit 9500, Corexit 9527) with 42,796 gallons being sprayed on the spill area (AMSA, 2010). Response operations concluded in December 2009 (AMSA, 2010).

The Montara Commission of Inquiry Report, released in 2010, contained 100 findings and 105 recommendations for government officials, regulators, and the offshore oil and gas industry (Australian Government, 2017). In 2011, the Australian Government released its Final Government Response to the Montara Commission of Inquiry in which it accepted 92 recommendations, noted 10 and did not accept three (Australian Government, 2017). In a progress report released in 2012, 81 of the 92 recommendations were complete (Australian Government, 2017). In 2017, the Australian Government released a Report on the Implementation of the Recommendations from the Montara Commission of Inquiry that detailed the implementation of the remaining recommendations. There were 11 recommendations completed between 2012 and 2017, which included the need for changes in national policy, response leadership and coordination, and monitoring of environmental recovery. While these recommendations have been implemented in Australia, they are topics that apply to the oil industry and countries worldwide.

Deepwater Horizon (DWH) **Oil Spill**

In April 2010, ~134 million gallons of oil was released from a subsea well blowout that followed an explosion and collapse of the *Deepwater Horizon* platform (also called the Macondo 252 well) during exploratory drilling (Deepwater Horizon Natural Resource Damage Assessment Trustees, 2016). The explosion on the rig killed 11 men and injured 17 others (Deepwater Horizon Natural Resource Damage Assessment Trustees, 2016). The well was temporarily capped on July 15, 2010, effectively stopping the release. The permanent well closure occurred on September 18, 2010. The oil spill caused damage to deep water and nearshore marine and wildlife habitats across the Gulf States and to the Gulf's fishing and tourism industries.

This spill was declared a SONS. Response to the *Deepwater Horizon* spill was diverse and conducted on a larger scale than any previous efforts. Different response mechanisms were deployed depending on the day, the weather conditions, and the amount and location of oiled shoreline. Response actions included: ISB, subsea and surface dispersant use, booming, and skimming. Application of 1.84 million gallons of dispersants, both aerially and sub-sea at the wellhead, was unprecedented, as was the use of controlled ISB (a global record of 411 individual burns were conducted) (ICCOPR, 2015). This spill was the first where dispersants were applied subsea at the wellhead. Members of the public submitted ideas for 120,000 response technologies that were evaluated through the Alternative Response Technologies Evaluation System (ARTES) Program (ICCOPR, 2015). A council of federal and state trustees was established to conduct a NRDA and develop restoration plans.

The most recent development from this incident was the release of the Final Programmatic Damage Assessment and Restoration Plan (PDARP) and Final Programmatic Environmental Impact Statement (PEIS) in April 2016. The Final PDARP/PEIS outlines alternatives to restore natural resources, and ecological and recreational use services (Deepwater Horizon Natural Resource Damage Assessment Trustees, 2016). The DWH NRDA process highlighted the need for additional training and research in the following SRAs:

- **Environmental Effects and Ecosystem Recovery (40000):** Develop NRDA training exercises for SONS to prepare trustees and responders for potential spills and NRDA requirements.
- **Environmental Effects and Ecosystem Recovery (40000):** Further study the effects of deep sea oil spills on ecosystems in different regions (e.g., Arctic, Gulf of Mexico).
- **Pre-Spill Baseline Studies (20000):** Conduct pre-spill baseline contamination and ecosystem monitoring studies to differentiate between oil stressors and natural variation.
- **Environmental Effects and Ecosystem Recovery (40000):** Evaluate recovery rates of different species in laboratory and mesocosm experiments.
- **Environmental Effects and Ecosystem Recovery (40000):** Assess historical recovery rates of natural resources injured in previous spills under different mitigation techniques.

7.4.3 Offshore Pipeline Spills

Shell LLOG Glider Flowline Jumper Failure

In October 2017, a fractured subsea wellhead pipeline, known as a jumper, released ~ 672,000 gallons of oil (BSEE, 2019). The jumper connected the Mississippi Canyon (MC) 209 wellhead to a subsea manifold Pipeline End Termination (PLET) in the Gulf of Mexico. The operator (LLOG Exploration Offshore, LLC (LLOG)) deployed an ROV to visually inspect the subsea system, which confirmed that the jumper had been cracked. An aerial overflight observed three separate sheens on the water. There was no recoverable oil detected and no shoreline impacts observed. BSEE’s investigation concluded that "the failure resulted from internal corrosion within the jumper and mechanical stress added from movement of the PLET and pipeline" (BSEE, 2019).

BSEE provided a list of recommendations on increasing operators' scrutiny in the design, placement, and maintenance of subsea infrastructure (BSEE, 2019):

Recommendations for flowline construction involve the following SRAs:

- **Subsea Systems Automation and Reliability (10900): "**Evaluate designs of applicable components for their tolerance under increased loads due to thermal expansion or other movement."
- **Subsea Systems Automation and Reliability (10900):** "Evaluate the use and placement of sleepers or other components that mitigate the buckling of pipelines."
- **Subsea Systems Automation and Reliability (10900):** "Evaluate the construction of flowline components to ensure that materials have adequate corrosion mitigation properties."
- **Subsea Systems Automation and Reliability (10900):** "Evaluate the use of different surveying methods such as LiDAR to confirm that pipeline systems remain within their design tolerances throughout their service life."

Recommendations for leak detection apply to the following SRAs:

- **Subsea Systems Automation and Reliability (10900):** Improve "subsea leak detection methods by employing conditional rate of change, mass in mass out, or other advanced monitoring technologies. These technologies should alarm, and where possible, initiate executive actions."
- **Human Error Factors (10000):** Develop training programs for control room operators that increase "the awareness of the possibility of flowline integrity loss to a higher consideration when undergoing startup operations."
- **Human Error Factors (10000):** Evaluate and enhance training on pressure trend analysis for leak detection.

<u>Pertamina Pipeline Spill, Republic of Indonesia</u>

In March 2018, the anchor of bulk carrier *MV Ever Judger* struck and ruptured a submerged oil pipeline in the Indonesian port city of Balikpapan releasing oil into Balikpapan Bay (NOAA, 2018b). The ruptured pipeline, owned by Pertamina, resulted in five casualties and released ~1.68 million gallons of marine fuel oil (Latif, 2018). Following the rupture, the slick caught fire (not ISB) releasing plumes of black smoke around the spill area and *MV Ever Judger*. Immediate response actions were focused on extinguishing the fire with multipurpose vessels and clearing the area of other boats. Aerial surveillance verified the extent of the spill, noting the effects to the shoreline (Manulong, 2018). During a shoreline assessment, responders observed an endangered marine mammal stranding and effects to local birds, fish, and other marine life (Manulong, 2018).

Emergency response equipment included: 3,953 ft and 36,781 ft of offshore and onshore boom, respectively; 56 offshore skimmers and 86 onshore skimmers; 16,461 gallons of dispersant; and over 1,000 personnel (Manulong, 2018). The spill caused localized air pollution, from the oil vapors and the burning (National Transportation Safety Committee, 2019). The spill affected mangroves, shorelines, and commercial fisheries including damaged fishing equipment (boats, ponds, buoys, nets) (National Transportation Safety Committee, 2019).

Based on the casual factors of the pipe rupture and subsequent oil spill, the National Transportation Safety Committee developed a series of recommendations. Below are recommendations that identify research gaps and/or technology limitations highlighted by this incident (National Transportation Safety Committee, 2019).

- **Pipeline Systems (10700):** Establish synchronized, detailed guidelines for subsea pipelines.
- **Human Error Factors (10000):** Develop guidelines for training drills including equipment, resources, and organization methods.
- **Waterways Management (10300):** Develop methods to enhance subsea installation security and monitoring systems in dense traffic waters.
- **Response Management Systems (20100):** Update oil spill contingency plans to account for unplanned fires at sea due to an oil spill.

7.4.4 Onshore Pipeline Spills

California Refugio Oil Spill

In May 2015, an underground pipeline ruptured near Refugio State Beach, CA and released over 120,000 gallons of heavy crude oil into the Pacific Ocean and surrounding environment (County of Santa Barbara, 2015). The failure occurred due to external corrosion under the pipeline's insulation that thinned the wall (Refugio Beach Oil Spill Trustees, 2021).

Following the spill, the California Department of Fish and Wildlife (CDFW) closed fisheries and the Governor declared a state of emergency for Santa Barbara Country (CDFW, 2016). Incident Command included representatives from USCG, OSPR, Santa Barbara Country, and the Responsible Party (CDFW, 2016). Other organizations, such as USEPA and NOAA, offered additional technical support. The first phase of the cleanup (active cleanup and gross removal) was completed in August 2015 and the second phase (refined oil cleanup endpoints for shorelines targeting maximum net environmental benefit) in January 2016 (CDFW, 2016). The third phase (monitoring and sampling for residual and buried oil) were finished in May 2016. The response ended in March 2017 (Refugio Beach Oil Spill Trustees, 2021).

Response operations included oil recovery, pipeline excavation, contaminated soil removal, community and responder air monitoring, and oil sampling. Shoreline response operations included: oil sampling; manual and mechanical recovery; wildlife recovery, rehabilitation, and release; and response technologies except for chemical dispersants (use criteria not met). On-water response operations included boom, skimmers, oil recovery vessels, and vessels of opportunity (outfitted with oil recovery equipment) (County of Santa Barbara, 2015). Injuries to natural resources included: 1,500 acres of shoreline habitat, 2,200 acres of benthic subtidal and fish habitat, 558 birds killed (28 different species), 156 pinnipeds and 76 cetaceans injured or killed, and 140,000 recreational user days lost (Refugio Beach Oil Spill Trustees, 2021).

NAS GRP, GoMRI, and the Gulf of Mexico Sea Grant Oil Spill Science Outreach Program hosted a day-long workshop on April 5, 2019, where attendees discussed the challenges, lessons learned, and research needs from the Refugio oil spill. The following are a selection of these needs (Chulhof, 2019):

- **Sociological and Economic Effects (40300):** Determine metrics for economic effects (e.g., fisheries, business, shipping, recreation, and commercial) from oil spills.
- **Human Safety and Health (40200):** Establish standards and metrics for acceptable air quality and pollutant levels before spills to have preapproved public health messaging.
- **Oil Spill Detection and Surveillance (30300):** Advance oil fingerprinting technologies including developing a kit that can be deployed in the field to discriminate between oil from a natural seep and oil leaked from the spill.
- **Pre-Spill Baseline Studies (20000):** Monitor and establish pre-spill baseline environmental conditions (e.g., water quality, air, pollution, ecology) and develop quantifiable metrics to measure effects in comparison to the baseline conditions.
- **Sociological and Economic Effects (40300):** Conduct research to better understand the public perception of safety concerns following a spill and how to best communicate what are real vs. perceived threats.
- **Chemical and Physical Modeling and Behavior (30200):** Determine the rates of weathering associated with different sources of oil (i.e., natural seep vs. spill) to inform the environmental persistence of different oil sources.
- **Pipeline Systems (10700):** Study drainage areas that are most vulnerable to oil spills and create mechanisms to immediately stem the flow of oil in these regions.

- **In and On-Water Containment and Recovery (30400):** Develop technology to facilitate retention of oil spilled within the surf zone.

Keystone Pipeline 2017

In November 2017, TC Oil Pipeline Operations (TransCanada) crude oil pipeline (Keystone) ruptured near Amherst, SD releasing ~ 210,000 gallons of crude oil into grasslands (PHMSA, 2017). The grasslands were environmentally sensitive, reserved for wildlife and public use. Response actions included shutting down the pipeline using remotely operated valves and deploying response personnel. Flow-blocking devices were placed in the piping system (stopple fittings) upstream and downstream of the rupture to minimize the section to be drained (PHMSA, 2017). The contaminated soil was excavated, and TransCanada reported that all released product was recovered (PHMSA, 2017). According to the NTSB, the "probable cause of the failure … was a fatigue crack, likely originating from mechanical damage to the pipe exterior by a metal-tracked vehicle during pipeline installation, that grew and extended in-service to a critical size, resulting in the rupture of the pipeline" (NTSB, 2018b).

A Pipeline R&D Forum was held in September 2018 to identify challenges in pipeline safety. The forum is held periodically to allow stakeholders to make recommendations on identified gaps for future research (USDOT, 2018). While there were no specific research gaps identified from the Keystone spill, the following Research Needs from this conference are applicable:

- **Pipeline Systems (10700):** Develop leak detection technologies that can deploy multiple sensors (e.g., remote sensing) and validate them under different operating conditions.
- **Pipeline Systems (10700):** Validate existing in-line inspection capabilities to detect damage (e.g., plain shallow dent, dent with gouge).
- **Pipeline Systems (10700):** Evaluate pipeline construction, materials, and field standards to improve long-term management of damage.
- **Pipeline Systems (10700):** Evaluate and improve data collection, normalization, and integration methods to enhance decision-making tools.
- **Pipeline Systems (10700):** Improve existing in-line inspection technology and other sensor platforms to be used in spaces that are currently challenging to conduct in-line inspections (i.e., unpiggable pipelines).
- **Pipeline Systems (10700):** Develop a method, other than destructive testing, to determine toughness along an entire pipeline.

7.4.5 Facility Spills

Port William Shuyak Island Bunker C Spill

In April 2018, an estimated 3,000 gallons of No. 6 fuel oil (Bunker C) were released in Port William, AK at the southern end of Shuyak Island (located approximately 50 miles NNW of Kodiak, AK) (ADEC, 2018). The dock supporting a building collapsed during a serve windstorm, which caused a tank containing fuel to fall to the shoreline and water below (ADEC, 2018).

Response actions included deploying 3,280 feet of large inflatable boom and 550 feet of fast water boom around the facility and nearby beaches (NOAA, 2018c). Sorbent was placed inside the booms and responders collected 1,878 bags of oily waste (NOAA, 2018c). Throughout the response, 54 personnel were on-site or in the incident command post and 11 vessels were used to transport crews and supplies (NOAA, 2018c). A multi-agency Shoreline Cleanup and Assessment technique (SCAT) team evaluated the affected beach areas on multiple occasions and the remaining area was assessed daily (ADEC, 2018). Oiled rocks were pressure washed and beaches were tilled and deluged to free the oil and collect it using sorbent booms and materials. There were no reports of affected wildlife.

This incident is one example of how storms, which are increasing in frequency and intensity, can affect aging infrastructure. While no specific Research Needs were identified, the USCG After Action Report recommendations noted the following areas for improvement (USCG, 2019):

- **Onshore Facilities and Systems (10200):** Develop administrative controls to prevent the storage of oil in, on, or nearby aging infrastructure, especially in remote locations such as the Arctic.
- **Human Error Factors (10000):** Improve methods of managing responder fatigue in remote locations with harsh environmental conditions (e.g., Arctic).
- **Human Error Factors (10000):** Increase training and crew performance through exercises focusing on response, mitigation, and oil recovery in the Arctic.
- **Response Management Systems (20100):** Improve communication methods within and between response crews in remote locations with limited internet connectivity.
- **Environmental Effects and Ecosystem Recovery (40000):** Develop metrics to determine cleanup and removal endpoints.

Norilsk, Russia Fuel Tank Spill

In May 2020, an above ground fuel tank in Norilsk, Russia collapsed releasing ~15.7 million gallons of diesel fuel into the surrounding area and nearby river (ERM, 2020).

The tank was built on a concrete platform supported by piles and due to poor maintenance and construction, and thawing of permafrost, the piles sank and triggered the collapse of the tank and subsequent release (ERM, 2020). As of October 2020, 700 personnel, 245 bladder tanks, 25.48 miles of piping, 20 motor pumps, 311,680 ft of boom, and 129 tons of sorbents were used to respond to the spill (Nornickel, 2020a). Contaminated soil and oil recovered from the water were placed into temporary storage tanks to prevent additional contamination (Nornickel, 2020b). Air, drinking water, water quality, and wildlife monitoring was conducted (Nornickel, 2020b). Recovery efforts are ongoing and include replacing contaminated soil, seeding grass, releasing juvenile fish into water bodies, conservation efforts, and shoreline cleaning (Nornickel, 2020b).

In their assessment of the tank failure, Environmental Resources Management (ERM) provided recommendations that highlight the need for research in the following SRAs (ERM, 2020):

- **Onshore Facilities and Systems (10200):** Design a permafrost monitoring system for onshore tanks and facilities.
- **Onshore Facilities and Systems (10200):** Evaluate inspection guidelines and develop methods to account for climate change risks, such as permafrost.
- **Onshore Facilities and Systems (10200):** Evaluate the effects of climate change (e.g., permafrost) on aging onshore oil infrastructure.

8.0 Current State of Oil Pollution Knowledge

ICCOPR continually assesses the current state of oil pollution knowledge by monitoring and participating in studies, workshops, and other events to gain insight oil spill prevention, preparedness, response, and injury assessment and restoration. This chapter highlights the major sources of information since the 2015 OPRTP was published.

8.1 UNH Oil Spill Centers Workshops

UNH, in Durham, NH, administers two oil spill centers: CRRC and CSE. Both were established in 2004. CRRC is a partnership between the NOAA OR&R and UNH. CSE expands the scope of interaction and cooperation with all non-NOAA entities, including governmental agencies, universities, NGOs, and industry.

The centers hosted many workshops that brought together national and international oil spill experts to discuss future R&D Needs. The following workshops discussed lessons learned and identified Research Needs that are important to the improvement of oil spill response and the understanding of potential effects:

- Oil Observing Tools Workshop (October 2015)
- NOAA Regional Preparedness Trainings (NRPTs) Texas (May 2016), Alabama (June 2016), and Florida (June 2016)
- SCAT for Tomorrow (January 2017)
- DWH Long-Term Data Management Coordination Workshop (June 2017), Coordination of DWH Long-Term Data Management: The Path Forward (December 2018)
- Leveraging Science and Academic Engagement During Incidents (June 2019)
- Pacific Islands Natural Resource Damage Assessment (July 2019)
- Evaluation of Surface Oil Thickness (November 2019)
- Arctic Spill Modeling (December 2019), Part II (November 2020)
- Response Oil Assay (January 2020)

Oil Observing Tools Workshop (October 2015)

The Oil Observing Tools Workshop was convened by NOAA and CRRC to identify training gaps for oil spill observers and interpretation of remote sensing data to improve oil surveillance, observation, and mapping during spills. The workshop improved understanding, and greater use of newly developed technology to map and assess oil slicks during spill events. Thirteen recommendations resulted from this workshop including:

- “Develop a list of criteria/metrics where remote sensing tools are useful in oil spill response and assessment.”
- “Develop a short list of delivery requirements that could be included for remote sensing data collections to ensure complete and timely delivery of products.”
- “Develop workable combination packages of existing technologies and develop multiple platforms and sensor packages based on the most common response or assessment needs.”
- “Do not expect a “single solution” toolbox in the near term. Rely on a multi-platform, multi-sensor approach based on settings and conditions.”
- “Pursue joint agency and industry demonstrations of oil observing tools and focus on flexible funding mechanisms.”

NOAA Regional Preparedness Trainings (NRPTs) Texas (May 2016), Alabama (June 2016), and Florida (June 2016)

CRRC and the NOAA Gulf of Mexico Disaster Response Center (DRC) partnered to host three NRPTs to enhance coordination across NOAA line offices and among key state, federal, and other partners. The objective of each NRPT workshop was to better understand coastal disasters related to oil releases, particularly the human and natural resources at risk, the roles and responsibilities of different response agencies, the science that drives decision-making, and the importance of public outreach.

The first workshop was held in Galveston, TX and focused on preparedness, planning and improvement of response to a potential oil spill scenario in a marine sanctuary. The workshop examined response options such as dispersant use and *in situ* burning, while developing a framework for an environmental tradeoff analysis for a spill scenario at the Flower Garden Banks National Marine Sanctuary. The second workshop, held in Mobile, AL, focused on preparedness, planning, and improving response to an oil spill occurring during a natural disaster (e.g., flooding from a tropical storm). This workshop discussed the roles and responsibilities during an incident where the Stafford Act and OPA 90 were involved. The third workshop was in St. Petersburg, FL and focused on understanding the public's desire to be informed during an oil spill scenario affecting the Tampa Bay region and the need to plan and execute effective public communication.

Each workshop developed a series of recommendations. For example, the Mobile, AL workshop developed the following recommendations:

- "Continual and frequent Area Committee meetings and trainings with greater participation among stakeholders to: update and improve the Area Contingency Plans and Geographic Response Plans, better understand the roles and responsibilities of responders, and build relationships."
- "More training and equipment for local police departments for hazardous materials response."
- Develop an "internal and external process and procedure for developing and releasing press releases, and sharing information and data from the Unified Command, as well as a process to communicate with communities so they know what to expect when an incident happens."

SCAT for Tomorrow (January 2017)

NOAA OR&R updates existing tools and creates new ones related to oil spills as part of its role to support the USCG in emergency response and conduct damage assessment and restoration. This workshop discussed SCAT data standards and data exchange. One of the primary goals was to develop a common data standard for SCAT that would be acceptable to federal and state agencies and the private sector to enhance information sharing. The workshop resulted in a series of recommendations including:

- Incorporate the Data Standard within SCAT data management tools and field data collection tools.
- Include SCAT data management as part of American Society for Testing and Materials (ASTM) International.
- Incorporate best practices in the NOAA Shoreline Assessment Manual.

DWH Long-Term Data Management Coordination Workshop (June 2017), Coordination of DWH Long-Term Data Management: The Path Forward (December 2018)

In June 2017, CRRC and NOAA OR&R and NOAA NMFS Restoration Center (RC) partnered for the DWH Long Term Data Management (LTDM) workshop. The organizing committee for this workshop consisted of representatives from NOAA, Gulf of Mexico Alliance, Florida RESTORE Act Centers of Excellence Program, GRIIDC, BOEM, Gulf Coast Ecosystem Restoration Council, Gulf of Mexico IOOS, NCEI, Ocean Conservancy, U.S. Department of the Treasury, University of Miami, National Fish and Wildlife Foundation, NAS, USGS, and state agencies. This workshop reviewed existing data management systems and opportunities to advance the integration as well as the data available for restoration planning, project implementation and monitoring. It also provided a platform for increased communication among the various Gulf of Mexico restoration-focused entities. Three working groups resulted from this workshop: Data Management Standards, Interoperability, and Discovery/Searchability. The groups addressed various complex topics related to DWH LTDM.

In December 2018, a second workshop entitled DWH Long Term Data Management: The Path Forward was held and resulted in five recommendations: adoption/adaption/development of data exchange format/materials, identification of vocabularies development of best management practices for data integration, a pilot project to use as proof of concept of data systems interoperability, and communication/advocacy of successes of interoperable systems. Following the workshop, the DWH LTDM Core Team drafted work plans and objectives as next steps for the five actions items.

Leveraging Science and Academic Engagement During Incidents (June 2019)

NOAA OR&R and CRRC partnered for this workshop that focused on the integration of academic resources and expertise into a conventional oil spill response. The goal of the workshop was to provide a focused discussion regarding lessons learned from academic engagement during oil spill response. Participants included representatives from industry, government, and academia. A list of recommended next steps included:

- Develop a matrix identifying information academics need to know about response,
- Create a guidance document that could assist academic institutions in creating organizational action plans for oil spill response participation,
- Develop a comprehensive directory of academics to promote engagement during spills,
- Develop relationships between academics and area committees/state and federal SSCs.

Additional short-term actions included: reviewing and updating existing lists of scientists across area committee plans, increasing awareness of academic engagement during spills, encouraging regions with existing engagement models to continue to make connections between responders and academics, including academic liaisons for each RRT, and developing standardized methods pre-event that facilitate academic engagement during a spill.

Pacific Islands NRDA (July 2019)

This workshop was conducted to train agency staff and scientists in the Pacific Islands on how to initiate and conduct a successful NRDA for an oil spill, or threat of an oil spill based on the difficulties resulting from DWH. The workshop covered basic NRDA principles, organizational planning, ephemeral data collection, coordination with response, data collection for exposure and assessment, and data management and focused on NRDA in remote island settings and marine mammal issues.

Evaluation of Surface Oil Thickness (November 2019)

This project is sponsored by NOAA OR&R using funding from the Canadian Oceans Protection Plan's MPRI in partnership with BSEE. The project consists of three distinct phases. Phase I was a workshop to discuss the strengths and weaknesses of available technologies for oil thickness measurements. Phase II consists of experiments in small scale tanks with controllable conditions to test the different technologies. Phase III is using BSEE's facility to test the technologies under "field" related anomalies (i.e., wind generated patchiness). The workshop brought together an international team of experts to synthesize a list of technologies. The project's core team used this information to plan subsequent small scale and large tank experiments.

Arctic Spill Modeling (December 2019) and Part II (November 2020)

The USDHS Arctic Domain Awareness Center provided a two-year grant to CSE entitled Oil Spill Modeling for Improved Response to Arctic Maritime Spills: The Path Forward. The goal of the grant was to gather expert advice to improve response modeling that addresses USCG and FOSC needs during a potential oil spill in the Arctic. The project involved identifying FOSC needs/questions to be addressed by Arctic oil spill response models, a three-day Arctic Maritime Spill Response Modeling Workshop (Workshop Part I), formation of working groups on specific response model components/criteria, and a two-day workshop to review working group drafts and integrate feedback (Workshop Part II).

The first workshop, held in 2019, focused on: establishing the current state of the art Arctic maritime oil spill models and their usefulness to response modeling; identifying gaps in Arctic maritime oil spill modeling; and determining the topics to be discussed by working groups following the completion of the workshop. There were four working groups created to focus on the following major themes: 1) oil and ice interactions at the meter/sub grid scale, 2) oil and ice interactions at the kilometer + scale, 3) new and existing technologies for observing ice and informing models, and 4) visualization and uncertainty. The second workshop, held virtually in 2020, including a presentation from each Working Group on their findings and recommendations and a discussion to solidify recommendations and ensure cross topic collaborations and initiatives. The project provided recommendations for new components and algorithms for oil and ice interactions, methods for improving communication of model output uncertainty, recommendations for remote sensing tools useful in Arctic spill response, and coordination of further oil and ice modeling efforts.

Response Oil Assay (January 2020)

This workshop was in support of NOAA's effort to create a new database of oil physico-chemical properties to aid in oil spill response decision-making with funding provided by the Canadian MPRI. The workshop identified questions that needed to be answered in oil spill response, assessment, and planning, and then compiled a list of physico-chemical properties oil to address those questions. The workshop also focused on analytical methods used by laboratories to measure the properties of oil and considered the merits of different methods for artificially weathering oil in a controlled stetting. Following the workshops, four working groups were created focusing the following needs: 1) what should be in the database, 2) interlaboratory evaluation of methods for measuring properties of petroleum products, 3) responder's data sheet, 4) response oil assay data model.

A number of deliverables were produced by the four working groups including:

- A document that defined the use cases for the data and ranked the relative importance of specific measured oil properties (e.g., oil density, viscosity, pour point).
- A series of reports presenting the results of property-by-property analytical method comparison, written in a format useful to oil spill responders and those supporting their work (e.g., hazard assessment teams, response modelers).
- Responder data sheet templates that could be automatically generated from the data in the Response Oil Assay.

8.2 U.S. Department of Energy (USDOE) Programs

USDOE's ongoing research within the Office of Fossil Energy is focused on the prudent development of domestic oil and gas resources. USDOE's Office of Oil and Natural Gas' Division of Upstream Research promotes safety and environmental sustainability of oil and gas exploration and production by providing early-stage research. The Upstream

Offshore Oil and Gas Research Program research portfolio includes projects on spill prevention and innovative solutions to address challenges associated with geohazard prediction, well control, surface systems and umbilicals, and subsea systems reliability and automation, while increasing ultimate recovery of offshore oil and gas resources. USDOE's upstream onshore research portfolio focuses on developing basin-specific technologies to maximize resource recovery and prudent environmental stewardship, accelerating the potential of emerging and untapped oil and gas resources, and treatment of produced water for reuse.

8.3 National Petroleum Council: Arctic Potential – Realizing the Promise of U.S. Arctic Oil and Gas Resources

At the request of the Secretary of Energy, the National Petroleum Council (NPC) conducted a comprehensive study considering the research and technology opportunities that would enable development of U.S. Arctic oil and gas resources. The study included an in-depth assessment of available offshore oil and gas technology, ongoing studies, and research opportunities on: ice characterization, oil and gas exploration and development, logistics and infrastructure, oil spill prevention and response, the ecological and human environments. Published in 2015, the study concluded that the physical, ecological, and human environment were well understood, and that the technology was available to explore for and develop oil and gas in the U.S Arctic as well as significant undiscovered offshore oil potential there. The study noted that pursuing oil and gas in the Arctic was hindered by economics, a regulatory framework taken from southern regions where work could be done year-round, and a lack of public confidence that it could be conducted safely and responsibly. Technology validation and demonstrations were recommended to improve understanding and public confidence.

A supplemental assessment was published in 2019 that concluded that the findings of the 2015 report were still valid. In the supplemental assessment, there were two additional findings. Improvements to the current Arctic OCS regulations and their implementation could enhance safety, environmental stewardship, and public confidence. Lease availability and terms, and regulatory requirements reduce the competitiveness of the Alaska OCS, compared with other opportunities worldwide. The supplemental assessment developed a series of recommendations, directly related to oil spills:

- "Arctic OCS drilling regulation and their implementation should be performance-based, emphasizing prevention of loss of well control and oil spills, and use of the effective technologies to improve safety, environmental performance, and economic viability."

- "Preapproval to use dispersants and *in-situ* burning should be granted to facilitate rapid oil spill response."
- "Regulatory authorities should grant permits for controlled experimental spill response drills in U.S. waters."
- "Government authorities should participate in Joint Industry Projects and continue to participate in oil spill response exercises, to promote knowledge transfer and improve public confidence."

8.4 Industry Reports

The oil industry convened the Joint Industry Oil Spill Preparedness and Response (OSPR) JITF in June 2010 to evaluate procedures and lessons learned during the *Deepwater Horizon* oil spill response. The initial focus of the JITF was to identify potential opportunities for improvement to oil spill response systems in the areas of planning and coordination, optimization of response tools, R&D, technology advancement, and training/education of all parties preparing for or responding to an oil spill.

The JITF examined industry's ability to respond to a SONS and the actual response to the Gulf of Mexico spill. The JITF divided its recommendations into eight categories, or work streams: spill response planning, dispersants, shoreline protection, oil sensing and tracking, ISB, inland response, mechanical recovery, and alternative response technologies.

This effort produced over 65 publications, the last of which was published in 2021. The publications included field operations guidance, technical reports, fact sheets, and newsletters. The final JITF products are publicly available at http://oilspillprevention.org/oil-spill-research-and-development-cente.

The Arctic Oil Spill Response Technology JIP launched in 2012 to undertake targeted research and technology projects to improve Arctic spill response capabilities. The JIP was a consortium of nine oil and gas companies and focused on dispersants, environmental effects, trajectory modeling, remote sensing, mechanical recovery, and *in-situ* burning. The JIP conducted technical assessments and state of knowledge reviews and laboratory, small and medium scale tank tests, and field research experiments. The project improved Arctic spill response capabilities and provided a better understanding of the environmental issues involved in selection and implementation of the most effective response strategies. The JIP Synthesis Report and all JIP research reports are found at http://www.arcticresponsetechnology.org/reports/.

8.5 NAS: Spills of Diluted Bitumen from Pipelines: A Comparative Study of Environmental Fate, Effects, and Response (2016)

The *Spills of Diluted Bitumen from Pipelines* report, published in 2016, identified the relevant properties and characteristics of the transport, fate, and effects of diluted bitumen and other transported crude oils when released into the environment. The report assessed whether the differences between properties of diluted bitumen and those of other commonly transported crude oil warrant modifications to regulations governing spill response plans and cleanup. The report developed recommendations designed to improve spill preparedness of diluted bitumen and to enable effective cleanup and mitigation measures:

1. "To strengthen the preparedness for pipeline releases of oil from pipelines, the Part 194 regulations implemented by PHMSA should be modified so that spill response plans are effective in anticipating and ensuring an adequate response to spills of diluted bitumen."
2. "USEPA, USCG, and the oil and pipeline industry should support the development of effective techniques for detection, containment, and recovery of submerged and sunken oils in aquatic environments."
3. "USEPA, USCG, and state and local agencies should adopt the use of industry-standard names for crude oils, including diluted bitumen, in their oversight of oil spill response planning."
4. "USCG should revise its oil-grouping classifications to more accurately reflect the properties of diluted bitumen and to recognize it as a potentially nonfloating oil after evaporation of the diluent. PHMSA and USEPA should incorporate these revisions into their planning and regulations."
5. "NOAA should lead an effort to acquire all data that are relevant to advanced predictive modeling for spills of diluted bitumen being transported by pipeline."
6. "USEPA, USCG, PHMSA, and state and local agencies should increase coordination and share lessons learned to improve the area contingency planning process and to strengthen preparedness for spills of diluted bitumen. These agencies should jointly conduct announced and unannounced exercises for spills of diluted bitumen."
7. "USEPA should develop a standard for quantifying and reporting adhesion because it is a key property of fresh and weathered diluted bitumen. The procedure should be compatible with the quantity of the custodial sample collected by pipeline operators."

8.6 NAS: The Use of Dispersants in Marine Oil Spill Response (2020)

In 2020, NAS published a report on the effects and efficacy of dispersants as an oil spill response tool. The report builds on two previous the National Research Council reports on dispersant use (1989 and 2005) and provides a current understanding of the state of science and future marine oil spill response operations including dispersants. The study evaluated trade-offs associated with dispersant use, in part through the use or review of net environmental benefit analysis (NEBA) conducted for past oil spills. The fate and effects of untreated and chemically dispersed oil were compared. The surface and subsurface use of dispersants during actual spills was investigated. The report concluded that dispersants can be an effective tool in oil spill response under certain circumstances (e.g., large-scale, offshore marine spills). The report considered oil spill response, the factors that contribute to response decision making, the trade-offs associated with dispersant use, and the process available for assessing the trade-offs.

The report made the following recommendations:

1. "Relevant federal authorities, including NOAA and the USCG, should track emerging technologies and provide support and opportunities for those technologies to be tested for applicability to marine oil spill response. Promising technologies should be supported and brought to a state of application readiness, perhaps with support from industrial partners. Responsible agencies should further coordinate such analyses during a major spill, perhaps with input from the scientific community, so as to achieve additive benefit from complementary approaches."
2. "Relevant response authorities, including NOAA and USCG, with support from industrial partners and other agencies, should formally incorporate and support aerial hydrocarbon quantification capabilities such as those demonstrated by Ryerson et al. (2011) as a flexible spill response tool to quantify discharge rate and transport processes."
3. "Molecular tools should be encouraged but only so long as the underlying assumptions of each assay is understood. Because these techniques can have biases, multiple assays and multiple lines of evidence are necessary to ensure that the conclusions from these techniques are correct. Developing detailed Field Sampling Plans with these molecular techniques and updating them on a regular basis with teams of experts is critical to avoid making incorrect conclusions about oil/dispersant efficacy for dispersion and bioremediation."
4. "Efforts to take detailed scientific measurements during future spills (spills of opportunity) and/or to conduct dedicated field experiments should be strongly encouraged. In the case of a spill of opportunity, preplanning and pre-deployment as well as focusing on the priorities for such observations are

essential to avoid delays in the start of taking these measurements. Given its long-term funding and mandate, the National Academies Gulf Research Program, or a foundation with similar long-term funding, would be in an ideal position to work with the Interagency Coordinating Committee on Oil Pollution Research to coordinate a field experiment or scientific efforts for deployment in a spill of opportunity."

5. "Analyze the large quantity of available experimental toxicity data to investigate the question whether exposure media containing chemically dispersed oil is more toxic than is exposure media containing physically dispersed oil. The analysis would need to include a quantitative estimate of the microdroplet concentration at each dilution, estimates of the dissolved concentrations, and the use of toxic units as the dose metric."
6. "Establish and maintain baseline health metrics, readily available and deployable biomarkers of exposure and effect, and study protocols that are activated at the start of an oil spill for recruitment and collection of biospecimens from response workers and affected shoreline communities."

8.7 GoMRI Synthesis and Legacy

The goal of GoMRI between 2010-2021 was to improve society's ability to understand, respond to and mitigate the effects of petroleum pollution and related stressors of the marine and coastal ecosystems, with an emphasis on conditions found in the Gulf of Mexico. GoMRI held a series of public meetings in 2010 to help develop the following five research themes to address science gaps and research needs:

1. "Physical distribution, dispersion, and dilution of petroleum (oil and gas), its constituents, and associated contaminants (e.g., dispersants) under the action of physical oceanographic processes, air sea interactions, and tropical storms."
2. "Chemical evolution and biological degradation of the petroleum/dispersant systems and subsequent interaction with coastal, open-ocean, and deep water ecosystems."
3. "Environmental effects of the petroleum/dispersant system on the sea floor, water column, coastal waters, beach sediments, wetlands, marshes, and organisms; and the science of ecosystem recovery."
4. "Technology developments for improved response, mitigation, detection, characterization, and remediation associated with oil spills and gas releases."
5. "Impact of oil spills on public health including behavioral, socioeconomic, environmental risk assessment, community capacity and other population health considerations and issues."

GoMRI conducted a S&L effort to document and apply scientific achievements and advances to lead to new understanding and improved practice. A S&L Committee was established and subsequently identified eight core areas of focus and a set of guiding principles: 1) Plume & Circulation Observations & Modeling; 2) Fate of Oil & Weathering: Biological & Physical-Chemical Degradation; 3) Ecological/Ecosystem Impacts; 4) Human Health and Socioeconomic Impacts; 5) Ecosystem Services, Human Health and Socioeconomic Impacts; 6) Microbiology, Metagenomics & Bioinformatics; 7) Integrated/Linked Modeling System; and 8) Knowledge Exchange with User Communities: Lessons Learned and Operational Advice. The first four core areas closely align with GoMRI's research themes. Core areas 5, 7, and 8 focus on how to apply research knowledge gained to the operational and user communities. Core area 6 was identified to synthesis and capture the advancements in microbiology, metagenomics, and bioinformatics since GoMRI began. Nearly 50 unique products resulted from the GoMRI synthesis effort culminating in the GoMRI Special Issue in the Journal Oceanography published in March 2021.

The Oceanography special issue, *GoMRI: Gulf of Mexico Oil Spill & Ecosystem Science 2010-2020,* is intended to be a high-level overview synthesizing new knowledge for a broad and general audience. This special issue builds upon the 2016 Oceanography special issue, *GoMRI: Deepwater Horizon Oil Spill and Ecosystem Science*, which highlighted scientific advances including how the DWH spill affected marine ecosystems and the fate of oil in the marine environment, data management, and education and outreach initiatives from 20 papers. The 2021 special issue discusses: the chemistry and physical properties of petroleum, dispersants and products of burned oil; geophysical transport processes; micro-physical and biogeochemical fate; interaction of physical transport and biogeochemical processes; dispersants; oil and dispersant effects on biological systems; effects of petroleum byproducts and dispersants on organisms and ecosystems; environmental recovery and restoration; human health and socioeconomic effects; technology advancements and developments; prevention and preparedness and advances in operation response; current knowledge gaps and lessons learned.

8.8 ADAC: Arctic Incidents of National Significance (IoNS) Workshops

Starting in 2016, ADAC facilitated Arctic IoNS workshops designed to understand the key drivers in the Arctic environment that affect the ability of USCG and other stakeholders to conduct safe, secure, and effective operations. The information gained from the workshops is used to prioritize gaps and research questions to direct future science and technology investments by the Department of Homeland Security's Science and Technology Directorate toward addressing high-priority gaps. Participants at the workshops included U.S. federal, state, and local government agencies, Alaska Natives and Alaska Native regional corporations, international partners, and representatives from the private sector.

The 2016 Arctic IoNS workshop was a Canada-U.S. forum that leveraged operators' and researchers' expertise to understand science and technology gaps associated with responding to a major rescue operation in the Arctic maritime domain. There were 20 research questions identified at this workshop as science and technology gaps. The research questions focused on: achieving total accountability of personnel; improving medical preparedness and response with rescue and recovery in Arctic region; identifying and mitigating related/relevant hazards to Arctic major response operations; and advancing Arctic region rescue response coordination, awareness, and communications.

In 2017, ADAC partnered with UNH CSE to conduct the "Coping with the Unthinkable… an Arctic Maritime Oil Spill" Artic IoNS workshop. This workshop brought together a multi-disciplined team of experts to review relevant baselines of applied research along with existing logistics and response capabilities associated with an Arctic maritime oil spill. The workshop addressed a distant offshore Arctic oil spill scenario by reviewing current research and soliciting recommendations from workshop participants. As a result of this workshop, 35 research questions were identified. The research questions focused on: logistical support of the response and responders; response techniques for dispersant use; detection, tracking, and modeling of oil; and degradation and fate of oil.

The 2019 Arctic IoNS workshop series was conducted in two parts: 1) Alaska native and rural Arctic "insights" community workshop, and 2) "Stressing the system…managing a complex Arctic crisis" workshop. The workshop used a scenario of a major storm in the Bering Sea resulting in a maritime accident, followed by widespread damage to Western Alaska coastal regions to "*stress the system*" and identify shortfalls in "*managing a complex Arctic crisis response.*" The combined workshops yielded 32 research questions regarding limitations and gaps in voice and data communications, maritime domain awareness, incident response logistics and resourcing, and latent detection technologies needed to respond to an Arctic crisis effectively and efficiently.

8.9 NAS GRP Workshops

The goals of the NAS GRP are: to reduce the likelihood of a catastrophic accidents and lessen the severity of consequences associated with offshore energy operations, protect, and enhance the socioecological systems of the Gulf region and enhance health and well-being in the Gulf region. The GRP conducts programs/studies on: offshore energy safety; environmental protection and stewardship; healthy and community resilience; data, data products and knowledge; and education and capacity building.

The GRP hosted the following workshops that encouraged stakeholders to brainstorm research needs and recommendations:

- Opportunities for the Gulf Research Program: Middle-Skilled Workforce Needs (2014)
- Opportunities for the Gulf Research Program: Community Resilience and Health (2015)
- Opportunities for the Gulf Research Program: Monitoring Ecosystem Restoration and Deep Water Environments (2015)
- Preparing for a Rapid Response to Major Marine Oil Spills: Protecting and Assessing the Health and Well-Being of Communities (2017)
- The Human Factors of Process Safety and Worker Empowerment in the Offshore Oil Industry (2018)

Opportunities for the Gulf Research Program: Middle-Skilled Workforce Needs (2014)

In 2014, GRP held a workshop to facilitate discussions of the current state of education and training pathways for preparing the region's middle-skilled workforce in the short- and long-term. Middle-skilled jobs typically require significant training and skill, but not an advanced degree (e.g., geological and petroleum technicians, oil and gas rotary drill operators, and oil and gas derrick operators). The workshop identified perceived needs and potential opportunities that the GRP could addressed. Participants discussed opportunities to build middle-skilled workforce capacity in the Gulf region, including the need for competency-based education and training approaches and stronger partnerships among the region's employers and higher education institutions.

Opportunities for the Gulf Research Program: Community Resilience and Health (2015)

This GRP workshop examined opportunities to improve the health, well-being, and resilience of communities in the Gulf region through a discussion with about 50 participants with diverse expertise and experience. These discussions identified perceived needs, challenges, and opportunities that align with the GRP's mission and goals. The following are examples of the recommendations suggested by participants during the workshop:

- Foster creation of a "central hub" in the Gulf to support transdisciplinary research, education, and training to link research to practice.
- Advance human health and environmental monitoring technologies.
- Focus on mental health effects of disasters.
- Explore opportunities to improve how communities are involved and engaged in scientific research.

Opportunities for the Gulf Research Program: Monitoring Ecosystem Restoration and Deep Water Environments (2015)

This GRP workshop gathered about 40 participants from the private sector, state and federal government, academia, and nongovernmental organizations to examine time-sensitive opportunities in the Gulf for restoration and accelerating development of energy resources in the deep Gulf. The two highlighted workshops were monitoring ecosystem restoration and deep water environments. The workshop participants discussed: the role that communication and outreach play in successful monitoring; the importance of applying an ecosystem service approach to monitoring and forming partnerships among stakeholders; and supporting efforts to organize and manage monitoring data. The following are examples of the recommendations suggested by participants during the workshop:

- Conduct public awareness, education, and outreach campaigns to explain restoration science, as well as the importance of the deep ocean.
- Support development of new technologies, including biomarkers, sensors, satellite telemetry, adaptive sampling, and improved analytical methods.
- Partner with the oil and gas industry to map benthic and benthic-associated habitats in the deep ocean to encourage the release and utilization of bathymetric data.

Preparing for a Rapid Response to Major Marine Oil Spills: Protecting and Assessing the Health and Well-Being of Communities (2017)

In August 2017, NAS facilitated a workshop that: explored research needs and other opportunities for improving public health preparedness, response, and protection related to oil spills; considered how to work within and complement the existing oil spill response framework to improve the protection of community health and well-being; informed discussion about how the GRP and other division of NAS can support these efforts; and fostered connections among public health, oil spill practitioners, disaster research communities, and leaders from communities affected by oil spills.

The workshop characterized four groups of challenges related to incorporating protection of community health and well-being into oil spill response: complex and long-term effects; communication and engagement at a local level; gaps in knowledge for prevention and mitigation strategies; competition of priorities and sustainability. Workshop participants acknowledged culture change would be necessary on many levels to broaden the scope of oil spill response. Opportunities for this include: aligning existing policies, funding, and systems; improving communications and building trust; including communities in planning and response efforts; and improving understanding of oil spill science, effects, and mitigation strategies.

The Human Factors of Process Safety and Worker Empowerment in the Offshore Oil Industry (2018)

In June 2018, more than 100 experts in offshore oil and gas drilling, safety procedures, and government regulation gathered to discuss ways to prevent accidents in the offshore oil industry. The workshop focused on understanding and applying the human factors involved in process safety and worker empowerment to reduce and mitigate offshore hazards. Scientific research from fields such as human-systems integration, human factors, recognition primed decision making, hazard recognition, risk management, risk analysis, perception, and process safety design were reviewed. Best practices and lessons learned were explored from other high-risk, high-reliability industries including airlines, health care, railroads, and nuclear power.

The workshop discussed barriers and methods for effective worker empowerment for offshore safety and the roles of different stakeholders, lessons learned from offshore operations in other regions, current systems for worker responses to unsafe conditions, and worker interventions and reporting.

8.10 Prince William Sound (PWS) OSRI

OSRI sponsors research, education, and demonstration projects that improve understanding and response to oil spills in Arctic and Subarctic marine environments. Below are notable research studies funded by OSRI during this reporting period:

- **Buried Oil Detection by Canines in Northern Prince William Sound.** During this study, a series of beach surveys were conducted using canines trained to detect subsurface oil at different sites in Prince William Sound, AK; some of which had subsurface oil present. A trained canine was able to detect subsurface oil that had been in place for over 25 years, demonstrating that a trained canine can quickly and accurately detect subsurface oil on a beach.
- **Feasibility Study: Developing Integrated Herder Delivery and Ignition Systems**. This study evaluated alternative aerial and surface methods of combined herder delivery and ignition systems to propose concepts that justify further testing. This research explored different options for integrated systems that could use a helicopter, or other systems (e.g., unmanned surface vehicle (USV)), for herder delivery and ignition. In addition to providing recommendations for further development and testing, the study concluded that the current gelled gasoline method for ignition is the most effective option.
- **Ensuring Food Safety Following an Oil Spill in Alaska: Regulatory Authorities and Responsibilities.** This report informed the Alaska Regional Response Team (ARRT) as they developed their policy and guidance on handling food safety issues in a spill response. The report offered ARRT policy recommendations

including “advancing a shared understanding within Area Committees of the food resources at risk and the partners and practices in place to address them.” The report noted the importance of “exercising procedures in place for a major freshwater spill in Alaska and identifying best practices for communicating advisories (particularly with and to subsistence communities).”

9.0 Oil Spill Research and Technology Priority Research Needs

ICCOPR selected 171 priority Research Needs to address the 28 SRAs and SRA Subcategories using the deliberative process described in Chapter 6. The priority Research Needs discussed in this chapter represent the federal opinion on where research programs should focus to address the broader scope of Research Needs identified throughout the OPRTP development. Federal agencies should consider these priorities as they make research investments and ICCOPR also encourages non-federal research programs to use these priorities. Progress toward addressing these priorities is tracked by ICCOPR. A new set of priorities will be established during the next OPRTP cycle.

ICCOPR organized the priority Research Needs by the four Classes that represent the general groupings of oil spill research: Prevention, Preparedness, Response, and Injury Assessment and Restoration (**Figure 9-1**).

Figure 9- 1 The Oil Spill Research Categorization Framework

As discussed in Section 4.2, the OPRTP framework embodies the concept that research in each Class can inform and support the research from other Classes; and the Preparedness Class plays a central role in supporting the others. ICCOPR’s member organizations may conduct or support research across one or multiple Classes depending on their specific mission, regulatory responsibilities, and/or expertise.

Table 9-1 lists the Classes and the SRAs. The following sections present the top priority Research Needs by Class and SRA or Subcategory. The order of the three priorities listed within an SRA or Subcategory is not indicative of their relative importance. All three priority Research Needs are of equal importance in the SRA or Subcategory.

The Prevention Class includes research that supports the development of practices and technologies designed to predict, reduce, or eliminate the likelihood of discharges, or, if a discharge occurs, minimize the volume discharged into the environment.

The Preparedness Class includes research that supports the activities, programs, and systems developed prior to an oil spill to improve the planning, decision-making and management processes needed for responding to and recovering from oil spills.

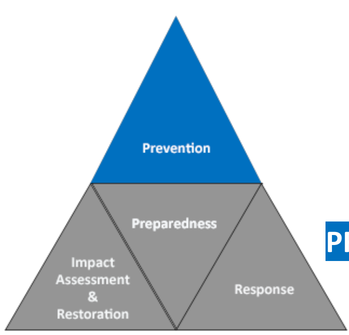
The Response Class includes research that supports techniques and technologies that address the immediate and short-term effects of an oil spill and encompasses all activities involved in containing, cleaning up, treating, and disposing of oil. The goal of response research is to: 1) maintain the safety of human life; 2) stabilize a situation to preclude further damage; and, 3) minimize adverse environmental and socioeconomic effects.

The Injury Assessment and Restoration Class includes research that involves the collection and analysis of information to: 1) evaluate the nature and extent of environmental, human health, and socioeconomic injuries resulting from an incident; 2) determine the actions needed to restore natural resources and their services to pre-spill conditions; and 3) make the environment and public whole after the intervening losses.

Table 9- 1 SRAs by Research Class

Prevention	Preparedness	Response	Injury Assessment & Restoration
• Human Error Factors • Offshore Facilities and Systems • Onshore Facilities and Systems • Waterways Management • Vessel Design • Drilling • Rail & Truck Transportation • Pipeline Systems • Geohazards • Subsea Systems Automation and Reliability	• Pre-spill Baseline Studies • Response Management Systems • Renewable Energy Systems	• Structural Damage Assessment and Salvage • At Source Control and Containment • Chemical and Physical Behavior Modeling • Oil Spill Detection and Surveillance • In- and On-water Containment and Recovery • Shore Containment and Recovery • Dispersants • *In-situ* Burning • Alternative Chemical Countermeasures • Oily and Oil Waste Disposal • Bioremediation	• Environmental Effects and Ecosystem Recovery • Environmental Restoration Methods and Technologies • Human Safety and Health • Sociological and Economic Effects

9.1 Prevention Priority Research Needs



PREVENTION

9.1.1 10000 Series: Human Error Factors Research Priorities (Section 4.3.1.1)

This SRA focuses on how human performance and factors contribute to accidents in the oil production/transportation system. It includes the development of advanced methods and systems for training operational personnel, basic research on personnel performance in preventing oil spills (i.e., safe navigation on vessels, proper oil transfer practices, analysis/evaluation of equipment monitoring systems, decision-making processes). It also includes the development of methods and technologies to evaluate the ability and knowledge of personnel in performing their duties. This extends to the overall management culture and its ability to foster the appropriate organizational safety, preparedness, and response operating environment.

The priorities in this SRA focus on enhancing human performance to reduce potential spills through improved technology and training methods. ICCOPR selected Research Needs that evaluate lessons learned from previous training exercises and encourage the development of innovative training methods, particularly those that incorporate simulations, gaming, and unmanned systems.

10000 Series: Human Error Factors Research Needs
A. Investigate how to integrate unmanned aircraft systems into the safety monitoring of commercial operations to minimize potential emergency situations and increase operator safety.
B. Evaluate lessons learned from training exercises encompassing a broad spectrum of sea ice, ocean, and meteorological conditions, including extreme cold and harsh weather conditions, to identify common human error factors unique to these conditions.
C. Identify human performance causal factors and develop innovative training and evaluation methods to reduce workplace errors and improve decision-making to prevent oil spills from occurring, including the use of artificial intelligence, readiness evaluations, gaming, hands-on exercises, and simulators.

9.1.2 10100 Series: Offshore Facilities and Systems Research Priorities (Section 4.3.1.2)

This SRA includes: offshore exploration and development wells, platforms, and well control systems; the methods, techniques, and equipment for system reliability inspections; measures to ensure well bore integrity; systems to detect and prevent oil and gas discharges; and equipment to regain control of a well blowout or any other unplanned discharge. It also includes equipment, storage units, and piping used to transfer oil within the offshore system and connect the system to transfer pipelines. This technology is relevant for the multiple operating environments of exploration and production activities (e.g., Arctic, shallow, deep, and ultra-deep waters). The term “well bore stability and integrity” recognizes that offshore wells include an engineered system reaching from the ocean floor to surface facilities, supported by the drilling platform that undergoes continual stresses and corrosion. It also includes production platforms (after drilling) that undergo stress and corrosions over the 30–40-year lifetime of the well, and the plugged and permanently decommissioned wellbore. To ensure wellbore stability and integrity throughout the well's lifecycle, cumulative fatigue must be addressed in design and maintenance.

This SRA has two Subcategories: Met-Ocean Effects; and Surface Systems and Umbilicals. The selected priorities acknowledge the risk of potential releases due to aging offshore infrastructure in regions subjected to severe environmental conditions (e.g., hurricanes, blizzards, high pressure and high/low temperature environments). ICCOPR recognizes the need for technologies to improve the safety and productivity of subsea tiebacks, umbilicals, and related infrastructure systems.

10100 Series: Offshore Facilities and Systems Research Needs
MET-OCEAN EFFECTS (10101)
A. Conduct met-ocean studies for infrastructure life extension to determine the effects and impacts of severe weather conditions (e.g., hurricanes, blizzards).
B. Study sea spray icing and ice force impacts to mitigate their effects on offshore facilities.
C. Conduct longevity testing of drilling, completion, and other equipment under extreme conditions to address high pressure and high or low temperature conditions in the Arctic and Gulf of Mexico.
SURFACE SYSTEMS AND UMBILICALS (10102)
A. Develop a detailed technology roadmap for systems to improve umbilicals and seabed power generation, transmission, storage, and chemical transport.
B. Develop mitigation and maintenance methodologies that do not require significant reinvestment or shut-in to extend the life of aging infrastructure.
C. Develop methods to improve safety and productivity in long subsea tiebacks.

9.1.3 10200 Series: Onshore Facilities and Systems Research Priorities (Section 4.3.1.3)

This SRA includes designs, techniques, operational procedures and equipment for fixed onshore facilities, including wells. It covers inspections and systems to detect, prevent, and mitigate oil and gas discharges from the facilities and their systems, including transfer equipment, storage, and piping.

There are two Subcategories under this SRA: Tank and Piping Inspection, Operations, Design, and Data; and Emerging Issues. Research is needed to minimize potential discharge and facilitate waste treatment of tank residues. The priorities recognize the need to address the effects of extreme (e.g., Arctic) and subsurface environments on onshore facilities operation and spill cleanup. ICCOPR recommends the development of technologies that can assess aging infrastructure.

10200 Series: Onshore Facilities and Systems Research Needs
TANK AND PIPING INSPECTION, OPERATIONS, DESIGN, AND DATA (10201)
A. Analyze the causes and magnitude of upstream and/or downstream discharges from tanks, appurtenances, and associated piping to better understand system failures.
B. Develop automated methods that rapidly clean hydrocarbon wastes from the interior of industrial tanks in a cost-effective manner.
C. Evaluate and improve the efficacy of sorbent and similar technologies used for storm water filtration and secondary containment shut-off drains.
EMERGING ISSUES (10202)
A. Develop protocols and industry standards to rapidly predict, detect and minimize failures of aging oil storage infrastructure (tanks, appurtenances, and piping systems).
B. Analyze the effect of subsurface pipeline ruptures on the environmental vulnerability of aquifers and the resulting implications for spill assessment and cleanup equipment.
C. Assess the effects of Arctic and cold weather environments, including climate change, on the operation and maintenance of tanks, appurtenances, and associated piping.

9.1.4 10300 Series: Waterways Management Research Priorities (Section 4.3.1.4)

This SRA includes methods, equipment, and integrated systems designed to improve navigation at sea and in ports, rivers, and inland waterways. It includes on-board navigation systems, such as integrated navigation and bridge systems and collision avoidance systems. It also includes systems external to the vessel, such as vessel traffic and tracking systems, navigational aids and piloting systems, and general research into navigation risks, the effects of navigational safety programs, and the development of decision support tools for waterways management. This SRA includes development of navigational channel maintenance programs and analysis of voyage pre-planning processes.

The selected priorities focus on identifying and mitigating current navigation technology gaps (i.e., automatic identification system (AIS)), improving waterways management in the Arctic, and advancing the compatibility of maritime communication systems.

10300 Series: Waterways Management Research Needs
A. Identify geographic and temporal gaps in the reception and transmission of U.S. automatic identification system (AIS) data and develop plans to mitigate them.
B. Improve Arctic waterways management/vessel accident prevention, including improvements in (a) communications, (b) emergency response paradigms for vessel casualties (e.g., vessel foundering), (c) ice piloting requirements and qualifications, (d) weather, (e) ice forecasting, (f) aids to navigation, and (g) charting.
C. Develop solutions to improve compatibility of international and domestic maritime communication and navigation systems.

9.1.5 10400 Series: Vessel Design Research Priorities (Section 4.3.1.5)

This SRA includes the development, physical and numerical modeling, and testing of advanced tanker and barge designs to make these vessels less susceptible to damage and less likely to discharge cargoes into the waterways when a grounding, collision or structural failure occurs. This SRA also includes research on non-tank vessel designs (e.g., double-hulled fuel and lube oil tanks) to minimize the possibility of spillage from a wide range of vessels.

The priorities in this SRA emphasize the need for improved survivability for vessels and the development of tools for ships operating in the extreme environments, including thin ice in the Arctic.

10400 Series: Vessel Design Research Needs
A. Develop improved designs and analytical tools (procedures, computer models, and software) for design and operation of ships and marine structures conducting drilling operations in extreme environments.
B. Continue to develop an understanding of thin-ice mechanics and its implications for ships operating in such conditions.

C. Develop designs and methods to improve survivability of ships and structures in damaged condition.

9.1.6 10500 Series: Drilling Research Priorities (Section 4.3.1.6)

This SRA focuses on: the design, construction, and placement of wells (shallow, deep water, ultra-deep water, onshore); materials, sensors, and systems needed for offshore drilling and production platforms, and well heads/risers; and techniques and equipment for well and facility monitoring and inspection under extreme pressure and temperature environments. Also included are efforts aimed at understanding the chemical and physical characteristics for the full range of petroleum oils under varying conditions of pressure and temperature; predicting their phase/state, behavior, and their physical interaction with other materials in the environment (e.g., rock, sediments); and their impact on engineered systems. Examples include: early kick detection; systems for communicating and responding to changes in downhole parameters; strategies and methods for training operational personnel on the use of advanced technology; systems to detect and prevent oil and gas discharges; and well- head systems and equipment to control wild wells and cap well blowouts.

There are two Subcategories to this SRA: Deep Water Drilling and Technology; and Reservoir Characterization. The selected priorities identify the need for tools, nanotechnology, and gap analysis to manage deep water drilling and prevent accidents. The Research Needs for Reservoir Characterization focus on hydrocarbon movement near the seafloor and in overpressure zones that can reduce the risk of accidents.

10500 Series: Drilling Research Needs
DEEP WATER DRILLING AND TECHNOLOGY (10501)
A. Develop advanced downhole tools to assess wellbore integrity, barriers that contain/constrain reservoir fluids to prevent uncontrolled flow into another formation or to the surface, and investigate the long-term stability of boreholes, including integration and failure potential at system interfaces (formation - cement - instrumentation).
B. Use nano-technology, hydrogen intrusive inhibitors, and other advancements to develop permanent and self-healing coatings, and surface and subsea materials (including unique combinations thereof) with high fracture toughness at high and low temperatures for critical drilling and well construction equipment and parts.

C. Conduct a gap analysis on current managed pressure drilling (MPD) techniques to identify future critical needs.
10500 Series: Drilling Research Needs
RESERVOIR CHARACTERIZATION (10502)
A. Develop monitoring and surveillance techniques to assess the potential for hydrocarbon movement to the seafloor by measuring deformation of the overburden (e.g., subsidence measurements, 4D seismic techniques, fiber optics installed along wellbores etc.).
B. Evaluate risk and mitigation strategies related to reservoir-specific issues including potential impacts of shallow water flow systems on facility safety and geology, such as bounding strata weaknesses.
C. Develop methods to predict thin sandstone intervals that represent overpressure zones ahead of the drill bit.

9.1.7 10600 Series: Rail and Truck Transportation Research Priorities (Section 4.3.1.7)

This SRA includes the development and testing of rail and truck transport system designs, operations, and infrastructure to make oil tank cars less susceptible to damage and loss of cargo during normal operations, and train and truck accidents. This SRA includes evaluation of vehicle designs, construction materials, spill prevention devices, and loading/unloading systems and equipment. It also includes evaluations of: the physical and chemical characteristics and behavior of crude oils being shipped, the effects of those characteristics on the tanks during operations and accidents, and systems to control these characteristics. This SRA also includes evaluations of safety systems and processes to: manage the movement and composition of trains and trucks carrying crude oil, prevent accidents and derailments, select preferred shipping routes, and respond safely to an oil spill.

ICCOPR recognizes the unique characteristics and potential environmental hazards of crude oils transported by rail and trucks. The selection of priorities under this SRA focus on developing risk-management frameworks and identifying alternative designs to reduce oil spill accidents, including those that impact environmentally sensitive areas.

10600 Series: Rail and Truck Transportation Research Needs
A. Develop an integrated risk-management framework to optimize the allocation of resources and minimize the risk of petroleum product transport in the most cost-effective manner.
B. Evaluate oil spill accident and incident trends to identify ways to minimize rail and truck accidents and improve methods to reduce environmental impacts including sensitive areas such as marine and freshwater bodies.
C. Assess and identify alternative designs and modifications to minimize risk of oil spills during accidents for truck transportation.

9.1.8 10700 Series: Pipeline Systems Research Priorities (4.3.1.8)

This SRA includes the development of technology, models, and knowledge-based solutions to prevent and mitigate spills from offshore and onshore pipeline systems used to transport oil between facilities. It includes solutions to prevent damage from corrosion, outside forces, and other threats to pipeline integrity, and considers methods to detect and locate leaks and to mitigate volumes released. It also includes solutions to detect and characterize defects to repair or replace them before failure.

There are three Subcategories for this SRA: Threat/Damage Prevention; Leak Detection; and Anomaly Detection/Characterization. The priorities acknowledge the need to develop model criteria to predict pipeline failures and repair needs and to inform industry-wide guidance documents. Other Research Needs focus on developing and advancing pipeline monitoring technology to detect leaks in a variety of environments. ICCOPR recognizes the need for improved signal processing technology that will more reliably detect potential anomalies and improve performance.

10700 Series: Pipeline Systems Research Needs
THREAT/DAMAGE PREVENTION (10701)
A. Improve technology to detect the presence, location, and separation between multiple utilities (underground, through various soil conditions) in a common corridor to reduce damage from an excavation.
B. Develop quantitative risk models to rank repair needs and predict pipeline failures.
C. Evaluate risk tolerability criteria for pipeline risk models to develop industry-wide guidance for operators.

10700 Series: Pipeline Systems Research Needs
LEAK DETECTION (10702)
A. Advance existing leak detection technology and health monitoring sensors that are miniaturized, automatic, robust and withstand harsh environments.
B. Develop advanced technology for sensing leaks that will minimize false alarms for new construction and existing pipelines.
C. Develop approaches to permanently and safely install fiber optics along pipelines to allow for high-speed accurate monitoring.
ANOMALY DETECTION/CHARACTERIZATION (10703)
A. Develop technology to identify defects by type and accurately determine the depths of anomalies.
B. Develop reliable and effective signal processing and data analysis methods for signal noise removal of in-line inspection (ILI) data and defect evaluation.
C. Advance signal processing methods within the pipeline industry to remove noise, improve sizing accuracy, and provide better performance.

9.1.9 10800 Series: Geohazards Research Priorities (4.3.1.9)

This area consists of studies to identify and understand geohazards and conditions that are potential "precursors" to drilling and production incidents potentially resulting in oil spills or loss of life. Research in this area enhances the understanding of the geological formations and their rock properties, enabling operators to reduce the risk of encountering unexpected hazards (e.g., pressure anomalies, salt formations, faults), thereby increasing safety of drilling activity. Resources for profiling the geologic environment include remote sensing surveys that provide information for determining "precursors" to potential drilling and production incidents that could result in oil spills or loss of life. Examples of geologic precursors include: weak formations that have an unusually low fracture gradient, which indicates a tendency for the formation to destabilize wellbore integrity by losing drilling mud to the formation. Research opportunities include activities such as regional geologic studies (especially geohazards), advanced pre-drill seismic/sensing technology (especially "look ahead"), and combined reservoir and geologic studies to minimize geologic and operational exposure associated with exploration wells.

This SRA has two Subcategories: Monitoring; and Identification and Characterization. The priorities focus on developing MMPA compliant technology to collect seismic data, improve geohazard warnings, and understand seafloor stress. ICCOPR also recommends updating current petrophysical technologies, improving characterization of rock interactions during drilling, and advancing data analytics to predict seafloor failures.

10800 Series: Geohazards Research Needs
MONITORING (10801)
A. Develop passive acoustic monitoring technologies that collect high-quality seismic data while remaining compliant with the Marine Mammals Protection Act (MMPA).
B. Develop logging technologies that improve understanding of the *in-situ* state of stress.
C. Develop innovative technologies to improve geohazard warnings.
IDENTIFICATION AND CHARACTERIZATION (10802)
A. Develop advanced data analytics (big data/machine learning) that will predict seafloor failure of various types at different water depths.
B. Investigate the characterization of rock interactions with oilfield mud, chemicals, pressure, and temperature.
C. Identify areas in petrophysical technologies that are unreliable and need improvement and develop methods to improve those shortfalls.

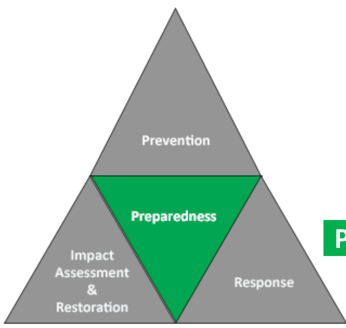
9.1.10 10900 Series: Subsea Systems Automation and Reliability Research Priorities (4.3.1.10)

This area includes analysis and improvement of the reliability of components within complex production systems operating autonomously on the ocean floor. These efforts serve the purpose of reducing the risk of spills by identifying issues earlier, with greater accuracy, and with a faster response time and lessening the environmental impact should a failure occur. Topics include: advanced equipment packaging; improved sensor and system reliability for ROV maintenance and intervention; ROV interface standardization; and advanced flow assurance understanding, especially under HPHT conditions (USDOE, 2015).

ICCOPR recommends developing technologies to improve decommissioning of older wells. Other priorities focus on developing subsea power generation and increasing automation, especially to allow for real-time analysis by off-site experts.

10900 Series: Subsea Systems Automation and Reliability Research Needs
A. Develop safe and cost-effective technologies to better locate and plug older wells.
B. Develop subsea power generation technologies (e.g., fuel cells at hydrostatic pressure).
C. Develop technologies that increase automation such as sophisticated surveillance technology leading to real time data exchange with off-site subject matter experts.

9.2 Preparedness Priority Research Needs



PREPAREDNESS

9.2.1 20000 Series: Pre-spill Baseline Studies Research Priorities (4.3.2.1)

This SRA includes research to acquire, characterize and analyze baseline data on the natural environment, human health, and socio-economic conditions in areas at risk for oil spills. Risk factors include (but are not limited to) extensive exploration and/or production, busy transportation routes, remote areas, and fragile ecosystems. Baseline information and studies may include: location and population data on species and their habitats, especially ecologically sensitive species; the epidemiology/human health characteristics of people in potential impact areas; and potential community and economic impacts in these areas (e.g., tourism, commercial/recreational fishing, seafood industry, underserved community impacts, human health).

ICCOPR divided this SRA into three Subcategories: Habitat and Species Baselines; Oceanographic and Geological Baselines; and Environmental Baseline Planning. The Habitat and Species Baselines identified the need for more research in intertidal, Arctic, fresh water, and deep-and-ultra deep waters. Oceanographic and Geological Baselines included priorities specific to the coastal Gulf of Mexico and Arctic shelf exchanges, surf and inner shelf zones. Spatial connectivity of biota and habitats, easily interpretable biotic indices, and biodegradation rates for key areas (e.g., transportation hubs) are needed for Environmental Baseline Planning.

20000 Series: Pre-spill Baseline Studies Research Needs
HABITATS AND SPECIES BASELINES (20001)
A. Study and synthesize existing information for wetlands (i.e., sand beaches, rocky and cobble habitats) regarding productivity, species diversity, community structure, and the effects of oil on these parameters, including recovery time, with consideration for regional variation.
B. Develop a better understanding of Arctic ecological baselines, including 1) presence, abundance, and distribution of aquatic species and unique characteristics that may influence their vulnerability to oil; 2) factors influencing the fall migration of the bowhead whale; 3) climate change effects on food web complexity and trophic transfer efficiency; and 4) model validation.
C. Characterize deep water and ultra-deep water habitats in the Gulf of Mexico, including ecological structure, populations, biodiversity, and productivity, with an emphasis on key indicator species, protected species; and develop geographically-specific offshore environmental sensitivity indices (ESIs).
OCEANOGRAPHIC AND GEOLOGICAL BASELINES (20002)
A. Develop a better understanding of coastal processes unique to the Gulf of Mexico (i.e., changing shorelines due to erosion, deposition from the Mississippi River) to help inform protection and recovery strategies for oil spills.
B. Characterize the Arctic shelf basin exchanges under-ice river plumes, oil movement and storage capacity, sea-ice boundaries, presence of polynyas, leads, and land fast ice to better inform spill modeling and response.
C. Identify the physical processes controlling the exchange between the surf zone and the inner shelf, as well as the internal circulation and dynamics.
ENVIRONMENTAL BASELINE PLANNING (20003)
A. Evaluate the oil degradation potential of water column and sediment microbial populations to define rates of microbial processes and model baseline dynamics in regions where oil is transported or extracted (e.g., Great Lakes, rivers, ports, offshore).
B. Study the spatial connectivity (horizontal, vertical, meta-populations) of biota and habitats in the Gulf of Mexico and evaluate how they relate to the resiliency of populations and ecosystems following an oil spill.

C. Develop marine biotic indices that provide easy to interpret baseline benthic habitat suitability and ecological health data for waters at risk of oil spills (e.g., Gulf of Mexico, Arctic waters).

9.2.2 20100 Series: Response Management Systems Research Priorities (Section 4.3.2.2)

This SRA includes development of systems to manage how data and information are collected, analyzed, documented, and shared between and among, the planning/preparedness and response communities, NIMS, and the public. These systems are used to integrate diverse sets of narrative, graphic, and video information and many sets and types of raw and analyzed data. Examples of oil spill information systems include: ICS forms; computer systems; data management software and databases; GIS; spill and incident management tracking systems; electronic mail and web content; documents, photographs, and video management and archiving systems; communication systems; public information messages and protocols; remote sensing; and graphical displays.

ICCOPR priorities under this SRA recognize the need to improve virtual information management systems, develop methods to integrate remote sensing data into common operational pictures, and develop spill response planning tools for remote locations.

20100 Series: Response Management Systems Research Needs
A. Identify needed and available remote sensing (satellite and autonomous systems) data sets, develop methods, and formats that facilitate streamlined integration into common operational pictures.
B. Evaluate existing virtual oil spill response systems and make recommendations for improvements and best management practices.
C. Develop spill planning and response management tools based on gap analysis of the availability of countermeasures in Arctic and other remote locations.

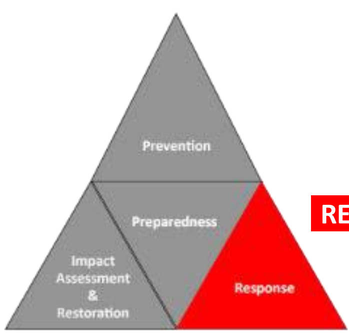
9.2.3 20200 Series: Renewable Energy Systems Research Priorities (Section 4.3.2.3)

This SRA focuses on the challenges posed by the development of renewable energy facilities and their use of OPA regulated products that may behave differently than products traditionally considered in spill response plans. This SRA seeks to determine the extent and nature of the fluids used, or planned for use, in renewable energy systems. It also covers research to better understand how the fluids are used, the associated sources and risks of releases, their potential health and environmental consequences, and the ability of current response systems to recover these materials.

Research Needs under this SRA recognize the growth of the renewable energy sector and the need to identify potential discharge sources from these systems. ICCOPR recommends updating spill response tools and mitigation strategies to include methods specific to the fluids and volumes that could be discharged from renewable energy facilities.

20200 Series: Renewable Energy Systems Research Needs
A. Update existing response tools to incorporate the types of oil products that are, or will be, used on renewable energy facilities in significant quantities (e.g., dielectric fluids).
B. Develop effective spill response mitigation strategies specific to the risks associated with discharges from wind farms and offshore renewable energy facilities.
C. Identify the potential types, sources, and volumes of oil and fluid discharges from renewable energy systems and associated infrastructure, and how the layouts of these systems may necessitate altering spill response strategies and techniques.

9.3 Response Priority Research Needs



RESPONSE

9.3.1 30000 Series: Structural Damage Assessment and Salvage Research Priorities (Section 4.3.3.1)

This SRA includes the development of methodologies and equipment for assessing the extent of damage to a vessel resulting from collision, allision, grounding, explosion, or improper hull stresses during cargo transfers. This area also includes development of methods and technology to graphically present the implications of various measures that can be implemented to stabilize a vessel’s condition, reduce the potential for further pollution, and allow it to be moved safely for repairs or disposal.

The priorities in this SRA include the need to use new technologies to assess the integrity of vessels, marine structures, and tanks/voids, and determine the potential for an oil release. Another important priority is to evaluate the residual strength of damaged ships more quickly.

30000 Series: Structural Damage Assessment and Salvage Research Needs
A. Develop and improve the use of unmanned systems and emerging technologies for underwater assessment of vessels, marine structures, and tanks/voids.
B. Develop and refine technologies and techniques to better determine the presence of oil and the probability of its release from specific sunken vessels.
C. Evaluate and improve the understanding of residual strength of a ship structure with localized damage and simplify residual strength calculations for quicker results.

9.3.2 30100 Series: At-Source Control and Containment Research Priorities (Section 4.3.3.2)

This SRA includes the development of methods, systems, and equipment for containing and recovering oil at or from the source and for mitigating flow from a damaged vessel, onshore/offshore pipeline, exploration or production platform, temporarily abandoned (plugged) well, or well-head once a spill has begun. Such technologies include wellhead capping systems, ROVs for subsea containment activities, and patching, plugging and sealing systems. This technology is applicable to all geographic/environmental areas (Arctic, terrestrial, water surface, subsurface shallow, and deep and ultra-deep water).

The priorities recognize the need to develop: lightweight subsea capping stacks for extreme environmental conditions, subsea containment that can be integrated into response, technologies for in-field volume and flow rate estimates of blowouts, and estimations (i.e., volume and flow rate) during a subsurface blowout.

30100 Series: At-Source Control and Containment Research Needs
A. Develop subsea containment equipment for integration into spill response operations.
B. Develop measurement tools and processes for in-field determination of relative oil and gas bubble volumes and flow rate in subsurface blowouts.
C. Develop and evaluate lightweight subsea capping stacks and components for High Pressure High Temperature (HPHT) environment conditions.

9.3.3 30200 Series: Chemical and Physical Modeling and Behavior Research Priorities (4.3.3.3)

This SRA includes laboratory research, theoretical research, and field studies aimed at understanding the behavior and characteristics of the full range of petroleum oils.

Topics cover behavior and transport in the environment, partitioning of hydrocarbon constituents, and physical interaction with other materials (e.g., rock, sediments, ice). It includes studies of oil behavior and changes throughout the water column in different systems (e.g., riverine, marine). There is particular interest in non-conventional oils such as those produced from the Bakken and Canadian tar sands (diluted bitumen (dilbit) and synthetic bitumen (synbit)). It also incorporates the development and verification of numerical models to predict surface and subsurface movement and weathering (i.e., spreading, evaporation, dispersion, dissolution) of oil spills. This SRA includes methods to provide accurate input data to verify model outputs and development of user-friendly programs to enhance contingency planning and serve as training aides for spill response teams. Models should be available for various spill scenarios at specific locations for different flow and weather conditions to pre-plan potential boom deployment strategies and estimate response resource needs.

There are six Subcategories for this SRA: Arctic Behavior and Modeling; Oil Behavior Models; Transport Models; Oceanographic Models; Emerging Crudes; and Sinking Oil and Marine Oil Snow Sedimentation and Flocculent Accumulation (MOSSFA). ICCOPR recognizes the importance of addressing Research Needs related to the fate and transport of oil in Arctic conditions when it is released on water and in permafrost, including its persistence/degradation. Research Needs also include the development of three-dimensional models for applications with different response conditions on the subsurface and near surface. ICCOPR recognizes Research Needs related to the characteristics, behavior, and toxicity of emerging crudes and production and fate of MOSSFA in spills.

30200 Series: Chemical and Physical Modeling and Behavior Research Needs
ARCTIC BEHAVIOR AND MODELING (30201)
A. Develop and improve algorithms for trajectory models in order to better forecast transport of oil in different weather, ice types and conditions in the Arctic; specifically, the oil transport in ice and brine channels, behavior of oil during ice cover freeze or break up, and scaling issues.
B. Study the fate of oil in Arctic conditions; including open water, ice infested water and oil trapped in ice, under-ice turbulence and currents to develop longer term forecasts, especially during the winter seasons.
C. Evaluate how petroleum contamination behaves at the active layer/permafrost interface and determine pathways by which petroleum contamination seeps into the permafrost zone.

30200 Series: Chemical and Physical Modeling and Behavior Research Needs
OIL BEHAVIOR MODELS (30202)
A. Evaluate the persistence and degradation rates of spilled oil in low temperature conditions.
B. Develop and improve transport model parameters (e.g., volatilization, solubilization, emulsification, biodegradation, photo-oxidation) for a variety of oil types and environmental conditions.
C. Develop three-dimensional oil spill models to predict the effect of oil spills in the water column.
TRANSPORT MODELS (30203)
A. Improve subsea oil detection systems so they are readily deployable and produce reliable input variables for three-dimensional oil spill trajectory models.
B. Validate existing oil trajectory and fate models to predict the behavior and transport of dispersed oil using data from appropriately designed experimental setting or actual spills.
C. Evaluate the structure of the near-surface velocity profile and the related dynamics for simulating surface oil transport.
OCEANOGRAPHIC MODELS (30204)
A. Develop and improve nonproprietary algorithms for oil spill models based on the current state of science.
B. Improve reliability of modelling systems or methods that can scale down from the ocean to coastal environments.
C. Evaluate the near-surface ocean velocity structure and interfacial stresses between air, oil and water under different wind, wave and current conditions to improve oil spill models.
EMERGING CRUDE (30205)
A. Determine the toxicity and environmental fate of unweathered and weathered dilbits to support hazard assessments in aquatic and terrestrial environments.
B. Conduct research on the physical properties and behavior of the diluent component of oil sands mixtures to improve fate and transport models that address public health concerns.
C. Synthesize existing information on chemical and physical characteristics of emerging crudes (including blends of dilbit, synbit and Bakken Crude) to inform models and provide science-based guidance on response tactics.

30200 Series: Chemical and Physical Modeling and Behavior Research Needs
SINKING OIL AND MARINE OIL SNOW SEDIMENTATION AND FLOCCULENT ACCUMULATION (MOSSFA) (30206)
A. Determine the factors that enhance or diminish MOS production across a variety of environments to develop an understanding of the forcing factors that lead to MOSSFA events.
B. Develop research on marine oil snow sedimentation and flocculent accumulation (MOSSFA) timescales for formation, sinking, and incorporation into sediments as a basis for modelling parameters.
C. Conduct laboratory experiments to establish the parameters affecting resuspension and breakup of oil- particle aggregates for oil spill models.

9.3.4 30300 Series: Oil Spill Detection and Surveillance Research Priorities (Section 4.3.3.4)

This SRA refers to methods and equipment for characterizing and monitoring oil spills pre- and post-implementation of response options, and the detection of unknown discharges. This SRA includes surface and subsurface oil spill surveillance including devices, sensors, and systems for detecting and tracking spills, determining the area and thickness of a slick, and measuring the physical properties of the oil. Examples of equipment considered in this area are: surface spill tracking buoys; airborne remote sensors and data analysis systems; fluorometers and light-scattering sensors; and satellite remote sensing data and on/in-water detection devices with the ability to conduct nighttime and low light recovery operations. It includes research supporting development of monitoring protocols for subsea and surface responses or improvements to existing ones such as the NRT Atypical Use guidance or the SMART guidance, as applicable. Evaluation of techniques for autonomous sensing operations and reporting from remote locations where logistical challenges limit human accessibility is included.

There are three Subcategories for this SRA: Remote Detection; Monitoring; and Submerged Oil Detection. The priorities for this SRA focus on the development of improved technologies, chemical sensors, lasers, and new technologies for monitoring and detecting oil in deep water and on the bottom, including dispersed oil. The Research Needs also focus on the use of autonomous and unmanned vehicles for remote sensing of surface and subsurface oil characteristics, including in the Arctic. ICCOPR also recognizes the need to further refine the existing SMART protocols.

30300 Series: Oil Spill Detection and Surveillance Research Needs
REMOTE DETECTION (30301)
A. Develop/advance algorithms, sensors, and platforms (e.g., UAS, ROV, AUV) to accurately characterize, quantify, and measure the surface oil state (i.e., emulsified or not), oil volume, and oil thickness including under low visibility conditions (e.g., night, fog, and ice cover) in near real time, above and below surface.
B. Develop near real time data processing tools, products, and protocols that integrate data across all sensors and platforms.
C. Advance technologies that enable remote oil spill detection and mapping in the Arctic to minimize false-positives and to accurately measure slick thickness.
MONITORING (30302)
A. Develop or refine protocols (e.g., SMART or equivalent) for the detection and monitoring of floating, submerged, and burned oil during subsea and surface releases.
B. Develop and advance the use of unmanned and autonomous systems to monitor and characterize surface and subsurface oil spills.
C. Evaluate new technologies to improve oil, dispersed oil, and dispersant detection in the water column and on the seafloor for monitoring dispersant effectiveness and hydrocarbon concentrations.
SUBMERGED OIL DETECTION (30303)
A. Develop new or improve existing chemical sensors and platforms for detecting submerged and sunken oil in deep water (over 1,000 feet) and ultra-deep water (over 5,000 feet).
B. Evaluate and advance technologies (e.g., laser fluorosensors, LiDAR) for detecting submerged and sunken oil including oil-particle aggregates mixed into bottom sediments.
C. Identify and develop new methods of detecting, monitoring, containing and recovering sunken or submerged oil.

9.3.5 30400 Series: In- and On-water Containment and Recovery Research Priorities (Section 4.3.3.5)

This SRA includes the development of methods, equipment, and materials for physically containing and removing oil from the surface, in the water column, or on the bottom of the sea/lake/riverbed. This SRA focuses on improving traditional equipment such as booms, skimmers, and sorbent materials, as well as developing new approaches to surface containment, and equipment and systems specific to containment and recovery of subsurface oils.

ICCOPR identified priorities in two Subcategories: Control and Recovery Technology; and Recovery Operations and Testing. The priority Research Needs focus on conducting field trails to identify operational response gaps and developing recovery tools for emerging oils and submerged, suspended, and sunken oil. ICCOPR acknowledges the need for advanced tools and technologies that operate in cold and harsh environments.

30400 Series: In- and On-water Containment and Recovery Research Needs
CONTROL AND RECOVERY TECHNOLOGY (30401)
A. Conduct field trials or use spills of opportunity to find and address specific gaps in current operational response capability of Arctic offshore oil spill detection and response.
B. Improve efficiency and develop recovery tools and systems for oil submerged, suspended in the water column, or on/within submerged sediments (sea, lake, river).
C. Develop skimmers for emerging oils (e.g., very low sulfur fuel oil, dielectric fluids).
RECOVERY OPERATIONS AND TESTING (30402)
A. Develop methods, tools, and technologies customized to the specific characteristic of cold and harsh environment (e.g., oil trapped in or under ice, subsea spills).
B. Develop surrogates for different types of oil for training, research, development, and testing of oil spill recovery equipment.
C. Develop oil collection and containment systems that can increase encounter and capture rate of surface oil slicks that are compatible with existing Oil Spill Response Organization (OSRO) equipment.

9.3.6 30500 Series: Shoreline Containment and Recovery Research Priorities (Section 4.3.3.6)

This SRA covers new methods, treating agents, and equipment for removing oil from shorelines, as well as mitigating the environmental impact of oil that remains. Specifically, it includes water washing and flooding techniques, the use of chemical treating agents, and novel applications of mechanical removal techniques and equipment. It also includes analysis, evaluation, and decision-making (risk, benefits) for the use of active shoreline oil removal techniques versus passive naturally occurring processes.

ICCOPR recognizes the difficulty of relying on physical recovery on shorelines and exploring the role of alternative response technologies. Priorities in this SRA focus on the effectiveness of airborne technologies, and the use of canines for oil detection and their integration into SCAT.

30500 Series: Shoreline Containment and Recovery Research Needs
A. Evaluate the effectiveness of alternative response technologies for shoreline or nearshore clean-up; including bioremediation agents, surface washing agents, and mechanical methods.
B. Evaluate oil detection sensors on/in different platforms (e.g., satellite, aircraft, and drone) for Shoreline Cleanup and Assessment Technique (SCAT) data collection to develop best practices.
C. Expand current capabilities of Oil Detection Canines (ODCs) to support shoreline spill response surveys and operations.

9.3.7 30600 Series: Dispersants Research Priorities (Section 4.3.3.7)

This SRA addresses the deployment and use of chemical products designed to interact with marine oil slicks by reducing the oil/water interfacial tension and creating tiny droplets with the aid of waves or other energy sources. Research areas for dispersants include: developing appropriate dispersant applications for cold weather and deep sea environments; increasing dispersant effectiveness for water surface and subsurface applications (e.g., effective on a wider viscosity and emulsification range, calm sea conditions); reducing ecological effects of individual components and the overall dispersant in the water column; refining vessel, aircraft, and subsea application methods and equipment; developing enhanced monitoring methods and systems for determining the effectiveness of surface and subsea application of dispersants; distinguishing physically versus chemically dispersed oil; studying the distribution and impact of chemically dispersed oil in the environment; and understanding regional variations in dispersant performance and potential environmental impacts. This SRA includes research that enhances the ability to predict dispersant effectiveness on various oil types and at varying application rates, including weathered/emulsified oils and a range of water salinities. This SRA also encompasses studies to determine the suitability of subsea application of dispersants in the Arctic region where the unique conditions (e.g., shallow depths, water salinity, ice-infested water, under-ice discharges) could influence their fate and effects. An important supporting activity is the development of an information database on dispersant product effectiveness, application procedures, and effects. Also included in this SRA is research on the potential acute and chronic effects of dispersants on organisms and populations at various depths.

This SRA includes six Subcategories: Cold Weather and Ice Conditions; Behavior; Environmental Effects; Efficacy and Effectiveness; Fate: and Subsurface. It is important to understand how dispersants behave in the environment and their potential impacts. Specifically, ICCOPR identified Research Needs that focus on understanding the: efficacy, deployment methods, and timing of dispersant use in cold environments; behavior, transport, and efficacy of dispersants over longer times (e.g., storage, aerosolization greater than four hours after application); toxicological effects on humans and marine organisms in a variety of environments under real-world conditions; incorporation of methods, including remote sensing, in determining the effectiveness of dispersant application, especially when interpreting results for laboratory and tank testing; the fate (e.g., photo-oxidation) of dispersants, including their persistent components and dispersed oil in a variety of environments; and the effects of subsea dispersant injection on the fate and transport of oil under real-world conditions.

30600 Series: Dispersants Research Needs
COLD WEATHER AND ICE CONDITIONS (30601)
A. Investigate the "windows of opportunity" for potential deployment of dispersants for various oil types and weathering states over a range of environmental conditions in the Arctic and sub-Arctic.
B. Determine the efficacy of dispersants for various oil types over a range of cold water and ice conditions.
C. Develop chemical dispersant products and dispersant spray systems with associated deployment equipment that are designed for cold environments.
BEHAVIOR (30602)
A. Conduct efficacy testing on stockpiled chemical dispersants as a function of shelf life.
B. Evaluate the behavior and transport of dispersants and dispersed oil under a range of environmental conditions.
C. Determine potential for aerosolization of chemically dispersed oil droplets during emergency operations (e.g., aerial or boat spray application) no sooner than 4 hours after slick formation.

30600 Series: Dispersants Research Needs
ENVIRONMENTAL EFFECTS (30603)
A. Conduct research on the ecotoxicological effects of oil and chemically dispersed oil in surface waters and the deep-sea compared to nearshore environments.
B. Evaluate the toxicity of dispersants and chemically dispersed oil on key Arctic marine species with experimental designs that incorporate real-world conditions and concentrations.
C. Investigate the human health effects of dispersants to determine exposure thresholds to further inform exposure limits for setback distances.
EFFICACY AND EFFECTIVENESS (30604)
A. Evaluate the ability of commercially available remote sensors to detect operational effectiveness of surface applied dispersants to enhance SMART protocols.
B. Develop methods to determine the relative effectiveness of surface dispersant delivery techniques/systems and their relationship to encounter rate.
C. Develop methods to quantify the factors needed to scale results of laboratory and wave tank experiments so that they become more representative of real-world dispersant effectiveness.
FATE (30605)
A. Evaluate the environmental fate and transport of dispersed oil and dispersants within surface, subsurface, and deep water scenarios.
B. Study and understand the fate of persistent components of dispersants (e.g., DOSS, DGBE, solvents) and the metabolic processes underlying oil and dispersant co-degradation.
C. Determine the effects of photo-oxidation on floating oil and on chemically and physically dispersed oil droplets for a range of oils (light to heavy, sweet to sour) and dispersant mixtures.
SUBSURFACE (30606)
A. Investigate and quantify the effects of sub-surface dispersant injection (SSDI) use on the fate of oil constituents, such as volatile organic compounds (VOC) concentrations, at the sea surface.
B. Quantify the relationship between oil properties and dispersant effectiveness and its effect on subsurface transport of oil constituents under different subsea injection scenarios.

C. Conduct large-scale experiments that mimic real world conditions to understand the size of droplets emanating from a blowout and their coalescence and resurfacing both before and after application of dispersants.

9.3.8 30700 Series: *In-Situ* Burning (ISB) Research Priorities (Section 4.3.3.8)

This SRA addresses equipment and techniques required to ignite and sustain combustion of oil spills on the water, along shorelines, and on land. Also considered is research on IWI as a source control measure. A source of ignition must be present, as well as the necessary mix of fuel (e.g., oil) and oxidant (e.g., oxygen) to burn. Because slick thickness is a key variable determining whether the oil will burn, this research area includes development of equipment such as fire-resistant booms and herders to concentrate the slick thickness, and improved ignition devices. This SRA also covers developing knowledge of the conditions under which equipment and techniques can be applied effectively, including evaluation of use in frigid (i.e., Arctic) environments, where cold conditions and ice limit operational effectiveness of mechanical containment and recovery of spilled oil. This SRA also includes research to develop new methods to enhance efficiency and burn weathered, emulsified, and more viscous oils. Research into the production of residuals including soot and other ISB byproducts, and the techniques and equipment to recover them is also included in this SRA.

There are two Subcategories: Effectiveness and Impacts; and Planning and Technology. The priorities for this SRA address monitoring and improving burn efficiency (e.g., extending burn times) and understanding the fate and effects of residue and smoke plumes on humans and benthic organisms. ICCOPR recognizes the need for research on ISB in extreme environments, specifically the Arctic.

30700 Series: *In-Situ* Burning (ISB) Research Needs
EFFECTIVENESS AND IMPACTS (30701)
A. Develop techniques (e.g., booming, ignition strategies) that enhance burn efficiency, expand ignition envelopes, and delay extinction for oil slicks and emulsions and in extreme environments.
B. Conduct research on *in-situ* burning residue toxicity, physical and chemical properties, and bioavailability, including potential benthic community effects.
C. Develop improved pre- and post-spill air plume modeling to support decision making for protection of sensitive areas and populations.

30700 Series: *In-Situ* Burning (ISB) Research Needs
PLANNING AND TECHNOLOGY (30702)
A. Develop models of physical processes to predict the fate and transport of sinking residues.
B. Develop a deployable remote sensing system to monitor open water burning parameters and estimate efficiency.
C. Determine ignition methods, limitations and burning behaviors of crude oils in the Arctic.

9.3.9 30800 Series: Alternative Chemical Countermeasures Research Priorities (Section 4.3.3.9)

This SRA includes the development and use of various spill response chemicals to treat slicks on the surface of the water making oil more amenable to mechanical recovery, ISB, and other techniques. These chemicals include solidifiers, herding agents, elasticity modifiers, shoreline pre-treatment agents, and emulsion treating agents (de-emulsifiers). Research includes improving chemical formulations, refining application techniques, and conducting studies of effectiveness and environmental effects.

ICCOPR priorities in this SRA recognize the potential of alternate chemical treatments to herd oil slicks and break emulsions to enhance response. The priorities focus on evaluating the effects of these treatments when used in conjunction with ISB and oil recovery.

30800 Series: Alternative Chemical Countermeasures Research Needs
A. Characterize the differences in biodegradation and toxicity of burnt oil residues and native crude oil when chemical agents are used.
B. Evaluate the effectiveness of herding surfactants and emulsion breakers in conjunction with *in-situ* burning.
C. Study the potential use of chemical herders to enhance response capabilities of *in-situ* burning, recovery of oil-in-ice, or recovery of oil in confined/covered spaces.

9.3.10 30900 Series: Oily and Oil Waste Disposal Research Priorities (Section 4.3.3.10)

This SRA includes study and development of analytical methods, procedures, equipment, and techniques to manage and dispose of oil, oily water, oiled soils, and oiled debris recovered on-water and on land during pollution responses. Specific technologies include waste segregation, temporary storage, solidification and stabilization prior to landfill disposal or recycling, oil reclamation, incineration, and biological treatment (i.e., land farming, composting). It also includes techniques and equipment for onsite oil-water separation, filtration, and decanting operations that reduce the volumes of material to be handled, transported, and disposed.

ICCOPR priorities for this SRA focus on storage, waste issues and recycling. The priorities acknowledge the need to develop new systems and methods for remote and harsh environments, various oil types, and to reduce secondary waste.

30900 Series: Oily and Oil Waste Disposal Research Needs
A. Investigate and develop methods for onsite treatment, storage or disposal of recovered oil/pollutants and secondary waste in remote or harsh environments.
B. Test developed systems for oil/water separation decanting to verify performance and optimize operational use for various oil types.
C. Develop methods to reduce secondary waste from oil spill recovery through the development of reusable sorbent materials, portable incinerator units and other techniques.

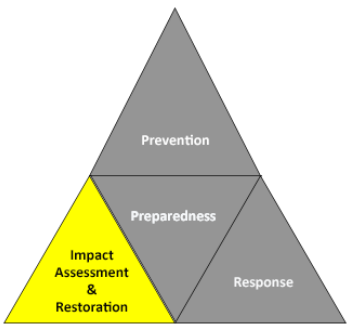
9.3.11 31000 Series: Bioremediation Research Priorities (Section 4.3.3.11)

This SRA includes research and technology to exploit the capabilities of microorganisms and plants to accelerate the rate of degradation of oil in soil and water. Bioremediation is largely an *in-situ* technology as *ex-situ* use requires removal and further manipulations that may have a greater potential for environmental harm. Research methods are needed for nutrient and/or microbial enrichment to accelerate the biodegradation process on land (bio-augmentation). Research is also needed on bioremediation in the presence of dispersants, herders, and other chemical agents in water. In areas such as coastal wetlands, where stranded oil may have penetrated the anaerobic subsurface, topics include wicking oil to aerobic conditions and nutrient enrichment. This SRA also includes the application of bioremediation for more effective response and restoration including phytoremediation (remediation using plants), as longer-term restoration technique.

ICOCPR priorities under this SRA focus on gaining a better understanding of the bioremediation process and the factors associated with its use in oil spill remediation. The Research Needs recognize the need to understand biodegradation in Arctic conditions and on oil droplets, as well as the effectiveness of biodegradation as a response technology for a variety of oils in the field.

31000 Series: Bioremediation Research Needs
A. Conduct research on the relative effectiveness and environmental impacts of natural and enhanced bioremediation technologies with a variety of oils under a range of field conditions.
B. Evaluate the biodegradation rate, spatial heterogeneity of oil degraders, and oil degradation pathways in Arctic marine environments.
C. Evaluate the lag time associated with the onset of biodegradation in laboratory experiments and how it translates to microbial growth on oil droplets in the field.

9.4 Injury Assessment and Restoration Priority Research Needs



INJURY ASSESSMENT AND RESTORATION

9.4.1 40000 Series: Environmental Effects and Ecosystem Recovery Research Priorities (Section 4.3.4.1)

This SRA includes laboratory research, field studies, and modeling efforts to understand and predict the short- and long-term effects of oil spills at the ecosystem level. It includes research into the short- and long-term recovery of various types of environments and the chronic effects of oil spills on habitats, species, recovery and rehabilitation of wildlife, and communities. This SRA includes the effects of the oil and the countermeasures and cleanup techniques used to remove it. It also includes research to determine the rate of ecosystem recovery with and without countermeasures and cleanup.

The priorities selected by ICCOPR reflect the continued need to assess the short- and long-term effects of oil spills. ICCOPR identified priorities within six Subcategories for this SRA due to the large number of identified Research Needs: Species Impacts; Toxicological and Sub- lethal Impacts; Sunken and Submerged Oil Impacts; Ecosystem and Habitat Impacts; Recovery; and Risk Assessment and Impact Metrics.

40000 Series: Environmental Effects and Ecosystem Recovery Research Needs
SPECIES IMPACTS (40001)
A. Develop an increased understanding of the impacts of spilled oil and response measures (*in-situ* burning, chemical dispersants and herding agents) on Arctic ecology including: (1) sensitivity differences between Arctic organisms and commonly used test organisms, (2) identifying specific metrics and methods for evaluating oil exposure and impacts on organisms, populations, and habitats in the Arctic to support future NRDA activities in high risk for oil spills, and (3) impacts on populations of key Arctic species and their implications on resilience and recovery, and ecological processes (i.e., trophic level impacts).
B. Study the effect of exposure to oil on physiological functions of organisms (immune, reproductive, and other vital systems); potential impacts on individual fitness; and population viability rates, abundance, and trends.
C. Research on how oiling affects sea turtles and marine mammals, particularly about the types and concentrations of chemicals contained in the air directly above an oil spill, because sea turtles and marine mammals breathe in close proximity to the seawater–air interface.
TOXICOLOGICAL AND SUB-LETHAL IMPACTS (40002)
A. Conduct research on key species to determine the long-term, sub-lethal, and latent mortality effects of short-term exposure to oil and synthesize existing research to support extrapolation to population, community, and ecosystem effects.
B. Study oil-specific biomarkers of exposure and injury, establish mechanistic linkages between biomarkers and effects, and develop guidelines for using transcriptional and other biomarker methods for a range of species, including timing for sample collection and use and interpretation of data.
C. Study the acute and chronic toxicity, bioavailability, and other characteristics of oil sands products (i.e., dilbit etc.) and their byproducts to determine how they affect keystone or ecologically important species in addition to standard test species to support more informed hazard assessments of spills in aquatic and terrestrial environments.

40000 Series: Environmental Effects and Ecosystem Recovery Research Needs
SUNKEN AND SUBMERGED OIL IMPACTS (40003)
A. Study MOSSFA/MOS behavior, fate and effects on marine organisms and deep ocean ecosystems; and the role of dispersants in the formation of marine snow.
B. Use models, simulations, and field trials to develop an increased understanding of oil and oil-particle aggregate behavior and impacts in fresh and cold water such as the Great Lakes, including 1) fate and transport and 2) toxicity and physical effects on benthic environments.
C. Develop an understanding of the exposure pathways and long term effects to species and benthic communities from sunken and submerged oil and residues.
ECOSYSTEM AND HABITAT IMPACTS (40004)
A. Research the extent to which oil is transferred to the next trophic level within the water column by microbial and plankton communities under field relevant conditions.
B. Develop and define relevant exposure conditions (spatially and temporally) and examine connections between exposure and ecological effects.
C. Continue to study the long-term ecosystem and habitat impacts of oil spills so that findings may be incorporated into predictive models for cascading effects.
RECOVERY (40005)
A. Conduct follow up studies from historical spills to evaluate the recovery rates of various resources exposed and the effectiveness of the mitigation techniques used.
B. Study the recovery of injured habitats, develop conceptual models of ecological service loss, synthesize existing research, and use collected information to parameterize recovery models.
C. Study the recovery potential of pelagic resources (e.g., fish and marine mammals) from offshore spills and collect abundance, distribution, and movement ecology information from a broader cross-section of these open-ocean species.

40000 Series: Environmental Effects and Ecosystem Recovery Research Needs
RISK ASSESSMENT AND IMPACT METRICS (40006)
A. Investigate the value and feasibility of establishing pre-staged or mobile oiled wildlife response and rehabilitation kits, and facility modules in the Arctic region.
B. Conduct research to evaluate and improve existing metrics for assessing injury and damages to natural resources.
C. Improve components of ecosystem modeling capabilities, such as the collection of data for model development (e.g., parameterizing trophic interactions from diet studies), calibration, and validation for better estimates of natural resource injury.

9.4.2 40200 Series: Environmental Restoration Methods and Technologies Research Priorities (Section 4.3.4.2)

This SRA includes development of methods and technologies to facilitate and accelerate the recovery of resources following an oil spill. It includes research into the effectiveness of approaches for environmental restoration. It also includes evaluations and comparisons of the factors affecting success of the restoration methods and technologies and studies of previous restoration efforts and natural recovery.

The priorities in this SRA focus on optimizing best practices to sustain long-term restoration efforts and combined effects of oily and other co-occurring physical changes (e.g., flooding).

40200 Series: Environmental Restoration Methods and Technologies Research Needs
A. Study and identify indicators associated with long-term restoration to develop best practices and lessons learned. Use those results to inform and enhance future restoration practices, assessments methods, and performance metrics.
B. Conduct comparative analysis of rates of recovery following restoration vs. natural attenuation to improve restoration and monitoring protocols.
C. Determine the combined effects of oiling at the marsh edge to inland sediments, functional changes at the microbial level, and the confounding effects of physical changes to the marshes over time, such as from flooding and marsh erosion.

9.4.3 40300 Series: Human Safety and Health Research Priorities (Section 4.3.4.3)

This SRA includes studies on the effects of spilled oil and response activities on human health and safety for workers and the public. It includes the study of oil weathering throughout the water column and the potential concerns relative to worker health and safety. It focuses on the development of monitoring instruments, procedures, and processes to inform personnel engaged in response activities, as well as the general public, who could be affected by the spill and response options. It also includes studies of the safety of seafood that can impact commercial and recreational fishing and subsistence seafood use. in a spill area to determine if they are safe to market and consume. Research on seafood safety may include petrochemical toxicology and profiling, risk analysis, sampling and testing methodology development, and risk communications.

There are two Subcategories to this SRA: Safety; and Human Exposure. The research priorities focus on worker safety, human exposure, and seafood safety. ICCOPR recommends incorporating toxicity and human exposure data into long-term health studies of responders and response frameworks. ICCOPR also recommends more research on consumption risks associated with seafood during oil spills, protocols for rapid exposure assessments for oil spills including the OSP-related exposures.

40300 Series: Human Safety and Health Research Needs
SAFETY (40201)
A. Review, evaluate, and enhance current state of personal protective equipment (PPE) standards and practices for protecting on-scene personnel from exposure, including identifying and addressing needs for cold weather and Arctic operations.
B. Study the potential toxicity of polycyclic aromatic hydrocarbons (PAHs) to human health and incorporate them into human health risk assessments and characterizations; including long-term health studies of oil spill responders.
C. Study methods to detect levels of air pollutants at the source and methods to communicate risks and notify communities and responders as the plume drifts.

40300 Series: Human Safety and Health Research Needs
HUMAN EXPOSURE (40202)
A. Evaluate and enhance frameworks to rapidly collect data and assess human exposure during and after oil spills.
B. Continue to develop methods for evaluating human exposure to and risk from consumption of seafood potentially contaminated by oil spills, focusing on 1) culturally tailored dietary assessments, 2) concentrations of oil-derived compounds that lead to bioaccumulation, and 3) the injuries from long-term exposure or high consumption rates.
C. Study the human exposure pathways associated with discharges of oil sands products (OSP) and processing byproducts.

9.4.4 40400 Series: Sociological and Economic Effects Research Priorities (Section 4.3.4.4)

This SRA includes studies on how oil spills and response affect the sociological fabric of communities and their economies. Disciplines encompassed in this research area include sociology, economics, behavioral sciences, political science, and law. It also involves studies on risk communication and community resilience.

There are two Subcategories in this SRA: Community and Economic Impacts; and Human Impacts. The priority Research Needs focus on improving risk and crisis communication methods and understanding the impacts of spills on community vulnerability and resilience, including those in more at-risk areas. ICCOPR acknowledges the need to develop methods for understanding and tracking mental health impacts and real-time public perception during and after a release.

40400 Series: Sociological and Economic Effects Research Needs
COMMUNITY AND ECONOMIC IMPACTS (40301)
A. Evaluate the changes in Arctic and subarctic communities in response to natural and anthropogenic stressors as predictors of how potential oil spills would affect the socioeconomic fabric of at-risk communities, especially those communities in remote and ice-edge communities.
B. Evaluate and enhance the effectiveness of methods for communicating risk tradeoffs to various audiences during oil spills.
C. Study the long-term impacts of spills on community vulnerability and resilience, including socioeconomic impacts.
HUMAN IMPACTS (40302)
A. Improve methods for oil spill crisis and risk communication with the general public.
B. Develop approaches and systems for tracking public fears, understanding, and behavior in real-time regarding oil spills.
C. Develop protocols and approaches to mitigate mental health impacts from oil spills, which can be incorporated into preparedness and response plans.

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APPENDICES

A. Numbered List of Standing Research Areas (SRAs)

B. List of Research Priorities (Raw Data) and Sources – 2021 Database

C. Survey Technical Report

D. Potential Impacts to Spill Response Options

Appendix A

Numbered List of Standing Research Areas (SRAs)

SRA Numbering System		
PREVENTION (10000 Series)		
ICCOPR #	**SRA**	**Subcategory**
10000	Human Error Factors	
10101	Offshore Facilities and Systems	Met-Ocean Effects
10102	Offshore Facilities and Systems	Surface Systems and Umbilicals
10201	Onshore Facilities and Systems	Tank/Piping Inspection, Operations, Design and Data
10202	Onshore Facilities and Systems	Emerging Issues
10300	Waterways Management	
10400	Vessel Design	
10501	Drilling	Deepwater Drilling/Technology
10502	Drilling	Reservoir Characterization
10600	Rail and Truck Transportation	
10701	Pipeline Systems	Threat/Damage Prevention
10702	Pipeline Systems	Leak Detection
10703	Pipeline Systems	Anomaly Detection/Characterization
10801	Geohazards	Monitoring
10802	Geohazards	Identification & Characterization
10900	Subsea Systems Automation and Reliability	
PREPAREDNESS (20000 Series)		
ICCOPR #	**SRA**	**Subcategory**
20001	Pre-Spill Baseline Studies	Habitats and Species Baselines
20002	Pre-Spill Baseline Studies	Oceanographic/Geologic Baselines
20003	Pre-Spill Baseline Studies	Environmental Baseline Planning
20100	Response Management Systems	
20200	Renewable Energy Systems	
RESPONSE (30000 Series)		
ICCOPR #	**SRA**	**Subcategory**
30000	Structural Damage Assessment and Salvage	
30100	At Source Control and Containment	
30201	Chemical and Physical Modeling and Behavior	Arctic Behavior and Modeling
30202	Chemical and Physical Modeling and Behavior	Oil Behavior Models
30203	Chemical and Physical Modeling and Behavior:	Transport Models
30204	Chemical and Physical Modeling and Behavior:	Oceanographic Models
30205	Chemical and Physical Modeling and Behavior:	Emerging Crude
30206	Chemical and Physical Modeling and Behavior:	Sinking Oil and Marine Oil Snow (MOS) Sedimentation and Flocculent Accumulation (MOSSFA)
30301	Oil Spill Detection and Surveillance:	Remote Detection
30302	Oil Spill Detection and Surveillance:	Monitoring
30303	Oil Spill Detection and Surveillance:	Submerged Oil Detection
30401	In and On-water Containment and Recovery	Control and Recovery Technology
30402	In and On-water Containment and Recovery	Recovery Operations and Testing
30500	Shore Containment and Recovery	
30601	Dispersants	Cold Water and Ice Conditions
30602	Dispersants	Behavior
30603	Dispersants	Environmental Effects
30604	Dispersants	Efficacy and Effectiveness
30605	Dispersants	Fate
30606	Dispersants	Subsurface
30701	*In-situ* Burning	Effectiveness and Impacts
30702	*In-situ* Burning	Planning and Technology
30800	Alternative Countermeasures	
30900	Oily and Oil Waste Disposal	
31000	Bioremediation	

SRA Numbering System		
INJURY ASSESSMENT AND RESTORATION(40000 Series)		
ICCOPR #	**SRA**	**Subcategory**
40001	Environmental Effects and Ecosystem Recovery	Species Impacts
40002	Environmental Effects and Ecosystem Recovery	Toxicological and Sublethal Impacts
40003	Environmental Effects and Ecosystem Recovery	Sunken and Submerged Oil Impacts
40004	Environmental Effects and Ecosystem Recovery	Ecosystem and Habitat Impacts
40005	Environmental Effects and Ecosystem Recovery	Recovery
40006	Environmental Effects and Ecosystem Recovery	Risk Assessment and Impact Metrics
40100	Environmental Restoration Methods and Technologies	
40201	Human Safety and Health	Safety
40202	Human Safety and Health	Human Exposure
40301	Sociological and Economic Effects	Community and Economic Impacts
40302	Sociological and Economic Effects	Human Impacts

Numbering System

10000	Research Class
0100	SRA
01	Subcategory

Appendix B

List of Research Priorities (Raw Data) and Sources 2021 Database

The information in this database has not been processed or reviewed by the ICCOPR and is considered source/raw data. The approved final list of ICCOPR Research Needs can be found in Chapter 9 of the Oil Pollution Research and Technology Plan.

ICCOPR NUMBER	ICCOPR SRA	Subcategory	Research Need	Source	Citation
PREVENTION (10000 SERIES)					
10000	Human Error Factors	No Subcategory	Develop innovative training methods, including readiness evaluations, gaming, and simulators, to continue to improve performance and decision-making.	SME Evaluation	N/A
10000	Human Error Factors	No Subcategory	Research the current level of expertise for operators within modern transportation systems, including marine, rail, truck, and pipeline, to determine human factor causations of spills and develop solutions to reduce the potential for reoccurrence.	SME Evaluation	N/A
10000	Human Error Factors	No Subcategory	Research the role of autonomous systems that do not rely on skilled operators to aid in preventing errors and/or reduce human errors that lead to spills.	SME Evaluation	N/A
10000	Human Error Factors	No Subcategory	Investigate how to integrate unmanned aircraft systems (UAS) into the safety monitoring of commercial operations to minimize potential emergency situations and increase operator safety.	Public Listening Sessions	N/A
10000	Human Error Factors	No Subcategory	Develop a common 3D SIM toolbox containing subsea response equipment models to allow training of personnel to utilize response equipment in different scenarios, in support of planning and preparedness.	Public Listening Sessions	N/A
10000	Human Error Factors	No Subcategory	Identify low cost in-situ condition monitoring methods that are suitable for operators and regulators to establish a low effort monitoring of higher risk areas.	Public Listening Sessions	N/A
10000	Human Error Factors	No Subcategory	Develop and conduct field exercises that encompass a broad spectrum of sea ice, ocean and meteorological conditions to increase operational readiness to respond to an Arctic oil spill.	Literature/Data Call	Wilkinson, J., Beegle-Krause, C., Evers, KU., Hughes, N., Lewis, A., Reed, M., & Wadhams, P. (2017). Oil spill response capabilities and technologies for ice-covered Arctic marine waters: A review of recent developments and established practices. *Ambio* , 46(S3), 423–441. https://doi.org/10.1007/s13280-017-0958-y
10000	Human Error Factors	No Subcategory	Develop and conduct exercises that evaluate an operator's ability to deal with situations outside of a response plan.	Literature/Data Call	Gralla, E., Greenberg, B., Voevodsky, P., Harrald, J., Shaw, G., & Babbitt, S. (2016). A capabilities-based framework for designing and evaluating oil spill response exercises (Project 1048).*U.S. Bureau of Safety and Environmental Enforcement.* https://www.bsee.gov/sites/bsee.gov/files/osrr-oil-spill-response-research/1048aa.pdf
10000	Human Error Factors	No Subcategory	Conduct training exercises in extreme cold and harsh weather (e.g., higher waves and wind) conditions to improve and build upon lessons learned; operational and tactical protocols; and equipment deployment, application, and design.	Literature/Data Call	Hansen, K. A. & Fitzpatrick, M. (2017). *Federal On-Scene Coordinator (FOSC) guide for oil in ice. United States Coast Guard Research and Development Center.* https://homeport.uscg.mil/Lists/Content/Attachments/43701/USCG%20FOSC%20Guide%20-%20Oil%20in%20Ice.pdf
10000	Human Error Factors	No Subcategory	Conduct large-scale training exercises, in which larger response teams are required, the response goes on for more than a few hours, and later parts of the response timeframe are played out (e.g., days 3 and 4).	Literature/Data Call	Gralla, E., Greenberg, B., Voevodsky, P., Harrald, J., Shaw, G., & Babbitt, S. (2016). A capabilities-based framework for designing and evaluating oil spill response exercises (Project 1048).*U.S. Bureau of Safety and Environmental Enforcement.* https://www.bsee.gov/sites/bsee.gov/files/osrr-oil-spill-response-research/1048aa.pdf
10000	Human Error Factors	No Subcategory	Create a comprehensive global training curriculum on oil spill response for global oil exploration and production.	Literature/Data Call	Montgomery, A. & Peach, D. (2017). Does the current global training curriculum meet the needs of exploration and production? *International Oil Spill Conference Proceedings 2017*, (1), 2017282. https://doi.org/10.7901/2169-3358-2017.1.000282
10000	Human Error Factors	No Subcategory	Continue to research the human factors related to accident prevention including surveying human behaviors in hazardous operating environments and developing tools to improve decision making capabilities.	Literature/Data Call	Robertson, K., Black, J., Grand-Clement, S., & Hall, A. (2016).*Human and Organisational Factors in Major Accident Prevention A Snapshot of the Academic Landscape* . RAND. https://www.rand.org/content/dam/rand/pubs/research_reports/RR1500/RR1512/RAND_RR1512.pdf
10000	Human Error Factors	No Subcategory	Develop a systematic way to integrate and analyze diverse measurements related to the overall safety of deepwater operations by determining the present scope of expert (case based) systems and identifying benefits and limitations that would reduce the risk of operating in deep water.	Literature/Data Call	Foster, D., Pye, D. S., Dokken, Q., & Litton, J. (2013). *RESEARCH & DEVELOPMENT PROGRAM SUBCOMMITTEE FINDINGS AND RECOMMENDATIONS* . U.S. Department of Energy. https://www.energy.gov/sites/prod/files/2013/12/f5/UDAC%20R%26D%20Program%20Subcommittee%20Findings%20and%20Recommendations.pdf
10000	Human Error Factors	No Subcategory	Build a "library" of spill scenarios, based on historical spill scenarios and on ideas from a panel of experts about what future spills might look like.	Literature/Data Call	Gralla, E., Greenberg, B., Voevodsky, P., Harrald, J., Shaw, G., & Babbitt, S. (2016). A capabilities-based framework for designing and evaluating oil spill response exercises (Project 1048).*U.S. Bureau of Safety and Environmental Enforcement.* https://www.bsee.gov/sites/bsee.gov/files/osrr-oil-spill-response-research/1048aa.pdf
10101	Offshore Facilities and Systems	Met-Ocean Effects	Study effects of ice force impact with respect to prevention of oil spills from offshore facilities.	SME Evaluation	N/A
10101	Offshore Facilities and Systems	Met-Ocean Effects	Conduct longevity testing under extreme conditions to address extreme high pressure and temperature (XHPHT) conditions such as that expected in the Gulf of Mexico Lower Tertiary drilling and completion.	SME Evaluation	N/A
10101	Offshore Facilities and Systems	Met-Ocean Effects	Conduct life extension research to determine the effects of deepwater conditions, ice forces, severe weather conditions (e.g., hurricanes, blizzards) on offshore infrastructure.	Public Listening Sessions	N/A
10101	Offshore Facilities and Systems	Met-Ocean Effects	Investigate of the influence of precipitation on sea spray icing and the impacts on offshore structures.	Literature/Data Call	Horjen, I. (2015). Offshore drilling rig ice accretion modeling including a surficial brine film. *Cold Regions Science and Technology,* (119), 84-100. https://doi.org/10.1016/j.coldregions.2015.07.006
10101	Offshore Facilities and Systems	Met-Ocean Effects	Conduct met-ocean studies in the Gulf of Mexico, Atlantic, and the Arctic to design criteria for large-scale systems.	Literature/Data Call	U.S. Department of Energy. (2015b). *Chapter 7: Advancing Systems and Technologies to Produce Cleaner Fuels Offshore Safety and Spill Prevention Offshore Safety and Spill Prevention* . U.S. Department of Energy. https://www.energy.gov/sites/prod/files/2016/04/f30/QTR2015-7F-Offshore-Safety-and-Spill-Prevention.pdf
10101	Offshore Facilities and Systems	Met-Ocean Effects	Develop and design chemical sensing materials with high sensitivity, selectivity and stability to integrate with the sensing platforms, especially for HTHP and harsh environments in the subsurface wells or other extreme conditions.	Literature/Data Call	Wright, R.F., Lu, P., Devkota, J., Lu, F., Ziomek-Moroz, M., & Ohodnicki, P.R., Jr. (2019). Corrosion Sensors for Structural Health Monitoring of Oil and Natural Gas Infrastructure: A Review. *Sensors, 19* (18): 3964. https://doi.org/10.3390/s19183964
10101	Offshore Facilities and Systems	Met-Ocean Effects	Develop specific rules and guidelines to address the particular challenges associated with offshore operations under the difficult environmental conditions found in the Arctic and ice-prone seas in general.	Literature/Data Call	Necci, A., Tarantola, S., Vamanu, B., Krausmann, E., & Ponte, L. (2019). Lessons learned from offshore oil and gas incidents in the Arctic and other ice-prone seas. *Ocean Engineering,* (185), 12-26. https://doi.org/10.1016/j.oceaneng.2019.05.021
10101	Offshore Facilities and Systems	Met-Ocean Effects	Investigate the applicability and the effectiveness of various risk mitigation strategies such as robustness, resilience, and redundancy on the preparedness of critical infrastructures for extreme events at different intensities.	Literature/Data Call	Urlainis, A., Shohet, I.M., & Levy, R. (2015). Probabilistic Risk Assessment of Oil and Gas Infrastructure for Seismic Extreme Events. *Procedia Engineering,* (123), 590-598. https://doi.org/10.1016/j.proeng.2015.10.112
10102	Offshore Facilities and Systems	Surface Systems and Umbilicals	Evaluate corrosion and corrosion mitigation processes at the splash zone for offshore platforms.	SME Evaluation	N/A
10102	Offshore Facilities and Systems	Surface Systems and Umbilicals	Assess the effectiveness and required coverage rates for infrared polarization remote sensing techniques for full time monitoring at offshore facilities.	Public Listening Sessions	N/A
10102	Offshore Facilities and Systems	Surface Systems and Umbilicals	Advance corrosion resistant materials and inhibitor materials for new and aging infrastructure in the salt air zone and subsea.	Public Listening Sessions	N/A
10102	Offshore Facilities and Systems	Surface Systems and Umbilicals	Determine the impacts on crane performance and mechanical integrity/safety limits resulting from unconventional crane loading activities (e.g., shock loading).	Public Listening Sessions	N/A
10102	Offshore Facilities and Systems	Surface Systems and Umbilicals	Compare the effectiveness of tubular joints strengthened using grout fillings vs carbon fiber reinforced polymer (CFRP) installation technique on fatigue life of tubular joints.	Literature/Data Call	Dehghani, A. & Aslani, F. (2019). A review on defects in steel offshore structures and developed strengthening techniques. *Structures, 20,* 635-657. https://doi.org/10.1016/j.istruc.2019.06.002
10102	Offshore Facilities and Systems	Surface Systems and Umbilicals	Conduct basic research into CNT/metal composites to better understand connectivity in offshore wires.	Literature/Data Call	National Energy Technology Laboratory. (2016). *Development of Carbon Nanotube Composite Cables for Ultra Deep Water Oil and Gas Fields - EDX* . Edx.netl.doe.gov. https://edx.netl.doe.gov/dataset/development-of-carbon-nanotube-composite-cables-for-ultra-deep-water-oil-and-gas-fields
10102	Offshore Facilities and Systems	Surface Systems and Umbilicals	Develop methods to improve safety and productivity in long subsea tiebacks.	Literature/Data Call	U.S. Department of Energy. (2015). *Chapter 7: Advancing Systems and Technologies to Produce Cleaner Fuels Offshore Safety and Spill Prevention* . https://www.energy.gov/sites/prod/files/2016/04/f30/QTR2015-7F-Offshore-Safety-and-Spill-Prevention.pdf
10102	Offshore Facilities and Systems	Surface Systems and Umbilicals	Develop a detailed technology roadmap for systems to improve umbilicals and seabed equipment's power generation, transmission, storage, and chemical transport.	Literature/Data Call	U.S. Department of Energy. (2015). *Chapter 7: Advancing Systems and Technologies to Produce Cleaner Fuels Offshore Safety and Spill Prevention* . https://www.energy.gov/sites/prod/files/2016/04/f30/QTR2015-7F-Offshore-Safety-and-Spill-Prevention.pdf
10102	Offshore Facilities and Systems	Surface Systems and Umbilicals	Conduct high temperature aging tests on elastomers to better understand elastomer behavior in high temperature conditions.	Literature/Data Call	Salehi, S., Ahmed, R., Teodoriu, C., Ezeakacha, C. P., Patel, H., Kwatia, G., Ahmed, S., & Al-Ramadan, M. (2018). *Liner seal and cement studies* (Project 788). Bureau of Environmental Safety and Enforcement. https://www.bsee.gov/research-record/liner-seal-cement-studies.
10102	Offshore Facilities and Systems	Surface Systems and Umbilicals	Study the fatigue performance of tubular joints of steel offshore structures strengthened by grout filling or FRPs installation including various configurations of joints, different loading schemes on the chord and brace member of the joint, intact or corroded joints as well as multiplanar and uniplanar joints.	Literature/Data Call	Dehghani, A. & Aslani, F. (2019). A review on defects in steel offshore structures and developed strengthening techniques. *Structures, 20,* 635-657. https://doi.org/10.1016/j.istruc.2019.06.002

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ICCOPR NUMBER	ICCOPR SRA	Subcategory	Research Need	Source	Citation
10102	Offshore Facilities and Systems	Surface Systems and Umbilicals	Evaluate the long-term performance of inner grout, which can affect the interface between the steel tube and grout, for underwater application of grout filling technique.	Literature/Data Call	Dehghani, A. & Aslani, F. (2019). A review on defects in steel offshore structures and developed strengthening techniques. *Structures, 20,* 635-657. https://doi.org/10.1016/j.istruc.2019.06.002
10102	Offshore Facilities and Systems	Surface Systems and Umbilicals	Develop consistent guidance for the ideal material property requirements for the manufacture of fasteners used for critical subsea equipment.	Literature/Data Call	U.S. Bureau of Safety and Environemntal Enforcement. (2017). *OC-FIT evaluation of fasteners failures addendum II.* https://www.bsee.gov/sites/bsee.gov/files/qc-fit-nov-bop-bsr-bolt-report-7282017.pdf
10102	Offshore Facilities and Systems	Surface Systems and Umbilicals	Conduct a joint industry research project on fasteners to determine the ideal material and coating properties, design, torque specification based on the lubricant, installation, maintenance, human factors, fatigue loading, fastener thread manufacture, load capacity, cathodic protection, environment, and the impact of the stress load conditions on fastener performance and reliability during subsea service.	Literature/Data Call	U.S. Bureau of Safety and Environemntal Enforcement. (2017). *OC-FIT evaluation of fasteners failures addendum II.* https://www.bsee.gov/sites/bsee.gov/files/qc-fit-nov-bop-bsr-bolt-report-7282017.pdf
10102	Offshore Facilities and Systems	Surface Systems and Umbilicals	Investigate the structural failures due to pitting characteristics such as pit depth, pit rate, pit density and interfacial distances between pits.	Literature/Data Call	Bhandari, J., Khan, F., Abbassi, R., Garaniya, V., & Ojeda, R. (2015). Modelling of pitting corrosion in marine and offshore steel structures - A technical review. *Journal of Loss Prevention in the Process Industries, 37,* 39-62. https://doi.org/10.1016/j.jlp.2015.06.008
10102	Offshore Facilities and Systems	Surface Systems and Umbilicals	Analyze the current state of aging infrastructure by examining the extent to which extended life is possible using mitigation and maintenance methodologies without significant reinvestment or shut-in.	Literature/Data Call	U.S. Department of Energy. (2015). *Chapter 7: Advancing Systems and Technologies to Produce Cleaner Fuels Offshore Safety and Spill Prevention* . https://www.energy.gov/sites/prod/files/2016/04/f30/QTR2015-7F-Offshore-Safety-and-Spill-Prevention.pdf
10102	Offshore Facilities and Systems	Surface Systems and Umbilicals	Study precise prediction mechanism of long term anaerobic corrosion to develop a failure model.	Literature/Data Call	Bhandari, J., Khan, F., Abbassi, R., Garaniya, V., & Ojeda, R. (2015). Modelling of pitting corrosion in marine and offshore steel structures - A technical review. *Journal of Loss Prevention in the Process Industries, 37,* 39-62. https://doi.org/10.1016/j.jlp.2015.06.008
10102	Offshore Facilities and Systems	Surface Systems and Umbilicals	Research developing novel non-invasive diagnostic methods, which allow the evaluation of the cumulative damage of vital components exposed to recurrent harsh weather responsible for fatigue, wear, and corrosion phenomena.	Literature/Data Call	Necci, A., Tarantola, S., Vamanu, B., Krausmann, E., & Ponte, L. (2019). Lessons learned from offshore oil and gas incidents in the Arctic and other ice-prone seas. *Ocean Engineering, 185,* 12-26. https://doi.org/10.1016/j.oceaneng.2019.05.021
10102	Offshore Facilities and Systems	Surface Systems and Umbilicals	Perform scientific studies to test the conditions fasteners are exposed to in subsea service, in order to better understand and predict the failure modes of fasteners.	Literature/Data Call	U.S. Bureau of Safety and Environemntal Enforcement. (2017). *OC-FIT evaluation of fasteners failures addendum II.* https://www.bsee.gov/sites/bsee.gov/files/qc-fit-nov-bop-bsr-bolt-report-7282017.pdf
10201	Onshore Facilities and Systems	Tank and Piping Inspection, Operations, Design, and Data	Analyze upstream and/or downstream causes and magnitude of discharges from tanks, appurtenances, and associated piping.	SME Evaluation	N/A
10201	Onshore Facilities and Systems	Tank and Piping Inspection, Operations, Design, and Data	Develop improved methods and protocols used to determine the imperviousness of secondary containment structures.	SME Evaluation	N/A
10201	Onshore Facilities and Systems	Tank and Piping Inspection, Operations, Design, and Data	Evaluate the efficacy of sorbent and similar technologies used as oil spill control measures for storm water filtration and secondary containment shut-off drains.	SME Evaluation	N/A
10201	Onshore Facilities and Systems	Tank and Piping Inspection, Operations, Design, and Data	Develop smart mechanical seals for use on compressor and pump stations.	Literature/Data Call	Bennet, B. (2013). *SBIR phase I - Smart pipeline network - Seal sensor system.* U.S. DOT PHMSA. https://primis.phmsa.dot.gov/matrix/FilGet.rdm?fil=8229
10201	Onshore Facilities and Systems	Tank and Piping Inspection, Operations, Design, and Data	Investigate the effect of pressure and temperature on the foam flow in large scale facilities.	Literature/Data Call	Kelkar, M. & Sarica, C. (2015). Gas Well Pressure Drop Prediction under Foam Flow Conditions. *RPSEA.* http://www.tucrs.utulsa.edu/projects_past/09122-01_Final-Report.pdf
10201	Onshore Facilities and Systems	Tank and Piping Inspection, Operations, Design, and Data	Invent methods that clean industrial tanks in a short time, with an automated system that does not require people to enter the interior of the tank, with the ability to recover almost all hydrocarbons from the wastes in the lower cost.	Literature/Data Call	Chrysalidis, A., & Kyzas, G.Z. (2020). Applied cleaning methods of oil residues from industrial tanks. *Processess,* 8(5), 569. https://doi.org/10.3390/pr8050569
10202	Onshore Facilities and Systems	Emerging Issues	Develop protocols and industry standards to predict, detect and minimize failures of aging oil storage infrastructure (tanks, appurtenances, and piping systems) quickly and accurately.	SME Evaluation	N/A
10202	Onshore Facilities and Systems	Emerging Issues	Assess the effects of emerging crude oils and alternative fuels on tanks, appurtenances and piping.	SME Evaluation	N/A
10202	Onshore Facilities and Systems	Emerging Issues	Assess the effects of Arctic and cold weather environments on the operation and maintenance of tanks, appurtenances, and associated piping.	SME Evaluation	N/A
10202	Onshore Facilities and Systems	Emerging Issues	Understand the fate of volatile gasoline components through a variety of soil conditions and leak scenarios.	Literature/Data Call	Allen, M. G., Wainner, R. T., & Frish, M. B. (2018). *Fuelfinder: Remote leak detector for liquid hydrocarbons.* Pipeline and Hazardous Materials Safety Administration. https://primis.phmsa.dot.gov/matrix/FilGet.rdm?fil=12358
10202	Onshore Facilities and Systems	Emerging Issues	Identify the equipment to assess and cleanup potential subsurface spills that are potentially significant in an OSP spill.	Literature/Data Call	UNH Center for Spills in the Environment. (2013). *Alberta oil sands workshop.* https://crrc.unh.edu/sites/crrc.unh.edu/files/media/docs/Workshops/oil_sands_washington/OilSandsProductsWorkshopReport_Washington%20TOTAL.pdf
10202	Onshore Facilities and Systems	Emerging Issues	Research the consequences of pipeline bursts on the environmental vulnerability of aquifers.	Literature/Data Call	Ponsin, V., Maier, J., Guelorget, Y., Hunkeler, D., Bouchard, D., Villavicencio, H., & Hohener, P. (2015). Documentation of time-scales for onset of natural attenuation in an aquifer treated by a crude-oil recovery system. *Science of The Total Environment, 512-513,* 62-73. https://doi.org/10.1016/j.scitotenv.2015.01.033
10202	Onshore Facilities and Systems	Emerging Issues	Identify tactics to address potential subsurface spills of oil sands products.	Literature/Data Call	The Center for Spills in the Environment. (2013). *Alberta Oil Sands Workshop for Washington State Department of Ecology, the Regional Response Team 10 and the Pacific States/British Columbia Oil Spill Task Force* . University of New Hampshire. https://crrc.unh.edu/sites/crrc.unh.edu/files/media/docs/Workshops/oil_sands_washington/OilSandsProductsWorkshopReport_Washington%20TOTAL.pdf
10300	Waterways Management	No Subcategory	Improve navigation for both commercial and federal entities through enhanced piloting systems, electronic charts, and coordinate information systems between regions globally.	SME Evaluation	N/A
10300	Waterways Management	No Subcategory	Improve systems and protocols needed for traffic control in ports including consistently implementing satellite, radio, web based technologies and VTS in every port.	SME Evaluation	N/A
10300	Waterways Management	No Subcategory	Improve Arctic waterways management/vessel accident prevention, including improvements in (a) Arctic communications, (b) emergency response paradigms for vessel accidents (e.g., vessel foundering), (c) ice piloting requirements/qualifications, (d) Arctic weather, and (e) ice forecasting.	SME Evaluation	N/A
10300	Waterways Management	No Subcategory	Advance Arctic mapping by using satellite and airborne imagery to capture the dynamic, rapidly changing Arctic coastline including high quality bathymetry, nautical charting, and shoreline mapping data.	Public Listening Sessions	N/A
10300	Waterways Management	No Subcategory	Develop an automated communication system for vessel operators.	Literature/Data Call	Miller, S. (2020). Vessel traffic services: Review of technology, training, and protocols. *Prince William Sound Regional Citizen's Advisory Council.* https://www.pwsrcac.org/wp-content/uploads/filebase/programs/maritime_operations/VESSEL-TRAFFIC-SERVICES-Review-of-Technology-Training-and-Protocols.pdf
10300	Waterways Management	No Subcategory	Improve compatibility with other nations and other oil spill response organization's navigation and communication systems.	Literature/Data Call	Parker, H.A., Knutson, S.R., Nicoll, A., & Wadsworth, T. (2014). International offer of assistance guidelines - Developing an IMO tool to "internationalize" oil spill readiness and response. *2014 International Oil Spill Conference Proceedings,* (1), 328-339. https://doi.org/10.7901/2169-3358-2014.1.328
10300	Waterways Management	No Subcategory	Identify geographic and temporal coverage gaps in U.S. automatic identification system (AIS) data and develop plans to fill them.	Literature/Data Call	U.S. Committee on the Marine Transportation System. (2019). *Enhancing accessibility and usability of automatic identifcation system (AIS) data: Across the federal government and for the benefit of public stakeholders.* https://www.cmts.gov/downloads/Accessibility_and_Usability_of_AIS_Data.pdf

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10300	Waterways Management	No Subcategory	Develop forecasting tools to predict vessel movement given a variety of changing factors, (e.g. environmental, social, political).	Literature/Data Call	U.S. Committee on the Marine Transportation System. (2019). *Enhancing accessibility and usability of automatic identifcation system (AIS) data: Across the federal government and for the benefit of public stakeholders.* https://www.cmts.gov/downloads/Accessibility_and_Usability_of_AIS_Data.pdf
10300	Waterways Management	No Subcategory	Develop long-term storage solutions of automatic identification system (AIS) information that allow it to be readily accessible to users.	Literature/Data Call	U.S. Committee on the Marine Transportation System. (2019). *Enhancing accessibility and usability of automatic identifcation system (AIS) data: Across the federal government and for the benefit of public stakeholders.* https://www.cmts.gov/downloads/Accessibility_and_Usability_of_AIS_Data.pdf
10300	Waterways Management	No Subcategory	Develop an authoritative, comprehensive, and universal vessel hull database for U.S. waters that can be linked to AIS data and other databases.	Literature/Data Call	U.S. Committee on the Marine Transportation System. (2019). *Enhancing accessibility and usability of automatic identifcation system (AIS) data: Across the federal government and for the benefit of public stakeholders.* https://www.cmts.gov/downloads/Accessibility_and_Usability_of_AIS_Data.pdf
10400	Vessel Design	No Subcategory	Develop designs and methods to improve survivability of ships and structures in damaged condition.	SME Evaluation	N/A
10400	Vessel Design	No Subcategory	Analyze and improve designs and analytical tools (procedures, computer models, and software) used to prevent oil drilling impacts for the operation of ships and marine oil structures in extreme environments, such as the Arctic.	SME Evaluation	N/A
10400	Vessel Design	No Subcategory	Develop a model for residual stress relaxation as a function of the applied stress range, stress ratio and initial residual stress.	Literature/Data Call	Yuen, B. K., Koko, T. S., Polezhayeva, H., & Jiang, L. (2013). *Mean stress assessment in fatigue analysis and design* (Report No. SSC-466). Ship Structure Committee. http://www.shipstructure.org/pdf/466.pdf
10400	Vessel Design	No Subcategory	Conduct tests and numerical experiments to investigate mesh convergence in order to quantify the effect of mesh size in terms of the simulation time and force/damage ratio in a ship-grounding scenario.	Literature/Data Call	Prabowo, A. R., Putranto, T., & Sohn, J. M. (2019). Simulation of the behavior of a ship hull under grounding: Effect of applied element size on structural crash worthiness. *Journal of Marine Science Engineering, 7* (8), 270. https://doi.org/10.3390/jmse7080270
10400	Vessel Design	No Subcategory	Improve temporary storage systems for oil on board vessels.	Literature/Data Call	Hansen, K. A. (2014). Responding to oil spills in ice. *International Oil Spill Conference Proceedings, 2014* (1). https://doi.org/10.7901/2169-3358-2014.1.1200
10400	Vessel Design	No Subcategory	Evaluate the residual strength of a ship structure with localized corrosion damage.	Literature/Data Call	Walker, G., Connell, B., & Kery, S. (2018). *Structural assessment of aged ships* (Report No. SSC-474). Ship Structure Committee. http://www.shipstructure.org/pdf/474.pdf
10400	Vessel Design	No Subcategory	Improve more simple methods for residual strength calculations.	Literature/Data Call	Petričić, M. (2015). *Survivability of hull girder in damaged condition* (Report No. SSC-472). Ship Structure Committee. http://www.shipstructure.org/472.pdf
10400	Vessel Design	No Subcategory	Continue to develop thin-ice mechanics for ships operating in thin ice conditions.	Literature/Data Call	Dolny, J. (2018). *Methodology for defining technical safe speeds for light ice-strenghtened government vessels operating in ice* (Report No. SSC-473). Ship Structure Committee. http://www.shipstructure.org/pdf/473.pdf
10501	Drilling	Deepwater Drilling and Technology	Evaluate subsea blowout preventer control pod batteries including assessments of battery design, life expectancy, performance, and reliability with respect to different manufacturers.	SME Evaluation	N/A
10501	Drilling	Deepwater Drilling and Technology	Conduct a gap analysis on current managed pressure drilling (MPD) techniques to identify future critical needs.	SME Evaluation	N/A
10501	Drilling	Deepwater Drilling and Technology	Study the interaction and potential for failure at the interface of each system (formation - cement - instrumentation) and develop advanced downhole tools to assess the integrity of the system in situ.	SME Evaluation	N/A
10501	Drilling	Deepwater Drilling and Technology	Develop barrier or well-barrier integrity elements that contain fluid within a well and prevent an uncontrolled flow of fluid into another formation or to the surface.	Public Listening Sessions	N/A
10501	Drilling	Deepwater Drilling and Technology	Investigate systems to improve safe drilling operations and prevent loss of the well-control in deep-and ultra-deepwater Arctic conditions.	Public Listening Sessions	N/A
10501	Drilling	Deepwater Drilling and Technology	Create a continuous downhole monitoring system (dashboard) and periodic well testing plans with live safeguards in place to flag potential SSI risks associated with production/injection operations.	Public Listening Sessions	N/A
10501	Drilling	Deepwater Drilling and Technology	Identify methods to implement corrosion resistant coatings for critical drill through equipment bolting including nano technology, persistent and self-healing coating, and hydrogen intrusion inhibitors.	Public Listening Sessions	N/A
10501	Drilling	Deepwater Drilling and Technology	Continue to improve coating materials for safety critical bolts and parts.	Public Listening Sessions	N/A
10501	Drilling	Deepwater Drilling and Technology	Continue to improve the studies on subsea materials this includes unique combinations of steel and metals mineral compositions.	Public Listening Sessions	N/A
10501	Drilling	Deepwater Drilling and Technology	Conduct material testing of cladded steel in sour applications according to different recognized methods of cladding.	Public Listening Sessions	N/A
10501	Drilling	Deepwater Drilling and Technology	Explore effective inserts for degrading casings in aging wells that reduce the risk of failure.	Public Listening Sessions	N/A
10501	Drilling	Deepwater Drilling and Technology	Research subsurface hazards and develop new data acquisition technologies and remote sensing capabilities to provide higher resolution of subsurface detail prior to drilling and ahead of the bit during drilling.	Literature/Data Call	U.S. Department of Energy. (2015). *Chapter 7: Advancing Systems and Technologies to Produce Cleaner Fuels Offshore Safety and Spill Prevention* . https://www.energy.gov/sites/prod/files/2016/04/f30/QTR2015-7F-Offshore-Safety-and-Spill-Prevention.pdf
10501	Drilling	Deepwater Drilling and Technology	Research the long term stability of boreholes.	Literature/Data Call	U.S. Department of Energy. (2015). *Chapter 7: Advancing Systems and Technologies to Produce Cleaner Fuels Offshore Safety and Spill Prevention* . https://www.energy.gov/sites/prod/files/2016/04/f30/QTR2015-7F-Offshore-Safety-and-Spill-Prevention.pdf
10501	Drilling	Deepwater Drilling and Technology	Develop plugging and abandoning technology for long term containment of hydrocarbons.	Literature/Data Call	U.S. Department of Energy. (2015). *Chapter 7: Advancing Systems and Technologies to Produce Cleaner Fuels Offshore Safety and Spill Prevention* . https://www.energy.gov/sites/prod/files/2016/04/f30/QTR2015-7F-Offshore-Safety-and-Spill-Prevention.pdf
10501	Drilling	Deepwater Drilling and Technology	Study the effects of flow-induced erosion of shear ram components.	Literature/Data Call	Green, S.T., Mueschke, N., McCleney, A., & Chocron, S. (2017). *Subsea BOP stack shear/seal capability modeling tool* (Project No. 764). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/tap-764-subsea-bop-stack-shearseal-capability-modeling-tool
10501	Drilling	Deepwater Drilling and Technology	Review the degradation mechanisms of metallic materials, with specific emphasis on loss of fracture toughness at low temperatures.	Literature/Data Call	Wood Group Kenny. (2016). Low temperature effects on drilling equipment (seals, lubricants, embrittlement). *U.S. Bureau of Safety and Environmental Enforcement.* https://www.bsee.gov/sites/bsee.gov/files/research-reports//745aa.pdf
10501	Drilling	Deepwater Drilling and Technology	Develop relevant methods for analysis and experimental measurements of fracture toughness of metallic materials and welded metals.	Literature/Data Call	Wood Group Kenny. (2016). Low Temperature Effects on Drilling Equipment (Seals, Lubricants, Embrittlement). *U.S. Bureau of Safety and Environmental Enforcement.* https://www.bsee.gov/sites/bsee.gov/files/research-reports//745aa.pdf
10502	Drilling	Reservoir Characterization	Research reservoir-specific issues including potential impacts of shallow water flow systems on facility safety.	SME Evaluation	N/A
10502	Drilling	Reservoir Characterization	Characterize reservoirs to identify geologic details, such as bounding strata weaknesses that need special engineering considerations to ensure hydrocarbon containment.	SME Evaluation	N/A
10502	Drilling	Reservoir Characterization	Research in detail offshore clathrate characterization to identify potential issues associated with environmentally sensitive areas.	SME Evaluation	N/A
10502	Drilling	Reservoir Characterization	Research and determine the origin of overpressure in the shallow and deep reservoirs of the Arctic region.	Public Listening Sessions	N/A
10502	Drilling	Reservoir Characterization	Conduct research on monitoring and surveillance techniques to assess the potential for hydrocarbon movement to the seafloor by measuring deformation of the overburden (e.g., subsidence measurements, 4D seismic techniques, fiber optics installed along wellbores etc.).	Public Listening Sessions	N/A
10502	Drilling	Reservoir Characterization	Research deep oil reservoir characteristics (oil type, depth, temperature, pressure, GOR, rock and sediment strata, etc.) for all sites where exploration and/or production drilling are planned and make data and samples available to independent researchers.	Public Listening Sessions	N/A
10502	Drilling	Reservoir Characterization	Develop systems to monitor overburden variations over time.	Literature/Data Call	Foster, D., Pye, D. S., Dokken, Q., & Litton, J. (2013). *RESEARCH & DEVELOPMENT PROGRAM SUBCOMMITTEE FINDINGS AND RECOMMENDATIONS* . U.S. Department of Energy. https://www.energy.gov/sites/prod/files/2013/12/f5/UDAC%20R%26D%20Program%20Subcommittee%20Findings%20and%20Recommendations.pdf

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10502	Drilling	Reservoir Characterization	Research methods to predict thin sandstone intervals that represent overpressure zones ahead of the drill bit.	Literature/Data Call	U.S. Department of Energy. (2015). *Chapter 7: Advancing Systems and Technologies to Produce Cleaner Fuels Offshore Safety and Spill Prevention* . https://www.energy.gov/sites/prod/files/2016/04/f30/QTR2015-7F-Offshore-Safety-and-Spill-Prevention.pdf
10502	Drilling	Reservoir Characterization	Research how to use information from other domains (e.g., communications, navigation, radar, etc.) to develop and improve remote sensing technology to interpret reservoir dynamics.	Literature/Data Call	U.S. Department of Energy. (2015). *Chapter 7: Advancing Systems and Technologies to Produce Cleaner Fuels Offshore Safety and Spill Prevention* . https://www.energy.gov/sites/prod/files/2016/04/f30/QTR2015-7F-Offshore-Safety-and-Spill-Prevention.pdf
10502	Drilling	Reservoir Characterization	Research methods to mitigate leakage in and around the boreholes from reservoir fluids and gas as well as any injected liquids and materials.	Literature/Data Call	Foster, D., Pye, D. S., Dokken, Q., & Litton, J. (2013). *RESEARCH & DEVELOPMENT PROGRAM SUBCOMMITTEE FINDINGS AND RECOMMENDATIONS* . U.S. Department of Energy. https://www.energy.gov/sites/prod/files/2013/12/f5/UDAC%20R%26D%20Program%20Subcommittee%20Findings%20and%20Recommendations.pdf
10502	Drilling	Reservoir Characterization	Study the effects of transient flow and dynamic fluid impact loads that are inherent in bubbly and slugging flows.	Literature/Data Call	Green, S.T., Mueschke, N., McCleney, A., & Chocron, S. (2017). *Subsea BOP stack shear/seal capability modeling tool* (Project No. 764). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/tap-764-subsea-bop-stack-shearseal-capability-modeling-tool
10600	Rail and Truck Transportation	No Subcategory	Evaluate accident and incident trends to identify ways to minimize the derailments and to develop better ways to reduce the damage to the environment due to oil spills.	SME Evaluation	N/A
10600	Rail and Truck Transportation	No Subcategory	Evaluate alternative designs and modifications to minimize risk of oil spills during accidents for truck transportation.	SME Evaluation	N/A
10600	Rail and Truck Transportation	No Subcategory	Develop risk models for types of crude oil trains, accounting for the placement of crude oil cars in a train.	Literature/Data Call	Lui, X., & Dick, C.T. (2016). Risk-based optimization of rail defect inspection frequency for petroleum crude oil transportation. *Transportation Research Record, 2545* (1), 27-35. https://doi.org/10.3141/2545-04
10600	Rail and Truck Transportation	No Subcategory	Develop an integrated risk-management framework to optimize the allocation of resources and minimize the risk of crude oil transport in the most cost-effective manner.	Literature/Data Call	Lui, X., & Dick, C.T. (2016). Risk-based optimization of rail defect inspection frequency for petroleum crude oil transportation. *Transportation Research Record, 2545* (1), 27-35. https://doi.org/10.3141/2545-04
10600	Rail and Truck Transportation	No Subcategory	Improve oil spill planning along railroad corridors where spills could impact rivers, creeks, streams, wetlands and marine waters.	Literature/Data Call	Pilkey-Jarvis, L., & Irwin, N. (2017). Complexities of oil spill contingency planning for railroads - Lessons learned in Washington state. *2017 International Oil Spill Conference Proceedings,* (1), 2096-2109. https://doi.org/10.7901/2169-3358-2017.1.2096
10701	Pipeline Systems	Threat/Damage Prevention	Further develop technology that detects the presence, location and separation between multiple utilities (underground, through various soil conditions) in a common corridor to reduce damage from an excavation.	SME Evaluation	N/A
10701	Pipeline Systems	Threat/Damage Prevention	Develop a standardized method for identifying and classifying interacting threats to help estimate pipeline risk.	Literature/Data Call	Koduru, S., Adianto, R., Skow, J., Ayton, B., & Nessim, M. (2016). *Critical review of candidate pipeline risk models.* C-FER Technologies Inc. https://primis.phmsa.dot.gov/matrix/FilGet.rdm?fil=11106
10701	Pipeline Systems	Threat/Damage Prevention	Further understand the Arctic environment's equilibrium and necessary design requirements of pipelines to avoid oil spills across all parts of the US Arctic OCS.	Literature/Data Call	Myers, J., Roberts, B., Lee, B., & Hill, S. (2018). *US Outer Continental Shelf oil spill causal factors report.* U.S. Bureau of Ocean Energy Management. https://www.boem.gov/sites/default/files/boem-newsroom/Library/Publications/2018/BOEM-2018-032_Arctic-Causal-Factors-Report---Final.pdf
10701	Pipeline Systems	Threat/Damage Prevention	Develop acoustic technologies for field inspection of fusion joints in plastic pipes.	Literature/Data Call	Farrag, K., Marean, J., Stubee, E., Gauthier, S., & Oleksa, P. (2019). *Pipeline safety and integrity monitoring technologies assessment.* California Energy Commission. https://www.energy.ca.gov/publications/2019/pipeline-safety-and-integrity-monitoring-technologies-assessment
10701	Pipeline Systems	Threat/Damage Prevention	Develop quantitative risk models to rank repair needs and predict pipeline failures.	Literature/Data Call	Farrag, K., Marean, J., Stubee, E., Gauthier, S., & Oleksa, P. (2019). *Pipeline safety and integrity monitoring technologies assessment.* California Energy Commission. https://www.energy.ca.gov/publications/2019/pipeline-safety-and-integrity-monitoring-technologies-assessment
10701	Pipeline Systems	Threat/Damage Prevention	Develop other inspection technologies to monitor non-piggable pipelines.	Literature/Data Call	Xie, M. & Tian, Z. (2018). A review on pipelie integrity management utilizing in-line inspection data. *Engineering Failures Analysis, 92* , 222-239. https://doi.org/10.1016/j.engfailanal.2018.05.010
10701	Pipeline Systems	Threat/Damage Prevention	Develop training programs and situational awareness procedures for efficient and quick response to pipeline incidents and repair emergencies.	Literature/Data Call	Farrag, K., Marean, J., Stubee, E., Gauthier, S., & Oleksa, P. (2019). *Pipeline safety and integrity monitoring technologies assessment.* California Energy Commission. https://www.energy.ca.gov/publications/2019/pipeline-safety-and-integrity-monitoring-technologies-assessment
10701	Pipeline Systems	Threat/Damage Prevention	Develop an industry-wide guidance on defining risk tolerability criteria for the multitude of risk models used by the pipeline industry to establish a common basis so that all operators have a clear understanding of what is expected from them.	Literature/Data Call	Flamberg, S., Rose, S., Kurth, B., & Sallaberry, C. (2016). *Paper study on risk tolerance.* U.S. DOT PHMSA. https://primis.phmsa.dot.gov/matrix/FilGet.rdm?fil=10733
10701	Pipeline Systems	Threat/Damage Prevention	Further develop the material formulations, electronic circuitry and algorithms for the various flange bolt patterns that are used in O&G pipeline systems.	Literature/Data Call	Bennet, B. (2013). *SBIR phase I - Smart pipeline network - Seal sensor system.* U.S. DOT PHMSA. https://primis.phmsa.dot.gov/matrix/FilGet.rdm?fil=8229
10701	Pipeline Systems	Threat/Damage Prevention	Research failure stress prediction models since the same technology is involved in predicting failure pressure and in assessing critical defect sizes with conservatism in pressure leading to non-conservative critical sizes.	Literature/Data Call	Young, B.A., Olson, R.J. & O'Brian, J.M. (2013). *Comprehensive study to understand longitudinal electric resistance welded (ERW) seam failures.* U.S. Pipeline and Hazardous Materials Safety Administration. https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=390
10701	Pipeline Systems	Threat/Damage Prevention	Further develop in line inspection tools to be suitable for various operating conditions.	Literature/Data Call	Xie, M. & Tian, Z. (2018). A review on pipelie integrity management utilizing in-line inspection data. *Engineering Failures Analysis, 92* , 222-239. https://doi.org/10.1016/j.engfailanal.2018.05.010
10701	Pipeline Systems	Threat/Damage Prevention	Study available and emerging thin and thick film sensors having an extremely small form factor that are capable of detecting the wide array of hydrocarbons that are transported within the oil and gas transmission pipelines.	Literature/Data Call	Bennet, B. (2013). *SBIR phase I - Smart pipeline network - Seal sensor system.* U.S. DOT PHMSA. https://primis.phmsa.dot.gov/matrix/FilGet.rdm?fil=8229
10701	Pipeline Systems	Threat/Damage Prevention	Study the physical mechanism of the interaction between a buried pipeline and frost heave/thaw settlement, and the mechanical behavior of the buried pipeline must be investigated through model investigation, numerical research, theoretical study, thermodynamic theory and static mechanics.	Literature/Data Call	Li, H., Lai, Y., Wang, L., Yang, X., Jiang, N., Li, L., Wang, C., & Yang, B. (2019). Review of the state of the art: Interactions between a buried pipeline and frozen soil. *Cold Regions Science and Technology, 157,* 171-186. https://doi.org/10.1016/j.coldregions.2018.10.014
10701	Pipeline Systems	Threat/Damage Prevention	Further develop material formulations, electronic circuitry and algorithms for the various flange bolt patterns that are used in oil and gas pipeline systems.	Literature/Data Call	Bennet, B. (2013). *SBIR phase I - Smart pipeline network - Seal sensor system.* U.S. Pipeline and Hazardous Materials Safety Administration. https://primis.phmsa.dot.gov/matrix/FilGet.rdm?fil=8229
10701	Pipeline Systems	Threat/Damage Prevention	Investigate TiNi material in pipelines, specifically super elastic TiNi.	Literature/Data Call	Wang, C., Farhat, Z., Jarjoura, G., Hassan, M.K., & Abdullah, A.M. (2018). Indentation and bending behavior of electroless Ni-P-Ti composite coatings on pipeline steel. *Surface and Coatings Technology, 334* , 243-252. https://doi.org/10.1016/j.surfcoat.2017.10.074
10702	Pipeline Systems	Leak Detection	Develop new advanced technology for sensing pipeline leaks that will reduce leak detection false alarms for new construction and existing pipelines.	SME Evaluation	N/A
10702	Pipeline Systems	Leak Detection	Further improve the existing leak detection technology and health monitoring sensors so that they are miniaturized, automatic, robust and withstand harsh environments.	SME Evaluation	N/A
10702	Pipeline Systems	Leak Detection	Operationalize autonomous dielectric measurements to remotely sense the presence of oil and potentially its migration through sea ice in support of pipeline breach detection	Public Listening Sessions	N/A
10702	Pipeline Systems	Leak Detection	Establish agreements between dog training institutes and oil spill contingency organizations for operational use of such dogs.	Literature/Data Call	Brandvik, P.J. & Buvik, T. (2017). Using dogs to detect oil spills hidden in snow and ice - A new tool to detect oil in Arctic environments. *2017 International Oil Spill Conference,* (1), 2219-2236. https://doi.org/10.7901/2169-3358-2017.1.2219
10702	Pipeline Systems	Leak Detection	Research probabilistic fatigue analysis considering likely populations of defects based on the vintage and manufacturer of the pipe and the historic test failure behaviors of individual pipeline segments.	Literature/Data Call	Young, B.A., Olson, R.J. & O'Brian, J.M. (2013). *Comprehensive study to understand longitudinal electric resistance welded (ERW) seam failures.* U.S. Pipeline and Hazardous Materials Safety Administration. https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=390
10702	Pipeline Systems	Leak Detection	Find ways of permanently and safely install fiber optics along pipelines to allow for high speed accurate monitoring	Literature/Data Call	Ho, M., El-Borgi, S., Patil, D., & Song, G. (2019). Inspection and monitoring systems subsea pipelines: A review paper. *Structutal Health Monitoring, 19* (2), 606-645. https://doi.org/10.1177/1475921719837718
10702	Pipeline Systems	Leak Detection	Develop data management and machine learning approaches for analysis and quantification of leaks and other failure consequences.	Literature/Data Call	Farrag, K., Marean, J., Stubee, E., Gauthier, S., & Oleksa, P. (2019). *Pipeline safety and integrity monitoring technologies assessment.* California Energy Commission. https://www.energy.ca.gov/publications/2019/pipeline-safety-and-integrity-monitoring-technologies-assessment
10702	Pipeline Systems	Leak Detection	Advance data visualization tools to help in show the state of flow activities for decision making in leak detection, localization and characterization, and pipeline maintenance.	Literature/Data Call	Adegboye, M.A., Fung, W-K., & Karnik, A. (2019). Recent advances in pipeline monitoring and oil leakage detection technologies: Principles and approaches. *Sensing in Oil and Gas Applications, 19* (11), 2548. https://doi.org/10.3390/s19112548

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ICCOPR NUMBER	ICCOPR SRA	Subcategory	Research Need	Source	Citation
10702	Pipeline Systems	Leak Detection	Further improve "smart pipe" networks with integrated sensors to provide continuous real-time monitoring of stresses and leak detections.	Literature/Data Call	Farrag, K., Marean, J., Stubee, E., Gauthier, S., & Oleksa, P. (2019). *Pipeline safety and integrity monitoring technologies assessment.* California Energy Commission. https://www.energy.ca.gov/publications/2019/pipeline-safety-and-integrity-monitoring-technologies-assessment
10702	Pipeline Systems	Leak Detection	Further develop, test, and validate small sensors that lend themselves to integration within components of the smart pipeline (i.e., smart pipe, etc.).	Literature/Data Call	Bennett, B. (2013). *SBIR phase I - Smart pipeline network - Cased pipe for monitoring and sensor system.* U.S. Pipeline and Hazardous Materials Safety Administration. https://primis.phmsa.dot.gov/matrix/FilGet.rdm?fil=8389
10702	Pipeline Systems	Leak Detection	Further research non-invasive sensor technologies for pipelines such as methods of strain or vibration without removing coating or direct metallic contact.	Literature/Data Call	Gas Technology Institute. (2019). *Pipeline defense with combined vibration, earth movement, and current sensing.* U.S. Pipeline and Hazardous Materials Safety Administration. https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=655
10702	Pipeline Systems	Leak Detection	Research sensor placement in pipeline monitoring.	Literature/Data Call	Adegboye, M.A., Fung, W-K., & Karnik, A. (2019). Recent advances in pipeline monitoring and oil leakage detection technologies: Principles and approaches. *Sensing in Oil and Gas Applications, 19* (11), 2548. https://doi.org/10.3390/s19112548
10702	Pipeline Systems	Leak Detection	Develop requirements or guidelines associated with offshore pipeline monitoring and leak detection to address future Arctic offshore pipeline developments.	Literature/Data Call	Davis, A. (2018). *Status of Arctic pipeline standards and technology final report.* U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/sites/bsee.gov/files/research-reports/791aa.pdf
10702	Pipeline Systems	Leak Detection	Further develop pipe locating and depth identification technologies, including development and enhancement of ground-penetrating radar systems in plastic and difficult-to-inspect pipes.	Literature/Data Call	Farrag, K., Marean, J., Stubee, E., Gauthier, S., & Oleksa, P. (2019). *Pipeline safety and integrity monitoring technologies assessment.* California Energy Commission. https://www.energy.ca.gov/publications/2019/pipeline-safety-and-integrity-monitoring-technologies-assessment
10703	Pipeline Systems	Anomaly Detection/Characterization	Develop technology to identify defects by type and accurately determine the depths of anomalies.	Literature/Data Call	Young, B.A., Olson, R.J. & O'Brian, J.M. (2013). *Comprehensive study to understand longitudinal electric resistance welded (ERW) seam failures.* U.S. Pipeline and Hazardous Materials Safety Administration. https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=390
10703	Pipeline Systems	Anomaly Detection/Characterization	Develop and introduce advanced in-line inspection (ILI) platforms for use in gas transmission pipelines, including developing a timeline for implementation of these advanced platforms.	Literature/Data Call	Farrag, K., Marean, J., Stubee, E., Gauthier, S., & Oleksa, P. (2019). *Pipeline safety and integrity monitoring technologies assessment.* California Energy Commission. https://www.energy.ca.gov/publications/2019/pipeline-safety-and-integrity-monitoring-technologies-assessment
10703	Pipeline Systems	Anomaly Detection/Characterization	Research interacting infrastructures and how to model their emerging risks, as well as how to use readily available precursors as reasonable predictors of catastrophic failure.	Literature/Data Call	Gas Technology Institute. (2016). *Approaches for preventing catastrophic events.* U.S. Pipeline and Hazardous Materials Safety Administration. https://primis.phmsa.dot.gov/matrix/FilGet.rdm?fil=10803
10703	Pipeline Systems	Anomaly Detection/Characterization	Develop more reliable and effective signal processing and data analysis methods for noise removal in ILI data and accurate defect evaluation.	Literature/Data Call	Xie, M. & Tian, Z. (2018). A review on pipelie integrity management utilizing in-line inspection data. *Engineering Failures Analysis, 92* , 222-239. https://doi.org/10.1016/j.engfailanal.2018.05.010
10703	Pipeline Systems	Anomaly Detection/Characterization	Further develop signal processing methods within the pipeline industry to remove noise, improve sizing accuracy and provide better performance.	Literature/Data Call	Xie, M. & Tian, Z. (2018). A review on pipelie integrity management utilizing in-line inspection data. *Engineering Failures Analysis, 92* , 222-239. https://doi.org/10.1016/j.engfailanal.2018.05.010
10703	Pipeline Systems	Anomaly Detection/Characterization	Develop modeling technology to quantify failure pressure and defect criticality in balance, which is capable of quantifying the nature of the features found to control failure in ERW seams.	Literature/Data Call	Young, B.A., Olson, R.J. & O'Brian, J.M. (2013). *Comprehensive study to understand longitudinal electric resistance welded (ERW) seam failures.* U.S. Pipeline and Hazardous Materials Safety Administration. https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=390
10800 *	Geohazards	Siting Decisions	Conduct site-specific risk assessments as an element of lease sale identification and approval.	Public Listening Sessions	N/A
10800 *	Geohazards	Siting Decisions	Refine the concept of a maximum creditable event and establish it on a quantitative basis.	Literature/Data Call	Woo, G. (2017). Grand Challenges in Geohazards and Georisks. *Frontiers in Earth Science* , *5* . https://doi.org/10.3389/feart.2017.00019
10800 *	Geohazards	Siting Decisions	Study methods to chart extreme scenarios to that are unprecedented and without past geological evidence.	Literature/Data Call	Woo, G. (2017). Grand Challenges in Geohazards and Georisks. *Frontiers in Earth Science* , *5* . https://doi.org/10.3389/feart.2017.00019
10800 *	Geohazards	Siting Decisions	Research the dynamic coupling of geohazards, such as landslides causing massive tsunamis and the vulnerability of offshore structures.	Literature/Data Call	Woo, G. (2017). Grand Challenges in Geohazards and Georisks. *Frontiers in Earth Science* , *5* . https://doi.org/10.3389/feart.2017.00019
10800 *	Geohazards	Siting Decisions	Research and improve downhole geologic interpretation and data acquisition for better understanding of potential hazards during drilling	Literature/Data Call	U.S. Department of Energy. (2015b). *Chapter 7: Advancing Systems and Technologies to Produce Cleaner Fuels Offshore Safety and Spill Prevention Offshore Safety and Spill Prevention* . U.S. Department of Energy. https://www.energy.gov/sites/prod/files/2016/04/f30/QTR2015-7F-Offshore-Safety-and-Spill-Prevention.pdf
10800 *	Geohazards	Siting Decisions	Continue to improve quantitative geohazard and georisk assessments, especially in model calibration and validation.	Literature/Data Call	Woo, G. (2017). Grand Challenges in Geohazards and Georisks. *Frontiers in Earth Science* , *5* . https://doi.org/10.3389/feart.2017.00019
10800 *	Geohazards	Siting Decisions	Establish multi-hazard approaches to enhance resilience in critical infrastructure by investigating multiple geohazards and broadly disseminate the findings.	Literature/Data Call	Woo, G. (2017). Grand Challenges in Geohazards and Georisks. *Frontiers in Earth Science* , *5* . https://doi.org/10.3389/feart.2017.00019
10801	Geohazards	Monitoring	Develop logging technologies that represent the in-situ stress state of the rock accurately and makes sense to the data interpreter.	Literature/Data Call	U.S. Department of Energy. (2015b). *Chapter 7: Advancing Systems and Technologies to Produce Cleaner Fuels Offshore Safety and Spill Prevention Offshore Safety and Spill Prevention* . U.S. Department of Energy. https://www.energy.gov/sites/prod/files/2016/04/f30/QTR2015-7F-Offshore-Safety-and-Spill-Prevention.pdf
10801	Geohazards	Monitoring	Improve mapping and modeling capabilities of sub-salts to determine if some areas are more prone than others to overpressure.	Literature/Data Call	U.S. Department of Energy. (2015b). *Chapter 7: Advancing Systems and Technologies to Produce Cleaner Fuels Offshore Safety and Spill Prevention Offshore Safety and Spill Prevention* . U.S. Department of Energy. https://www.energy.gov/sites/prod/files/2016/04/f30/QTR2015-7F-Offshore-Safety-and-Spill-Prevention.pdf
10801	Geohazards	Monitoring	Develop passive acoustic monitoring technologies that collect high-quality seismic data while remaining compliant with the Marine Mammals Protection Act.	Literature/Data Call	U.S. Department of Energy. (2015b). *Chapter 7: Advancing Systems and Technologies to Produce Cleaner Fuels Offshore Safety and Spill Prevention Offshore Safety and Spill Prevention* . U.S. Department of Energy. https://www.energy.gov/sites/prod/files/2016/04/f30/QTR2015-7F-Offshore-Safety-and-Spill-Prevention.pdf
10801	Geohazards	Monitoring	Develop methods to increase the skill level in geohazard forecasting techniques to improve geohazard warnings.	Literature/Data Call	Woo, G. (2017). Grand Challenges in Geohazards and Georisks. *Frontiers in Earth Science* , *5* . https://doi.org/10.3389/feart.2017.00019
10801	Geohazards	Monitoring	Research methods to implement a network of seafloor observatories to increase understanding of geological processes and the resulting instabilities.	Literature/Data Call	Wilkin, S. M., Rowles, T. K., Stratton, E., Adimey, N., Field, C. L., Wissmann, S., Shigenaka, G., Fougères, E., Mase, B., Network, S. R. S., & Ziccardi, M. H. (2017). Marine mammal response operations during the Deepwater Horizon oil spill. *Endangered Species Research* , *33* , 107–118. https://doi.org/10.3354/esr00811
10802	Geohazards	Identification & Characterization	Study the influence of climate change on geohazards.	Literature/Data Call	Dikshit, A., Pradhan, B., & Alamri, A. M. (2020). Pathways and challenges of the application of artificial intelligence to geohazards modelling. *Gondwana Research* . https://doi.org/10.1016/j.gr.2020.08.007
10802	Geohazards	Identification & Characterization	Research consecutive geohazard events using data driven approaches.	Literature/Data Call	Dikshit, A., Pradhan, B., & Alamri, A. M. (2020). Pathways and challenges of the application of artificial intelligence to geohazards modelling. *Gondwana Research* . https://doi.org/10.1016/j.gr.2020.08.007
10802	Geohazards	Identification & Characterization	Develop robust models that can handle the large amounts of data involved in understanding the mechanisms involved behind a geohazard event.	Literature/Data Call	Dikshit, A., Pradhan, B., & Alamri, A. M. (2020). Pathways and challenges of the application of artificial intelligence to geohazards modelling. *Gondwana Research* . https://doi.org/10.1016/j.gr.2020.08.007
10802	Geohazards	Identification & Characterization	Further research the existence and extent of geological hazards in the Arctic.	Literature/Data Call	U.S. Department of Energy. (2015). *Chapter 7: Advancing Systems and Technologies to Produce Cleaner Fuels Offshore Safety and Spill Prevention Offshore Safety and Spill Prevention* . U.S. Department of Energy. https://www.energy.gov/sites/prod/files/2016/04/f30/QTR2015-7F-Offshore-Safety-and-Spill-Prevention.pdf
10802	Geohazards	Identification & Characterization	Research overburden characterization, including faulting and salts.	Literature/Data Call	U.S. Department of Energy. (2015). *Chapter 7: Advancing Systems and Technologies to Produce Cleaner Fuels Offshore Safety and Spill Prevention Offshore Safety and Spill Prevention* . U.S. Department of Energy. https://www.energy.gov/sites/prod/files/2016/04/f30/QTR2015-7F-Offshore-Safety-and-Spill-Prevention.pdf
10802	Geohazards	Identification & Characterization	Identify areas in petrophysical technologies that are unreliable and need improvement and develop methods to improve those shortfalls.	Literature/Data Call	U.S. Department of Energy. (2015). *Chapter 7: Advancing Systems and Technologies to Produce Cleaner Fuels Offshore Safety and Spill Prevention Offshore Safety and Spill Prevention* . U.S. Department of Energy. https://www.energy.gov/sites/prod/files/2016/04/f30/QTR2015-7F-Offshore-Safety-and-Spill-Prevention.pdf
10802	Geohazards	Identification & Characterization	Model the spatio-temporal relationships involved in a geohazard event at common scales, especially large scale (regional or national).	Literature/Data Call	Dikshit, A., Pradhan, B., & Alamri, A. M. (2020). Pathways and challenges of the application of artificial intelligence to geohazards modelling. *Gondwana Research* . https://doi.org/10.1016/j.gr.2020.08.007

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ICCOPR NUMBER	ICCOPR SRA	Subcategory	Research Need	Source	Citation
10802	Geohazards	Identification & Characterization	Develop technologies and methods for geological and geomechanical characterization of the subsurface from seabed to the reservoir.	Literature/Data Call	Foster, D., Pye, D. S., Dokken, Q., & Litton, J. (2013). *RESEARCH & DEVELOPMENT PROGRAM SUBCOMMITTEE FINDINGS AND RECOMMENDATIONS* . U.S. Department of Energy. https://www.energy.gov/sites/prod/files/2013/12/f5/UDAC%20R%26D%20Program%20Subcommittee%20Findings%20and%20Recommendations.pdf
10802	Geohazards	Identification & Characterization	Investigate the characterization of rock interactions with oilfield mud, chemicals, pressure, and temperature.	Literature/Data Call	U.S. Department of Energy. (2015). *Chapter 7: Advancing Systems and Technologies to Produce Cleaner Fuels Offshore Safety and Spill Prevention Offshore Safety and Spill Prevention* . U.S. Department of Energy. https://www.energy.gov/sites/prod/files/2016/04/f30/QTR2015-7F-Offshore-Safety-and-Spill-Prevention.pdf
10802	Geohazards	Identification & Characterization	Develop methods to forecast the possible geohazard after an event has occurred at different time scales (days, weeks, or months) to identify risks and mitigation strategies.	Literature/Data Call	Dikshit, A., Pradhan, B., & Alamri, A. M. (2020). Pathways and challenges of the application of artificial intelligence to geohazards modelling. *Gondwana Research* . https://doi.org/10.1016/j.gr.2020.08.007
10802	Geohazards	Identification & Characterization	Determine the role of storms or major events on marine snow/oil formation.	Literature/Data Call	UNH Center for Spills in the Environment (CSE). (2013). *"Marine oil snow sedimentation and flocculent accumulation (MOSSFA) workshop".* Tallahassee, Florida. October 22-23, 2013. https://gulfresearchinitiative.org/wp-content/uploads/MOSSFAWorkshopReport2014.pdf
10900	Subsea Systems Automation & Reliability	No Subcategory	Conduct mechanical testing of corrosion resistant materials for high pressure high temperature (HPHT) application with sour service conditions.	Public Listening Sessions	N/A
10900	Subsea Systems Automation & Reliability	No Subcategory	Advance well control by adding additional barriers to a blowout preventer (BOP) to rapidly mitigate a well blowout.	Public Listening Sessions	N/A
10900	Subsea Systems Automation & Reliability	No Subcategory	Identify the optimal corrosion materials for drilling operations and cathodic protection under high pressure high temperature (HPHT) applications.	Public Listening Sessions	N/A
10900	Subsea Systems Automation & Reliability	No Subcategory	Conduct elastomer extrusion BOP studies in sour service corrosive and high pressure high temperature (HPHT) environments.	Public Listening Sessions	N/A
10900	Subsea Systems Automation & Reliability	No Subcategory	Develop new technology to apply to existing subsea technology to surface well control with an emphasis on remote operating and real time monitoring.	Public Listening Sessions	N/A
10900	Subsea Systems Automation & Reliability	No Subcategory	Develop a guidance document for performing blowout preventer (BOP) reliability analyses to address the following issues: definition of BOP failure, reliability factors of merit of interest for all key stakeholders (e.g., drilling contractors, operators, regulators), reliability modeling approaches to be used for the differing factors of merit, and consideration of common cause failures in the quantitative models .	Literature/Data Call	Patel, H., Das, B., Cherbonnier, D., Montgomery, R., Lakhani, D., Nouri, K., Nouri, K., Montague, D., Rooney, J., & Quillin, A. (2013). *Blowout preventer maintenance and inspection in deepwater operations* (Project No. 693). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/tap-693-blowout-preventer-maintenance-and-inspection-deepwater-operations
10900	Subsea Systems Automation & Reliability	No Subcategory	Investigate the application and expanded use of predictive maintenance techniques to blowout preventer (BOP) maintenance, including the evaluation of common predictive tools used by other industries for possible application to BOP systems and the identification of any new predictive maintenance technologies needed for BOP maintenance applications.	Literature/Data Call	Patel, H., Das, B., Cherbonnier, D., Montgomery, R., Lakhani, D., Nouri, K., Nouri, K., Montague, D., Rooney, J., & Quillin, A. (2013). *Blowout preventer maintenance and inspection in deepwater operations* (Project No. 693). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/tap-693-blowout-preventer-maintenance-and-inspection-deepwater-operations
10900	Subsea Systems Automation & Reliability	No Subcategory	Develop automation and robotic technologies for placing drill rigs on the seafloor.	Literature/Data Call	U.S. Department of Energy. (2015). *Chapter 7: Advancing Systems and Technologies to Produce Cleaner Fuels Offshore Safety and Spill Prevention Offshore Safety and Spill Prevention* . U.S. Department of Energy. https://www.energy.gov/sites/prod/files/2016/04/f30/QTR2015-7F-Offshore-Safety-and-Spill-Prevention.pdf
10900	Subsea Systems Automation & Reliability	No Subcategory	Identify barriers in the wellbore vicinity and the subsurface to design facilities accordingly.	Literature/Data Call	Foster, D., Pye, D. S., Dokken, Q., & Litton, J. (2013). *RESEARCH & DEVELOPMENT PROGRAM SUBCOMMITTEE FINDINGS AND RECOMMENDATIONS* . U.S. Department of Energy. https://www.energy.gov/sites/prod/files/2013/12/f5/UDAC%20R%26D%20Program%20Subcommittee%20Findings%20and%20Recommendations.pdf
10900	Subsea Systems Automation & Reliability	No Subcategory	Investigate the presence of other equipment in the blowout preventer (BOP) stack and the effects of flow diverters and riser gas management systems in shear ram operation.	Literature/Data Call	Green, S.T., Mueschke, N., McCleney, A., & Chocron, S. (2017). *Subsea BOP stack shear/seal capability modeling tool* (Project No. 764). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/tap-764-subsea-bop-stack-shearseal-capability-modeling-tool
10900	Subsea Systems Automation & Reliability	No Subcategory	Research and develop technologies that enhance/improve oil recovery including low-salinity saltwater injection (where relatively fresh water is injected to displace saltwater in the reservoir, increasing oil recovery), submersible pumps or alternatives, HIPPS, and gas injection—particularly with CO2.	Literature/Data Call	U.S. Department of Energy. (2015b). *Chapter 7: Advancing Systems and Technologies to Produce Cleaner Fuels Offshore Safety and Spill Prevention Offshore Safety and Spill Prevention* . U.S. Department of Energy. https://www.energy.gov/sites/prod/files/2016/04/f30/QTR2015-7F-Offshore-Safety-and-Spill-Prevention.pdf
10900	Subsea Systems Automation & Reliability	No Subcategory	Develop safe and cost-effective technologies to better locate and plug older wells.	Literature/Data Call	U.S. Department of Energy. (2015b). *Chapter 7: Advancing Systems and Technologies to Produce Cleaner Fuels Offshore Safety and Spill Prevention Offshore Safety and Spill Prevention* . U.S. Department of Energy. https://www.energy.gov/sites/prod/files/2016/04/f30/QTR2015-7F-Offshore-Safety-and-Spill-Prevention.pdf
10900	Subsea Systems Automation & Reliability	No Subcategory	Research subsea power generation, specifically, developing technologies such as fuel cells at hydrostatic pressure.	Literature/Data Call	U.S. Department of Energy. (2015b). *Chapter 7: Advancing Systems and Technologies to Produce Cleaner Fuels Offshore Safety and Spill Prevention Offshore Safety and Spill Prevention* . U.S. Department of Energy. https://www.energy.gov/sites/prod/files/2016/04/f30/QTR2015-7F-Offshore-Safety-and-Spill-Prevention.pdf
10900	Subsea Systems Automation & Reliability	No Subcategory	Develop long term monitoring systems (i.e. downhole and well head pressure sensors, time lapse seismic surveying, sea bed monitoring, etc.).	Literature/Data Call	U.S. Department of Energy. (2015b). *Chapter 7: Advancing Systems and Technologies to Produce Cleaner Fuels Offshore Safety and Spill Prevention Offshore Safety and Spill Prevention* . U.S. Department of Energy. https://www.energy.gov/sites/prod/files/2016/04/f30/QTR2015-7F-Offshore-Safety-and-Spill-Prevention.pdf
10900	Subsea Systems Automation & Reliability	No Subcategory	Identify approaches to reduce the risk and associated safety and operational costs of technology and system failures, including materials.	Literature/Data Call	U.S. Department of Energy. (2015). *Chapter 7: Advancing Systems and Technologies to Produce Cleaner Fuels Offshore Safety and Spill Prevention Offshore Safety and Spill Prevention* . U.S. Department of Energy. https://www.energy.gov/sites/prod/files/2016/04/f30/QTR2015-7F-Offshore-Safety-and-Spill-Prevention.pdf
10900	Subsea Systems Automation & Reliability	No Subcategory	Develop technologies that increase automation that reduce and/or assist personnel on the rig to reduce the potential for incident or injury such as sophisticated surveillance technology, real time data exchange to subject matter experts off-site.	Literature/Data Call	U.S. Department of Energy. (2015). *Chapter 7: Advancing Systems and Technologies to Produce Cleaner Fuels Offshore Safety and Spill Prevention Offshore Safety and Spill Prevention* . U.S. Department of Energy. https://www.energy.gov/sites/prod/files/2016/04/f30/QTR2015-7F-Offshore-Safety-and-Spill-Prevention.pdf
PREPAREDNESS (20000 SERIES)					
20001	Pre-spill Baseline Studies	Habitats and Species Baselines	Study population size, life stage distribution, limiting factors, and ecological structure for key Arctic species; validate existing models, and document changing baseline conditions in high risk areas (e.g., exploration and production, refining, and transportation routes).	SME Evaluation	N/A
20001	Pre-spill Baseline Studies	Habitats and Species Baselines	Study and synthesize existing information for intertidal habitats (i.e., sand beaches, rocky and cobble habitats) regarding productivity, species diversity, community structure, and the effects of oil on these parameters, including recovery time, with consideration for regional variation.	SME Evaluation	N/A
20001	Pre-spill Baseline Studies	Habitats and Species Baselines	Study ecological structure and population of key indicator and protected species in Deepwater and ultra-Deepwater (including those with commercial, subsistence and ecosystem importance), particularly in areas that are likely to be explored/developed for oil and gas extraction in the near to mid-term and synthesize existing information.	SME Evaluation	N/A
20001	Pre-spill Baseline Studies	Habitats and Species Baselines	Conduct baseline studies in areas of ongoing or significant oil development to monitor key species and background variability of the ecosystem.	Public Listening Sessions	N/A
20001	Pre-spill Baseline Studies	Habitats and Species Baselines	Determine species-specific body burden constants of keystone tropical species to improve target lipid models (TLM) toxicity predictions for risk assessments in tropical environments.	Public Listening Sessions	N/A
20001	Pre-spill Baseline Studies	Habitats and Species Baselines	Develop and publish geographically-specific offshore environmental sensitivity indices (EISs) for Deepwater and ultra-Deepwater habitats in the Gulf of Mexico.	Public Listening Sessions	N/A
20001	Pre-spill Baseline Studies	Habitats and Species Baselines	Survey and quantify Deepwater biodiversity and productivity (e.g., microbes, benthos, fishes, mammals) in the Gulf of Mexico.	Public Listening Sessions	N/A
20001	Pre-spill Baseline Studies	Habitats and Species Baselines	Study the diets relative to availability of different foods for food-web analyses to predict response to changing conditions.	Public Listening Sessions	N/A
20001	Pre-spill Baseline Studies	Habitats and Species Baselines	Study the unique characteristics of Arctic species (i.e., lower metabolic rates, larger lipid content, the presence of blood antifreeze peptides, etc.) influence their vulnerability.	Literature/Data Call	Bejarano, A.C., Gardiner, W.W., Barron, M.G., Word, J.Q. (2017). Relative sensitivity of Arctic species to physically and chemically dispersed oil determined from three hydrocarbon measures of aquatic toxicity. *Marine Pollution Bulletin, 122* (1-2), 316-322. 10.1016/j.marpolbul.2017.06.064

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ICCOPR NUMBER	ICCOPR SRA	Subcategory	Research Need	Source	Citation
20001	Pre-spill Baseline Studies	Habitats and Species Baselines	Conduct longer-term (decadal) time-series collections and measurements to provide ongoing baselines and context for seasonal, annual, and decadal changes to benthic communities.	Literature/Data Call	Schwing, P. T., & Machain-Castillo, M. L. (2020). Impact and resilience of benthic foraminifera in the aftermath of the Deepwater Horizon and Ixtoc 1 oil spills. In S. A. Murawski, C. H. Ainsworth, S. Gilbert, D. J. Hollander, C. B. Paris, M. Schlüter, & D. L. Wetzel (Eds.), Deep Oil Spills: Facts, Fate, and Effects (pp. 374–387). Springer International Publishing. https://doi.org/10.1007/978-3-030-11605-7_23
20001	Pre-spill Baseline Studies	Habitats and Species Baselines	Study temporal and spatial variability in species-specific physiology (e.g., xenobiotic metabolism capability), nutritional status, and other baseline health indices to evaluate Gulf of Mexico fish health as it relates to chronic pollution.	Literature/Data Call	Snyder, S.M., Pulster, E.L. and Murawski, S.A. (2019), Associations between chronic exposure to polycyclic aromatic hydrocarbons and health indices in Gulf of Mexico tilefish (Lopholatilus chamaeleonticeps) post Deepwater Horizon. *Environmental Toxicology and Chemistry*, *38*, 2659-2671. https://doi.org/10.1002/etc.4583
20001	Pre-spill Baseline Studies	Habitats and Species Baselines	Develop baseline microbiome profiles.	Literature/Data Call	American Society for Microbiology. (24 April 2020). *Microbial genomics can measure change in the world's oceans, new report highlights discoveries* [Press release]. https://asm.org/Press-Releases/2020/Microbial-Genomics-Can-DiagnoseChange-in-the-World
20001	Pre-spill Baseline Studies	Habitats and Species Baselines	Research the factors contributing to observed changes in the fall migration of the bowhead whale across the Beaufort Sea is particularly acute, including altered wind and current patterns, resulting changes in zooplankton concentrations, and vessel traffic through the Chukchi and Beaufort seas in support of oil and gas exploration and development activities	Literature/Data Call	Bureau of Ocean Energy Management. (2020). *Alaska annual studies plan: FY 2021.* https://www.boem.gov/sites/default/files/documents/regions/alaska-ocs-region/environment/2021-studies-plan.pdf
20001	Pre-spill Baseline Studies	Habitats and Species Baselines	Research ecological baseline data for fish and lower trophic organisms in transboundary marine waters in the eastern Beaufort Sea including fish species presence, abundance and distribution in the lease area as well as their ecological interactions with habitat and other trophic levels (prey species and plankton).	Literature/Data Call	Bureau of Ocean Energy Management. (2017). *U.S.-Canada transvoudary fish and lower trophic communities* (AK-12-04). https://www.boem.gov/sites/default/files/environmental-stewardship/Environmental-Studies/Alaska-Region/Alaska-Studies/BIO_1204.pdf
20001	Pre-spill Baseline Studies	Habitats and Species Baselines	Investigate the quantitative aspects of the impact of global warming on food-web length and components, including primary production rates, grazing rates and growth rates at higher trophic levels, in order to estimate changes in trophic transfer efficiency in Arctic food webs	Literature/Data Call	Kędra, M., Moritz, C., Choy, E.S., David, C., Degen, R., Duerksen, S., Ellingsen, I., Górska, B., Grebmeier, J.M., Kirievskaya, D., Oevelen, D.V., Piwosz, K., Samuelsen, A., & Węsławski, J.M. (2015). Status and trends in the structure of Arctic benthic food webs. *Polar Research*, *34* (1). https://doi.org/10.3402/polar.v34.23775
20001	Pre-spill Baseline Studies	Habitats and Species Baselines	Research invertebrate species, particularly mollusks and echinoderms; regarding relative abundance, distribution, or species richness and how these metrics vary within or among years for each species group, especially for Arctic invertebrates.	Literature/Data Call	Bishop, M.A. & Schaefer, A. *Winter species in Prince William Sound, Alaska, 1989-2016.* Prince William Sound Science Center. https://www.pwsrcac.org/wp-content/uploads/filebase/programs/environmental_monitoring/Winter%20Species%20in%20Prince%20William%20Sound,%20Alaska,%201989-2016.pdf
20002	Pre-spill Baseline Studies	Oceanographic and Geological Baselines	Conduct a series of large-scale Arctic studies of oceanographic exchanges, shelf basin exchanges via wind and eddies, coastal boundaries, under-ice river plumes, and sea-ice boundaries to better inform pre- and post-spill modeling and response.	SME Evaluation	N/A
20002	Pre-spill Baseline Studies	Oceanographic and Geological Baselines	Develop a better understanding of coastal processes unique to the Gulf of Mexico (i.e., changing shorelines due to erosion, deposition from the Mississippi River) to help inform protection and recovery strategies for oil spills, especially for deepwater oil movement both laterally and vertically.	SME Evaluation	N/A
20002	Pre-spill Baseline Studies	Oceanographic and Geological Baselines	Develop a better understanding of coastal processes unique to the Gulf of Mexico (i.e., changing shorelines due to erosion, deposition from the Mississippi River) to help inform protection and recovery strategies for oil spills, especially for deepwater oil movement both laterally and vertically.	Literature/Data Call	National Academies of Sciences, Engineering, and Medicine. 2018. *Understanding the Long-Term Evolution of the Coupled Natural-Human Coastal System: The Future of the U.S. Gulf Coast*. Washington, DC: The National Academies Press. https://doi.org/10.17226/25108.
20002	Pre-spill Baseline Studies	Oceanographic and Geological Baselines	Collect accurate information on surface wind fields, ocean currents, and sea ice is important for assessing the fate of spilled oil and the potential impacts on biota.	Literature/Data Call	Bureau of Ocean Energy Management. (2020). Alaska Annual Studies Plan. *U.S. Department of the Interior*. https://doi.org/https://www.boem.gov/sites/default/files/documents/regions/alaska-ocs-region/environment/2021-studies-plan.pdf
20002	Pre-spill Baseline Studies	Oceanographic and Geological Baselines	Identify know locations and seasonal changes in polynyas, leads, and land fast ice, as well as the motion of the seasonal ice pack.	Literature/Data Call	Bureau of Ocean Energy Management. (2020). Alaska Annual Studies Plan. *U.S. Department of the Interior*. https://doi.org/https://www.boem.gov/sites/default/files/documents/regions/alaska-ocs-region/environment/2021-studies-plan.pdf
20002	Pre-spill Baseline Studies	Oceanographic and Geological Baselines	Develop a high-resolution coastal discharge forcing field that specifies the terrestrial discharge at sub-km resolution in space and at daily or hourly resolution in time.	Literature/Data Call	Bureau of Ocean Energy Management. (2018). *Development of a very high-resolution regional circulation model of Beaufort Sea nearshore areas* (AK-15-02). https://www.boem.gov/sites/default/files/environmental-stewardship/Environmental-Studies/Alaska-Region/Alaska-Studies/PO_1502.pdf
20002	Pre-spill Baseline Studies	Oceanographic and Geological Baselines	Collect baseline data at shorter intervals for the highly dynamic Gulf of Mexico to assess and evaluate sources of pollution.	Literature/Data Call	Pulster E.L., Gracia, A., Snyder, S.M., Romero, I.C., Carr, B., Toro-Farner, G., & Murawski, S.A. (2020). Polycyclic aromatic hydrocarbon baselines in Gulf of Mexico fishes. In S.A Murawski, C.H. Ainsworth, S. Gilbert, D.J. Hollander, C.B. Paris, M. Schlüter, & D.L. Wetzel (Eds.), *Scenarios and responses to future deep oil spills* (pp. 253-271). Springer, Cham. https://doi.org/10.1007/978-3-030-12963-7_15
20002	Pre-spill Baseline Studies	Oceanographic and Geological Baselines	Identify the physical processes controlling the exchange between the surf zone and the inner shelf, as well as the internal circulation and dynamics.	Literature/Data Call	Rong, Z., Hetland, R.D., Zhang, W., & Zhang, X. (2014). Current-wave interaction in the Mississippi-Atchafalaya river plume on the Texas-Louisiana shelf. *Ocean Modelling,* (24), 67-83. https://doi.org/10.1016/j.ocemod.2014.09.008
20003	Pre-spill Baseline Studies	Environmental Baseline Planning	Develop models of background variability relative to habitat and species data in various environments where oil is transported or extracted so that the impacts from oil or other stressor(s) can be delineated from those of natural variation, specifically for aquatic plants, invertebrates and deep vertebrate assemblages.	SME Evaluation	N/A
20003	Pre-spill Baseline Studies	Environmental Baseline Planning	Conduct in-situ monitoring and species health assessments to determine if oil is affecting species at the organism level or sub-cellular level at various life and reproductive stages.	SME Evaluation	N/A
20003	Pre-spill Baseline Studies	Environmental Baseline Planning	Research the potential for microbial hydrocarbon degradation for different oil types, gradients of bassline hydrocarbon concentrations, microbial assemblages, and environmental conditions in regions where oil is transported or extracted (e.g., Great Lakes, rivers, ports, offshore).	SME Evaluation	N/A
20003	Pre-spill Baseline Studies	Environmental Baseline Planning	Model of the baseline dynamics of microbial communities using a multiple model approach with sensitivity and uncertainty analysis.	SME Evaluation	N/A
20003	Pre-spill Baseline Studies	Environmental Baseline Planning	Conduct long-term monitoring to estimate chronic contaminates (either individually or in synergy) impacts for deep biota.	Public Listening Sessions	N/A
20003	Pre-spill Baseline Studies	Environmental Baseline Planning	Determine the spatial connectivity of ecological resources (both horizontally and vertically) as they relate to the resiliency of populations and ecosystems to oil spills in the Gulf of Mexico.	Public Listening Sessions	N/A
20003	Pre-spill Baseline Studies	Environmental Baseline Planning	Study Arctic-based indigenous microbial populations in the water column and benthic sediment, and define rates of microbial processes to determine the role such communities have in the oil weathering process.	Public Listening Session	N/A
20003	Pre-spill Baseline Studies	Environmental Baseline Planning	Improve public access to the chemistry composition (e.g., TPH, PAHs, metals, radioactive materials (NORM)) of water discharged into public waters from oil and gas platforms.	Public Listening Sessions	N/A
20003	Pre-spill Baseline Studies	Environmental Baseline Planning	Ratify the Law of Sea Treaty to further assure that marine hydrocarbon development in the Gulf of Mexico is done under consistent safety, environmental, and human health standards.	Public Listening Sessions	N/A
20003	Pre-spill Baseline Studies	Environmental Baseline Planning	Develop a marine biotic index (e.g., foraminifera- and/or macrofauna-based AMBI) for the entire Gulf of Mexico to provide an easy to interpret benthic habitat suitability and ecological health status tool that can be operationalized by living resource managers.	Literature/Data Call	Schwing, P.T., Montagna, P.A., Machain-Castillo, M.L., Escobar-Briones, E., Rohal, M. (2020). Benthic faunal baselines in the Gulf of Mexico: A precursor to evaluate future impacts. . In S.A Murawski, C.H. Ainsworth, S. Gilbert, D.J. Hollander, C.B. Paris, M. Schlüter, & D.L. Wetzel (Eds.), *Scenarios and responses to future deep oil spills* (pp. 96-108). Springer, Cham. https://doi.org/10.1007/978-3-030-12963-7_6
20003	Pre-spill Baseline Studies	Environmental Baseline Planning	Study long-term baseline data to monitor the health of GoM, changing environmental conditions, and the interactions of natural systems with anthropogenic activities.	Literature/Data Call	Pulster E.L., Gracia, A., Snyder, S.M., Romero, I.C., Carr, B., Toro-Farner, G., & Murawski, S.A. (2020). Polycyclic aromatic hydrocarbon baselines in Gulf of Mexico fishes. In S.A Murawski, C.H. Ainsworth, S. Gilbert, D.J. Hollander, C.B. Paris, M. Schlüter, & D.L. Wetzel (Eds.), *Scenarios and responses to future deep oil spills* (pp. 253-271). Springer, Cham. https://doi.org/10.1007/978-3-030-12963-7_15
20003	Pre-spill Baseline Studies	Environmental Baseline Planning	Collect comprehensive baseline of oil contamination in the Gulf of Mexico's sediments, water column, or biota.	Literature/Data Call	Murawski, S.A., Fleeger, J.W., Patterson III, W.F., Hu, C., Daly, K., Romero, I., & Toro-Farmer, G.A. (2016). How Did the Deepwater Horizon Oil Spill Affect Coastal and Continental Shelf Ecosystems of the Gulf of Mexico? *Oceanography, 29* (3), 160-173. https://doi.org/10.5670/oceanog.2016.80
20003	Pre-spill Baseline Studies	Environmental Baseline Planning	Develop a baseline understanding of the Arctic marine environment to accurately predict the impact of an oil spill on the short (less than a year) to medium (1-10 years) time frame.	Literature/Data Call	Wilkinson, J., Beegle-Krause, C., Evers, K.U., Hughes, N., Lewis, A., Reed, M., & Wadhams, P. (2017). Oil spill response capabilities and technologies for ice-covered Arctic marine waters: A review of recent developments and established practices. *Ambio, 46,* 423-441. https://doi.org/10.1007/s13280-017-0958-y
20003	Pre-spill Baseline Studies	Environmental Baseline Planning	Study of the effects of temperature on the metabolism and biochemical responses of various cold-blooded organisms and studies on the life histories of Arctic organisms to determine seasonal differences in their sensitivity to oil.	Literature/Data Call	National Research Council. (2014). *Responding to Oil Spills in the U.S. Arctic Marine Environment.* Washington, DC: The National Academies Press. https://doi.org/10.17226/18625.

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ICCOPR NUMBER	ICCOPR SRA	Subcategory	Research Need	Source	Citation
20100	Response Management Systems	No Subcategory	Refine developed techniques and/or software that automatically translate data collected from different sources into common, usable formats.	SME Evaluation	N/A
20100	Response Management Systems	No Subcategory	Develop spill planning and response tools based on gap analysis of the availability of countermeasures in different Arctic locations and seasons.	SME Evaluation	N/A
20100	Response Management Systems	No Subcategory	Develop improved information systems for decision-making, including the use of data from coastal mapping, baseline data, and other data related to the environmental effects of oil discharges and cleanup technologies.	SME Evaluation	N/A
20100	Response Management Systems	No Subcategory	Improve transparency and data sharing of routine operations and oil pollution events from offshore oil and gas facilities in USA waters.	Public Listening Sessions	N/A
20100	Response Management Systems	No Subcategory	Identify improvements to virtual response platforms for oil spill responders.	Public Listening Sessions	N/A
20100	Response Management Systems	No Subcategory	Develop a methodology for identifying the effectiveness of response strategies based on chemical characteristics of oils.	Public Listening Sessions	N/A
20100	Response Management Systems	No Subcategory	Evaluate the cost savings and preventative measures that unmanned automations (e.g., drones, robots) can provide and how to integrate them into the oil and gas industry.	Public Listening Sessions	N/A
20100	Response Management Systems	No Subcategory	Review the status of the global inventory of oil spill response equipment and develop a process for sharing response equipment inventory information across federal, state and local governments, operators and other stakeholders.	Public Listening Sessions	N/A
20100	Response Management Systems	No Subcategory	Develop additional mechanisms to improve international engagement in oil spill preparedness, response, siting, and injury assessment activities.	Public Listening Sessions	N/A
20100	Response Management Systems	No Subcategory	Broadly apply technology readiness level (TRL) calculators to the response community so they know where to find it and what needs to be improved.	Public Listening Sessions	N/A
20100	Response Management Systems	No Subcategory	Develop population/ecosystem level models to support oil spill response trade-off decision making.	Public Listening Sessions	N/A
20100	Response Management Systems	No Subcategory	Improve the ability to designate an exclusion and/or impacted zone more easily and communicate to unified command.	Public Listening Sessions	N/A
20100	Response Management Systems	No Subcategory	Integrate remotely sensed data into oil spill response decision-making via the common operational picture to streamline data assimilation for responses.	Public Listening Sessions	N/A
20100	Response Management Systems	No Subcategory	Research marine oil snow implications on practical spill response and how it plays into NEBA - SIMA based decision making.	Public Listening Sessions	N/A
20100	Response Management Systems	No Subcategory	Compile and classify the specifications of the various test facilities around the world and match them to various spill environments in more depth.	Literature/Data Call	Panetta, P. & Potter, S. (2016). *TRL definitions for oil spill response technologies and equipment* (Project No. 1042). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/osrr-1042-technology-readiness-level-trl-definitions-for-oil-spill-response
20100	Response Management Systems	No Subcategory	Create a list of standard mission types be developed for application to representative historical or hypothetical oil spills, to allow preferred sensors meeting mission requirements to be identified, as an aide to planning future remote sensing deployments.	Literature/Data Call	Burrage, D., Gallegos, S., Wesson, J., Gould, R., Crout, R., & McCarthy, S. (2016). *Remote sensing systems to detect and analyze oil spills on the US Outer Continental Shelf - A state of the art assessment* (Project No. 1058). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/osrr-1058-remote-sensing-systems-detect-and-analyze-oil-spills-us-outer-continental
20100	Response Management Systems	No Subcategory	Integrate an oil distribution model with a large-scale oil spill trajectory forecasting model to improve emergency planning and will support the quantification of harm to ice-associated biological communities and ecosystems in the aftermath of any spills, as well as benefit natural resource damage assessments (NRDA) and net environmental benefit analyses	Literature/Data Call	Oggier, M., Eicken, H., Wilkinson, J., Petrich, C., & O'Sadnick, M. (2020). Crude oil migration in sea-ice: Laboratory studies of constraints on oil mobilization and seasonal evolution. *Cold Regions Science and Technology, 174,* 102924. https://doi.org/10.1016/j.coldregions.2019.102924
20100	Response Management Systems	No Subcategory	Create more specific definitions of the spill environment to help the response community understand which technologies to deploy for a given spill and where to focus resources.	Literature/Data Call	Panetta, P. & Potter, S. (2016). *TRL definitions for oil spill response technologies and equipment* (Project No. 1042). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/osrr-1042-technology-readiness-level-trl-definitions-for-oil-spill-response
20100	Response Management Systems	No Subcategory	Develop a tool matrix that decision-makers can reference for preparedness and response planning.	Literature/Data Call	UNH Coastal Response Research Center. (2019). *NOAA regional preparedness and training (NRPT) - Norfolk, VA.* https://crrc.unh.edu/NRPT_Norfolk
20100	Response Management Systems	No Subcategory	Develop systems to communicate efficiently the spill properties and current weather conditions between FOSC and personnel at the spill site.	Literature/Data Call	McCleney, A.B., Supak, K., Manders, J., & Cortes, M. (2018). *Determine the relative efficiency of various surface chemical dispersant delivery techniques/systems* (Project No. 1090). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/determine-the-relative-efficiency-of-various-surface-dispersant-delivery
20100	Response Management Systems	No Subcategory	Summarize relevant ongoing and planned research worldwide to achieve synergy and avoid unnecessary duplication.	Literature/Data Call	National Research Council. (2014). *Responding to Oil Spills in the U.S. Arctic Marine Environment.* Washington, DC: The National Academies Press. https://doi.org/10.17226/18625.
20100	Response Management Systems	No Subcategory	Research the net environmental tradeoffs of various response strategies to make cleanup decisions in a variety of environments including subsurface.	Literature/Data Call	UNH Center for Spills in the Environment. (2013). *Alberta oil sands workshop.* https://crrc.unh.edu/sites/crrc.unh.edu/files/media/docs/Workshops/oil_sands_washington/OilSandsProductsWorkshopReport_Washington%20TOTAL.pdf
20200	Renewable Energy Systems	No Subcategory	Study the effects of offshore renewable energy facility infrastructure on oil spill recovery efforts (i.e.; strategies and tactics).	SME Comments	N/A
20200	Renewable Energy Systems	No Subcategory	Update existing response tools to incorporate the types of oil products that are, or will be, used on renewable energy facilities in significant quantities (e.g., dielectric fluids).	Public Listening Sessions	N/A
20200	Renewable Energy Systems	No Subcategory	Develop new tools that support the planning and response strategies for oil products stored in significant amounts on renewable energy facilities.	Public Listening Sessions	N/A
20200	Renewable Energy Systems	No Subcategory	Study the effects of dispersants on biodiesel and other biofuels, especially in colder environments.	Public Listening Sessions	N/A
20200	Renewable Energy Systems	No Subcategory	Study the potential impacts of a large discharge of transformer oil into the marine environment.	Literature/Data Call	Gunter, T. (2014). Potential impacts from a worst case discharge from an United States offshore wind farm. *International Oil Spill Conference Proceedings, 2014* (1), 869-877. https://doi.org/10.7901/2169-3358-2014.1.869
20200	Renewable Energy Systems	No Subcategory	Develop effective spill response mitigation strategies specific to the risks associated with discharges from wind farms.	Literature/Data Call	Gunter, T. (2014). Potential impacts from a worst case discharge from an United States offshore wind farm. *International Oil Spill Conference Proceedings, 2014* (1), 869-877. https://doi.org/10.7901/2169-3358-2014.1.869
RESPONSE (30000 SERIES)					
30000	Structural Damage Assessment and Salvage	No Subcategory	Study methods for remotely and rapidly determining whether a cargo tank contains sea water and the extent of the water bottom (height of the oil/water interface from the bottom of the tank).	SME Evaluation	N/A
30000	Structural Damage Assessment and Salvage	No Subcategory	Continue to develop and refine technologies and techniques to better determine the presence of oil and the probability of its release from specific sunken vessels.	SME Evaluation	N/A
30000	Structural Damage Assessment and Salvage	No Subcategory	Continue to develop improved use of remotely operated vehicles (ROVs) and emerging technologies for underwater assessment of vessel and marine structure integrity.	SME Evaluation	N/A
30000	Structural Damage Assessment and Salvage	No Subcategory	Continue surveying for shipwrecks to help identify and monitor nonleaking wrecks.	Literature/Data Call	Symons, L., Michel, J., Delgado, J., Reich, D., McCay, D. F., Etkin, D. S., & Helton, D. (2014). The remediation of underwater legacy environmental threats (RULET) risk assessment for potentially polluting shipwrecks in U.S. waters. *International Oil Spill Conference Proceedings, 2014* (1), 783-793. https://doi.org/10.7901/2169-3358-2014.1.783
30000	Structural Damage Assessment and Salvage	No Subcategory	Study the spatial extent over which escort tugs are required to operate by understanding the acceptable operating conditions for rescue vessels.	Literature/Data Call	Prince William Sound Regional Citizens' Advisory Council. (2018). *Hinchinbrook entrance wind wave extremes.* https://www.pwsrcac.org/wp-content/uploads/filebase/programs/maritime_operations/Hinchinbrook-Entrance-Wind-Wave-Extremes.pdf
30000	Structural Damage Assessment and Salvage	No Subcategory	Research corrosion and degradation of sunken vessels.	Literature/Data Call	Symons, L., Wagner, J., Delgado, J., Helton, D., Varmer, O., Gongaware, L., Michel, J., Weaver, J., Boring, C., Priest, B, Holmes, J., Early, W., Etkin, D. S., McCay, D. F., Reich, D., Balouskus, R, Fontenault, J, Isaji, T., Mendelsohn, J., & McStay, L. (2013). Risk assessment for potentially polluting wrecks in U.S. waters. *National Oceanic and Atmospheric Administration.* https://nmssanctuaries.blob.core.windows.net/sanctuaries-prod/media/archive/protect/ppw/pdfs/2013_potentiallypollutingwrecks.pdf

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ICCOPR NUMBER	ICCOPR SRA	Subcategory	Research Need	Source	Citation
30000	Structural Damage Assessment and Salvage	No Subcategory	Collect detailed structural loss data to better understand the underlying causes of accidents in the Arctic regions.	Literature/Data Call	Necci, A., Tarantola, S., Vamanu, B., Krausmann, E., & Ponte, L. (2019). Lessons learned from offshore oil and gas incidents in the Arctic and other ice-prone seas. *Ocean Engineering, 185,* 12-26. https://doi.org/10.1016/j.oceaneng.2019.05.021
30000	Structural Damage Assessment and Salvage	No Subcategory	Research the properties of oils from World War II shipwrecks and the chemical effects of submerged oil for 75 years.	Literature/Data Call	Bergstrøm, R. (2014). Lessons learned from offloading oil from potentially polluting ship wrecks from World War II in Norwegian waters. *International Oil Spill Conference Proceedings, 2014* (1), 804-813. https://doi.org/10.7901/2169-3358-2014.1.804
30100	At Source Control and Containment	No Subcategory	Study the range of failure states and flow rates for which subsea containment may be required.	SME Evaluation	N/A
30100	At Source Control and Containment	No Subcategory	Determine how extreme environmental conditions affect at-source containment and control (including ultra-deep and other extreme conditions).	SME Evaluation	N/A
30100	At Source Control and Containment	No Subcategory	Develop subsea containment equipment for integration into spill response operations, including relevant procedures and standards for training personnel.	SME Evaluation	N/A
30100	At Source Control and Containment	No Subcategory	Measurement methods and tools to provide the amount of oil and flow rate and gas bubble amount and flow rate in subsurface releases of oil and gas in the field	Public Listening Sessions	N/A
30100	At Source Control and Containment	No Subcategory	Develop tools and processes to determine the blowout volume and flow measurements in field conditions.	Public Listening Sessions	N/A
30100	At Source Control and Containment	No Subcategory	Develop light weight risers to improve intervention in deepwater wells and High Pressure High Temperature (HPHT) conditions.	Literature/Data Call	U.S. Department of Energy. (2015b). *Chapter 7: Advancing Systems and Technologies to Produce Cleaner Fuels Offshore Safety and Spill Prevention Offshore Safety and Spill Prevention* . U.S. Department of Energy. https://www.energy.gov/sites/prod/files/2016/04/f30/QTR2015-7F-Offshore-Safety-and-Spill-Prevention.pdf
30100	At Source Control and Containment	No Subcategory	Evaluate subsea capping stack components that can accommodate weight savings.	Literature/Data Call	Alba, J. (2016). *Subsea capping stack technology requirements* (Project No. 756). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/tap-756-capping-stack-technology-requirements
30100	At Source Control and Containment	No Subcategory	Develop subsea capping stacks for High Pressure High Temperature (HPHT) conditions.	Literature/Data Call	Alba, J. (2016). *Subsea capping stack technology requirements* (Project No. 756). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/tap-756-capping-stack-technology-requirements
30201	Chemical and Physical Modeling and Behavior	Arctic Behavior and Modeling	Develop improved modeling tools and trajectory models in order to predict spreading of oil in different weather and ice conditions in the Arctic, specifically the oil transport in ice and brine channels, and the behavior of novel oil types during ice cover freeze or break up.	SME Evaluation	N/A
30201	Chemical and Physical Modeling and Behavior	Arctic Behavior and Modeling	Study the fate of oil in Arctic conditions; including open water, ice infested water and oil trapped in ice, under-ice turbulence and currents to develop longer term forecasts, especially during the winter seasons..	SME Evaluation	N/A
30201	Chemical and Physical Modeling and Behavior	Arctic Behavior and Modeling	Study Arctic-based indigenous microbial populations in the water column and benthic sediment, and define rates of microbial processes to determine the role such communities have in the oil weathering process under real-world conditions.	SME Evaluation	N/A
30201	Chemical and Physical Modeling and Behavior	Arctic Behavior and Modeling	Characterize oil distribution in the sea ice cover from the millimeter to the meter scale.	Public Listening Session	N/A
30201	Chemical and Physical Modeling and Behavior	Arctic Behavior and Modeling	Research how petroleum contamination behaves at the active layer/permafrost interface and determine pathways in which petroleum contamination has seeped into the permafrost zone.	Public Listening Sessions	N/A
30201	Chemical and Physical Modeling and Behavior	Arctic Behavior and Modeling	Develop multiple nowcast and forecast models for Arctic environments for different oil spill scenarios.	Public Listening Session	N/A
30201	Chemical and Physical Modeling and Behavior	Arctic Behavior and Modeling	Develop a model to describe and predict the vertical distribution and movement (mm to m scale) of oil in the sea ice cover as a function of ice temperature, porosity and pore microstructure.	Public Listening Session	N/A
30201	Chemical and Physical Modeling and Behavior	Arctic Behavior and Modeling	Study and characterize the scattering behavior from the basal layer of ice, under varied ice conditions (particularly at different roughness scales).	Literature/Data Call	Maksym, T., Singh, H., Bassett, C., Lavery, A., Freitag, L., Sonniehsen, F., & Wilinson, J. (2014). *Oil spill detection and mapping under Arctic sea ice using autonomous underwater vehicles* (Project No. 1000). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/osrr-1000-oil-spill-detection-and-mapping-under-arctic-sea-ice-using-autonomous
30201	Chemical and Physical Modeling and Behavior	Arctic Behavior and Modeling	Research the albedo effect of oil encapsulated in ice – rate of melting of ice cover due to encapsulated oil.	Literature/Data Call	UNH Center for Spills and Environmental Hazards. (2019). *ADAC Arctic spill modeling (AMSM).* https://crrc.unh.edu/AMSM_Arctic_Modeling
30201	Chemical and Physical Modeling and Behavior	Arctic Behavior and Modeling	Develop and improve tools to detect and map oil among drifting broken ice and encapsulated in and under ice.	Literature/Data Call	Coastal Response Research Center. (2012). North Slope Borough Oil Spill Workshop: Natural Resource Damage Assessment (NRDA) & Environmental Response Management Application (ERMA ®). University of New Hampshire. https://crrc.unh.edu/sites/crrc.unh.edu/files/media/docs/Workshops/nsb_12/NorthSlopeBorough_workshop_report_FINAL_appendix.pdf
30201	Chemical and Physical Modeling and Behavior	Arctic Behavior and Modeling	Study different ice types (e.g., fresh, one year, frazil) and how oil interacts with them to develop algorithms for different types of ice.	Literature/Data Call	UNH Center for Spills and Environmental Hazards. (2019). *ADAC Arctic spill modeling (AMSM).* https://crrc.unh.edu/AMSM_Arctic_Modeling
30201	Chemical and Physical Modeling and Behavior	Arctic Behavior and Modeling	Study the role of under ice roughness in Lagrangian particle tracking mode and its us to develop ice models that produce an estimate of under-ice roughness.	Literature/Data Call	UNH Center for Spills and Environmental Hazards. (2019). *ADAC Arctic spill modeling (AMSM).* https://crrc.unh.edu/AMSM_Arctic_Modeling
30201	Chemical and Physical Modeling and Behavior	Arctic Behavior and Modeling	Collect nearshore meteorological ocean conditions to resolve the mismatch of scale of ice models and meteorological ocean models.	Literature/Data Call	UNH Center for Spills and Environmental Hazards. (2019). *ADAC Arctic spill modeling (AMSM).* https://crrc.unh.edu/AMSM_Arctic_Modeling
30201	Chemical and Physical Modeling and Behavior	Arctic Behavior and Modeling	Study the fate processes oil experiences when it is encapsulated in ice (e.g., dissolution, dissolve, partition, migration through ice, degradation).	Literature/Data Call	UNH Center for Spills and Environmental Hazards. (2019). *ADAC Arctic spill modeling (AMSM).* https://crrc.unh.edu/AMSM_Arctic_Modeling
30201	Chemical and Physical Modeling and Behavior	Arctic Behavior and Modeling	Study the effects of the presence of sea ice on oil weathering and movement as well as the feasibility and effectiveness of monitoring, modeling, response, and cleanup techniques.	Literature/Data Call	Li, P., Cai, Q., Lin, W., Chen, B., & Zhang, B. (2016). Offshore oil spill response practices and emerging challenges. *Marine Pollution Bulletin, 110* (1), 6-27. https://doi.org/10.1016/j.marpolbul.2016.06.020
30201	Chemical and Physical Modeling and Behavior	Arctic Behavior and Modeling	Further research the integration of ice cover into oil spill trajectory models to develop a high-resolution coupled ice-ocean models.	Literature/Data Call	Nordam, T., Dunnebier, D. A. E., Beegle-Krause, C., Reed, M., & Slagstad, D. (2017). Impact of climate change and seasonal trends on the fate of Arctic oil spills. *Ambio, 46,* 442-452. https://doi.org/10.1007/s13280-017-0961-3
30201	Chemical and Physical Modeling and Behavior	Arctic Behavior and Modeling	Conduct quantitative research to predict oil behavior and fate in ice-infested environments.	Literature/Data Call	Fingas, M.F. & Hollebone, B.P. (2014). Oil behaviour in ice-infested waters. *International Oil Spill Conference Proceedings.* (1), 1239-1250. https://doi.org/10.7901/2169-3358-2014.1.1239
30201	Chemical and Physical Modeling and Behavior	Arctic Behavior and Modeling	Estimate statistics of sub ice topography based on age and type of ice and/or be able to measure sub ice topography during spills to calibrate models for storage	Literature/Data Call	UNH Center for Spills and Environmental Hazards. (2019). *ADAC Arctic spill modeling (AMSM).* https://crrc.unh.edu/AMSM_Arctic_Modeling
30201	Chemical and Physical Modeling and Behavior	Arctic Behavior and Modeling	Quantify the impact of the microstructural differences of granular and columnar ice on oil transport processes through sea-ice.	Literature/Data Call	Oggier, M., Eicken, H., Wilkinson, J., Petrich, C., & O'Sadnick, M. (2020). Crude oil migration in sea-ice: Laboratory studies of constraints on oil mobilization and seasonal evolution. *Cold Regions Science and Technology, 174,* 102924. https://doi.org/10.1016/j.coldregions.2019.102924
30201	Chemical and Physical Modeling and Behavior	Arctic Behavior and Modeling	Study the weathering and persistence of oil in cold water marine systems and ice conditions	Literature/Data Call	North Pacific Research Board. (2018). *North Pacific research board science plan.* Baker, M.R. & Smith, B. (Eds.). https://www.nprb.org/nprb/integrated-ecosystem-research-program
30201	Chemical and Physical Modeling and Behavior	Arctic Behavior and Modeling	Study the chemistry and physics of spilled oil on/in/under ice and how its characteristics change over time in harsh environments.	Literature/Data Call	Li, P., Cai, Q., Lin, W., Chen, B., & Zhang, B. (2016). Offshore oil spill response practices and emerging challenges. *Marine Pollution Bulletin, 110* (1), 6-27. https://doi.org/10.1016/j.marpolbul.2016.06.020
30201	Chemical and Physical Modeling and Behavior	Arctic Behavior and Modeling	Develop models that capture the fate of oil in cold water (e.g., how hot oil behaves in cold waters).	Literature/Data Call	UNH Center for Spills and Environmental Hazards. (2019). *ADAC Arctic spill modeling (AMSM).* https://crrc.unh.edu/AMSM_Arctic_Modeling
30202	Chemical and Physical Modeling and Behavior	Oil Behavior Models	Better understand behavior of dissolvable components and pressure effects.	SME Evaluation	N/A
30202	Chemical and Physical Modeling and Behavior	Oil Behavior Models	Study bottom substrate dynamics which might affect submerged oil fate and behavior in estuarine and coastal systems.	SME Evaluation	N/A
30202	Chemical and Physical Modeling and Behavior	Oil Behavior Models	Use best available scientific data on oil weathering and fate to develop and improve transport model parameters (e.g., volatilization, solubilization, emulsification, biodegradation) for a variety of oil types and environmental conditions.	SME Evaluation	N/A
30202	Chemical and Physical Modeling and Behavior	Oil Behavior Models	Synthesize information on degradation rates in intertidal and shallow subtidal habitats to support modeling and estimation of impact duration.	SME Evaluation	N/A

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30202	Chemical and Physical Modeling and Behavior	Oil Behavior Models	Review of Low Sulfur Fuel Oil and their high variability characteristics	Public Listening Sessions	N/A
30202	Chemical and Physical Modeling and Behavior	Oil Behavior Models	Study the influence of photo-oxidation and emulsification on oil fate, dispersant effectiveness, and water column exposure to incorporate into oil weathering models.	Public Listening Sessions	N/A
30202	Chemical and Physical Modeling and Behavior	Oil Behavior Models	Develop commercial insitu subsea Mass Spectrometer capability to fingerprint hydrocarbon samples.	Public Listening Sessions	N/A
30202	Chemical and Physical Modeling and Behavior	Oil Behavior Models	Develop simulants that could be used to model submerged and sunken oils, as well as submerged oil plumes.	Literature/Data Call	DeCola, E.G., Robertson, T.L., Robida, J., House, B., & Pegau, W.S. (2014). Oil spill simulants workshop process and outcomes. *International Oil Spill Conference Proceedings, 2014* (1), 102-113. https://doi.org/10.7901/2169-3358-2014.1.102
30202	Chemical and Physical Modeling and Behavior	Oil Behavior Models	Study the persistence and degradation changes of spilled oil due to low temperature.	Literature/Data Call	Li, P., Cai, Q., Lin, W., Chen, B., & Zhang, B. (2016). Offshore oil spill response practices and emerging challenges. *Marine Pollution Bulletin, 110* (1), 6-27. https://doi.org/10.1016/j.marpolbul.2016.06.020
30202	Chemical and Physical Modeling and Behavior	Oil Behavior Models	Study the effects of wind and waves at different energy levels on weathering, movement, and containment of oil slicks.	Literature/Data Call	Li, P., Cai, Q., Lin, W., Chen, B., & Zhang, B. (2016). Offshore oil spill response practices and emerging challenges. *Marine Pollution Bulletin, 110* (1), 6-27. https://doi.org/10.1016/j.marpolbul.2016.06.020
30202	Chemical and Physical Modeling and Behavior	Oil Behavior Models	Develop three-dimensional oil spill modeling to predict the impact of oil spills to the subsurface.	Literature/Data Call	Bureau of Ocean Energy Management. (2021). *Assessing the impact of oil spills using three-dimensional oil spill modeling.* https://marinecadastre.gov/espis/#/search/study/100114
30203	Chemical and Physical Modeling and Behavior	Transport models	Validate existing oil trajectory and fate models used during spill response to predict the behavior and transport of dispersed oil in an appropriately designed experimental setting or during actual spills.	SME Evaluation	N/A
30203	Chemical and Physical Modeling and Behavior	Transport models	Conduct a literature review to develop a decision template or conceptual model of the conditions under which oil might become submerged that considers oil properties and environmental characteristics.	SME Evaluation	N/A
30203	Chemical and Physical Modeling and Behavior	Transport models	Develop a three dimensional tracer concentration simulation to understand how the diffusive process effect on oil transport.	Literature/Data Call	Kourafalou, V. (2020). *Operational oil spill forecasting.* Gulf of Mexico Research Initiative. https://gulfresearchinitiative.org/wp-content/uploads/Report_CoreArea7A_workshop.pdf
30203	Chemical and Physical Modeling and Behavior	Transport models	Study the structure of the near-surface velocity profile and the related dynamics for simulating surface oil transport.	Literature/Data Call	MacDonald, I.R., Dukhovskoy, D., Bourassa, M., Morey, S., Garcia-Pindea, O., Daneshgar, S., Hu, C., Reed, M., & Skancke, J. (2017). *Remote sensing assessment of surface oil transport and fate during spills in the Gulf of Mexico.* Bureau of Ocean Energy Management. https://marinecadastre.gov/espis/#/search/study/100036
30203	Chemical and Physical Modeling and Behavior	Transport models	Research and monitor the transport and fate of spreading oil in ice and below ice.	Literature/Data Call	Fitzpatrick, F.A., Boufadel, M.C., Johnson, R., Lee, K., Graan, T.P., Bejarano, A.C., Zhu, Z., Waterman, D., Capone, D.M., Hayter, E., Hamilton, S.K., Dekker, T., Garcia, M.H., & Hassan, J.S. (2015). *Oil-particle interactions and submergence from crude oil spills in marine and freshwater environments - Review of the science and future science needs.* U.S. Geological Survey. https://pubs.usgs.gov/of/2015/1076/
30203	Chemical and Physical Modeling and Behavior	Transport models	Study the effect of small-scale turbulence and 3-D flow characteristics on droplets transport.	Literature/Data Call	Cui, F., Boufadel, M.C., Geng, X., Gao, F., Zhao, L., King, T., & Lee, K. (2018). Oil droplets transport under a deep-water plunging breaker: Impact of droplet inertia. *Journal of Geophysical Research: Oceans, 123* (12), 9082-9100. https://doi.org/10.1029/2018JC014495
30203	Chemical and Physical Modeling and Behavior	Transport models	Research three dimensional subsurface oil spill trajectory modeling and oil detection systems to provide consistent results and be readily deployable during a sub-surface response operation.	Literature/Data Call	Elliott, J.E. & DeVilbiss, D. (2014). Advancements in underwater oil detection and recovery techniques. *International Oil Spill Conference Proceedings, 2014* (1), 2037-2052. https://doi.org/10.7901/2169-3358-2014.1.2037
30203	Chemical and Physical Modeling and Behavior	Transport models	Develop oil fate and transport models that incorporate photo-oxidation.	Literature/Data Call	Ward, C.P. & Overton, E.B. (2020). How the 2010 Deepwater Horizon spill reshaped our understanding of crude oil photochemical weathering at sea: a past, present, and future perspective. *Environmental Science: Processes & Impacts, 22* (5), 1101-1308. https://doi.org/10.1039/D0EM00027B
30204	Chemical and Physical Modeling and Behavior	Oceanographic models	Operationalize and maintain high-resolution, nearshore, circulation models.	SME Evaluations	N/A
30204	Chemical and Physical Modeling and Behavior	Oceanographic models	Integrate upper sea-surface turbulence, with particular emphasis on quantifying horizontal and vertical diffusivities and the rate of energy dissipation, to improve 3D and 4D spill transport models.	SME Evaluations	N/A
30204	Chemical and Physical Modeling and Behavior	Oceanographic models	Review and update oil spill model algorithms based on the current state of science and identify ways to improve the algorithms.	Public Listening Sessions	N/A
30204	Chemical and Physical Modeling and Behavior	Oceanographic models	Improve the ability of numerical models in simulating and predicting the vertical transport of oil spills with improvement in simulation of near-inertial internal waves.	Literature/Data Call	Jing, Z., Chang, P., DiMarco, S.F., & Wu, L. (2015). Role of near-inertial internal waves in subthermocline diapycnal mixing in the northern Gulf of Mexico. *Journal of Physical Oceanography, 45* (12), 3137-3154. https://doi.org/10.1175/JPO-D-14-0227.1
30204	Chemical and Physical Modeling and Behavior	Oceanographic models	Develop a publicly available subsea release plume model for subsea discharges that incorporates the subsea plume, weathering, and trajectory.	Literature/Data Call	Keramea, P.; Spanoudaki, K.; Zodiatis, G.; Gikas, G.; Sylaios, G.(2021).Oil Spill Modeling: A Critical Review on Current Trends, Perspectives, and Challenges. *J. Mar. Sci. Eng.* , 9, 181. https://doi.org/10.3390/jmse9020181
30204	Chemical and Physical Modeling and Behavior	Oceanographic models	Conduct simulations and detailed in-situ measurements in order to obtain reliable estimates for the vertical heat transport in the Arctic Ocean.	Literature/Data Call	Toffolon, M. & Piccolroaz, S. (Eds.). (2014). *Proceedings of the 17th International Workshop on Physical Processes in Natural Waters: PPNW2014.* Università degli Studi di Trento. http://eprints.biblio.unitn.it/4293/
30204	Chemical and Physical Modeling and Behavior	Oceanographic models	Research the uncertainties associated with the weather and ocean conditions and the impacts on spill modeling and response decision making.	Literature/Data Call	Li, P., Cai, Q., Lin, W., Chen, B., & Zhang, B. (2016). Offshore oil spill response practices and emerging challenges. *Marine Pollution Bulletin, 110* (1), 6-27. https://doi.org/10.1016/j.marpolbul.2016.06.020
30204	Chemical and Physical Modeling and Behavior	Oceanographic models	Develop cross-scale circulation models for the lagoonal estuaries along the Gulf coast that reproduce the dominant flow physics at the shelf-estuary interface.	Literature/Data Call	Feng, D. & Hodges, B.R. (2020). The oil spill transport across the shelf-estuary interface. *Marine Pollution Bulletin, 153,* 110958. https://doi.org/10.1016/j.marpolbul.2020.110958
30204	Chemical and Physical Modeling and Behavior	Oceanographic models	Develop an accepted model for bubble- or droplet-generated turbulence to resolve discrepancies between laboratory and ocean results.	Literature/Data Call	Boufadel, M.C., Socolofsky, S., Katz, J., Yang, D., Daskiran, C., & Dewar, W. (2020). A review on multiphase underwater jets and plumes: Droplets, hydrodynamics, and chemistry. *Review of Geophysics, 58* (3). https://doi.org/10.1029/2020RG000703
30204	Chemical and Physical Modeling and Behavior	Oceanographic models	Develop reliable modelling systems or methods that can scale down from the ocean to the coastal scale.	Literature/Data Call	Samaras, A.G., Gaeta, M.G., Miquel, A.M., & Archetti, R. (2016). High-resolution wave and hydrodynamics modelling in coastal areas: operational applications for coastal planning, decision support and assessment. *Natural Hazards and Earth System Sciences, 16,* 1499-1518. https://doi.org/10.5194/nhess-16-1499-2016
30204	Chemical and Physical Modeling and Behavior	Oceanographic models	Conduct experiments on plume behavior above the first intrusion.	Literature/Data Call	Socolofsky, S.A., Adams, E.E., Boufadel, M.C., Aman, Z.M., Johansen, Ø, Konkel, W.J., Lindo, D., Madsen, M.N., North, E.W., Paris, C.B., Rasmussen, D., Reed, M., Rønningen, P., Sim, L.H., Uhrenholdt, T., Anderson, K.G., Cooper, C., & Nedwed, T.J. (2015). Intercomparison of oil spill prediction models for accidental blowout scenarios with and without subsea chemical dispersant injection. *Marine Pollution Bulletin, 96* (1-2), 110-126. https://doi.org/10.1016/j.marpolbul.2015.05.039
30204	Chemical and Physical Modeling and Behavior	Oceanographic models	Create a more general framework incorporating the combined effects of shear turbulence, Langmuir circulations, breaking waves, and buoyancy on local and nonlocal fluxes is needed.	Literature/Data Call	D'Asaro, E.A., Carlson, D.F., Chamecki, M., Harcourt, R.R., Haus, B.K., Fox-Kemper, B., Molemaker, M.J., Poje, A.C., & Yang, D. (2020). Advances in observing and understanding small-scale open ocean circulation during the Gulf of Mexico research initiative era. *Fronteirs in Marine Science, 7.* https://doi.org/10.3389/fmars.2020.00349
30204	Chemical and Physical Modeling and Behavior	Oceanographic models	Study the dynamics of multiphase plumes in the combined presence of stratification and crossflow.	Literature/Data Call	Dehghani, A. & Aslani, F. (2019). A review on defects in steel offshore structures and developed strengthening techniques. *Structures, 20,* 635-657. https://doi.org/10.1016/j.istruc.2019.06.002
30204	Chemical and Physical Modeling and Behavior	Oceanographic models	Further study the near-surface ocean velocity structure and interfacial stresses between air, oil and water under different wind, wave and current regimes.	Literature/Data Call	MacDonald, I.R., Dukhovskoy, D., Bourassa, M., Morey, S., Garcia-Pindea, O., Daneshgar, S., Hu, C., Reed, M., & Skancke, J. (2017). *Remote sensing assessment of surface oil transport and fate during spills in the Gulf of Mexico.* Bureau of Ocean Energy Management. https://marinecadastre.gov/espis/#/search/study/100036
30204	Chemical and Physical Modeling and Behavior	Oceanographic models	Develop a surface heat flux model to correctly reproduce the long-term effect of evaporation on salinity.	Literature/Data Call	Rayson, M.D., Gross, E.S., & Fringer, O.B. (2015). Modeling the tidal and sub-tidal hydrodynamics in a shallow, micro-tidal estuary. *Ocean Modelling, 89,* 29-44. https://doi.org/10.1016/j.ocemod.2015.02.002
30204	Chemical and Physical Modeling and Behavior	Oceanographic models	Develop measurement and analysis techniques that better address the subsurface and vertical transport components of upper ocean motions.	Literature/Data Call	D'Asaro, E.A., Carlson, D.F., Chamecki, M., Harcourt, R.R., Haus, B.K., Fox-Kemper, B., Molemaker, M.J., Poje, A.C., & Yang, D. (2020). Advances in observing and understanding small-scale open ocean circulation during the Gulf of Mexico research initiative era. *Fronteirs in Marine Science, 7.* https://doi.org/10.3389/fmars.2020.00349
30204	Chemical and Physical Modeling and Behavior	Oceanographic models	Research simple and accurate parameterizations of wave breaking into operational ocean circulation models.	Literature/Data Call	D'Asaro, E.A., Carlson, D.F., Chamecki, M., Harcourt, R.R., Haus, B.K., Fox-Kemper, B., Molemaker, M.J., Poje, A.C., & Yang, D. (2020). Advances in observing and understanding small-scale open ocean circulation during the Gulf of Mexico research initiative era. *Fronteirs in Marine Science, 7.* https://doi.org/10.3389/fmars.2020.00349

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30204	Chemical and Physical Modeling and Behavior	Oceanographic models	Develop empirical data sets to incorporate photochemical processes into oil spill fate, transport, and response operation models.	Literature/Data Call	Ward, C.P., Reddy, C.M., & Overton, E.B. (2020, April 28). *Why sunlight matters for marine oil spills.* EOS, 101. https://doi.org/10.1029/2020EO143427.
30205	Chemical and Physical Modeling and Behavior	Emerging Crude	Synthesize existing information on fate and transport of oil sands products to provide science-based response advice.	SME Evaluation	N/A
30205	Chemical and Physical Modeling and Behavior	Emerging Crude	Study the persistence of oil sands products in marine and freshwater environments.	SME Evaluation	N/A
30205	Chemical and Physical Modeling and Behavior	Emerging Crude	Synthesize existing information on chemical and physical characteristics of various crudes (including blends of dilbit, synbit and Bakken Crude) to provide science-based response advice.	SME Evaluation	N/A
30205	Chemical and Physical Modeling and Behavior	Emerging Crude	Develop studies to quantify the weathering rates and final fate of chemically dispersed vs. physically-dispersed oil droplets under different scenarios with emerging crude oils.	SME Comments	N/A
30205	Chemical and Physical Modeling and Behavior	Emerging Crude	Research how dilbit and its chemical constituents behave in the aquatic environments to aide in evidence-based environmental risk assessments and spill-management strategies for this unconventional oil product.	Literature/Data Call	Stoyanovich, S.S., Yang, Z., Hanson, M., Hollebone, B.P., Orihel, D.M., Palace, V., Rodriguez-Gil, J.L., Faragher, R., Mirnaghi, F.S., Shah, K., & Blais, J.M. (2019). Simulating a spill of diluted bitumen: Environmental weathering and submergence in a model freshwater system. *Environmental Toxicology and Chemistry, 38* (12), 2621-2628. https://doi.org/10.1002/etc.4600
30205	Chemical and Physical Modeling and Behavior	Emerging Crude	Study the effects of different diluents and bitumens by conducting laboratory and meso-scale testing with additional blends..	Literature/Data Call	Witt O'Brien's, Polaris Applied Sciences, & Western Canada Marine Response Corporation. (2013). *A study of fate and behavior of diluted bitumen oils on marine waters.* Trans Mountain Pipeline ULC (TMPL). https://s3-us-west-2.amazonaws.com/transmountain-craftcms/documents/1391734754-astudyoffateandbehaviourofdilutedbitumenoilsonmarinewater.pdf?mtime=20170721171558
30205	Chemical and Physical Modeling and Behavior	Emerging Crude	Test dispersant effectiveness using fluorometers and for different dilbit blends under variable conditions of Day 0 to Day 1 weathering to evaluate its use as an early countermeasure option.	Literature/Data Call	Witt O'Brien's, Polaris Applied Sciences, & Western Canada Marine Response Corporation. (2013). *A study of fate and behavior of diluted bitumen oils on marine waters.* Trans Mountain Pipeline ULC (TMPL). https://s3-us-west-2.amazonaws.com/transmountain-craftcms/documents/1391734754-astudyoffateandbehaviourofdilutedbitumenoilsonmarinewater.pdf?mtime=20170721171558
30205	Chemical and Physical Modeling and Behavior	Emerging Crude	Conduct controlled burning tests on various dilbit blends and a range of initial oil thicknesses to determine operational feasibility and constraints as an early countermeasure.	Literature/Data Call	Witt O'Brien's, Polaris Applied Sciences, & Western Canada Marine Response Corporation. (2013). *A study of fate and behavior of diluted bitumen oils on marine waters.* Trans Mountain Pipeline ULC (TMPL). https://s3-us-west-2.amazonaws.com/transmountain-craftcms/documents/1391734754-astudyoffateandbehaviourofdilutedbitumenoilsonmarinewater.pdf?mtime=20170721171558
30205	Chemical and Physical Modeling and Behavior	Emerging Crude	Conduct real-world testing with recovery equipment on oil sands products to determine whether a region is prepared for an oil sands products spill, and which equipment will be effective.	Literature/Data Call	National Oceanic and Atmospheric Administration. (2013). *Transporting Alberta oil sands products: Defining the issues and assessing the risks.* https://crrc.unh.edu/sites/default/files/media/docs/noaa oil sands report 09.2013.pdf
30205	Chemical and Physical Modeling and Behavior	Emerging Crude	Study different classes of dilbit to determine how different variations in their chemical composition may impact their degradation rates.	Literature/Data Call	Deshpande, R.S., Sundaravadivelu, D., Techtmann, S., Conmy, R.N., Santo Domingo, J.W., & Campo, P. (2018). Microbial degradation of Cold Lake Blend and Western Canadian select dilbits by freshwater enrichments. *Journal of Hazardous Materials, 352,* 111-120. http://dx.doi.org/10.1016/j.jhazmat.2018.03.030
30205	Chemical and Physical Modeling and Behavior	Emerging Crude	Study how weathering affects the environmental fate and behavior of spilled oil sands products, particularly under differing conditions of salinity and temperature.	Literature/Data Call	National Oceanic and Atmospheric Administration. (2013). *Transporting Alberta oil sands products: Defining the issues and assessing the risks.* https://crrc.unh.edu/sites/default/files/media/docs/noaa oil sands report 09.2013.pdf
30205	Chemical and Physical Modeling and Behavior	Emerging Crude	Research the physical properties and behavior of the diluent component of oil sands mixtures, and the associated potential public health concerns	Literature/Data Call	National Oceanic and Atmospheric Administration. (2013). *Transporting Alberta oil sands products: Defining the issues and assessing the risks.* https://crrc.unh.edu/sites/default/files/media/docs/noaa oil sands report 09.2013.pdf
30205	Chemical and Physical Modeling and Behavior	Emerging Crude	Research the toxicity and environmental fate of unweathered and weathered dilbits is needed to allow for more informed hazard assessments in case of dilbit spills in aquatic and terrestrial environments.	Literature/Data Call	Barron, M.G., Conmy, R.N., Holder, E.L., Meyer, P., Wilson, G.J., Principle, V.E., & Willming, M.M. (2018). Toxicity of Cold Lake Blend and Western Canadian Select dilbits to standard aquatic test species. *Chemosphere, 191,* 1-6. https://doi.org/10.1016/j.chemosphere.2017.10.014
30205	Chemical and Physical Modeling and Behavior	Emerging Crude	Identify equipment to assess and cleanup potential subsurface spills that are potentially significant in an oil sands product spill.	Literature/Data Call	UNH Center for Spills in the Environment. (2013). *Alberta oil sands workshop.* https://crrc.unh.edu/sites/crrc.unh.edu/files/media/docs/Workshops/oil_sands_washington/OilSandsProductsWorkshopReport_Washington%20TOTAL.pdf
30205	Chemical and Physical Modeling and Behavior	Emerging Crude	Research the fate and transport of oil sands products in the environment.	Literature/Data Call	UNH Center for Spills in the Environment. (2013). *Alberta oil sands workshop.* https://crrc.unh.edu/sites/crrc.unh.edu/files/media/docs/Workshops/oil_sands_washington/OilSandsProductsWorkshopReport_Washington%20TOTAL.pdf
30206	Chemical and Physical Modeling and Behavior	Sinking Oil & MOSFFA	Study the marine snow process at low oil concentrations.	Public Listening Sessions	N/A
30206	Chemical and Physical Modeling and Behavior	Sinking Oil & MOSFFA	Explore the field-representative conditions with low oil concentrations and distinguish between scenarios with surface oil and oil dispersed subsea (naturally or not) including the development of lab protocols designed to duplicate representative conditions.	Public Listening Sessions	N/A
30206	Chemical and Physical Modeling and Behavior	Sinking Oil & MOSFFA	Model the factors controlling MOSSFA intensity and destruction.	Public Listening Sessions	N/A
30206	Chemical and Physical Modeling and Behavior	Sinking Oil & MOSFFA	Research the role of turbulence in formation of marine snow, specifically on how waves and wind impact the fate of aggregates.	Literature/Data Call	UNH Center for Spills in the Environment. (2013). *Marine oil snow sedimentation and flocculent accumulation (MOSSFA) workshop.* https://gulfresearchinitiative.org/wp-content/uploads/MOSSFAWorkshopReport2014.pdf
30206	Chemical and Physical Modeling and Behavior	Sinking Oil & MOSFFA	Research the role of particles on the formation of the snow/oil aggregates by synthesizing data on Saharan dust to determine how marine oil interacts with dust particles in the formation of aggregates.	Literature/Data Call	UNH Center for Spills in the Environment. (2013). *Marine oil snow sedimentation and flocculent accumulation (MOSSFA) workshop.* https://gulfresearchinitiative.org/wp-content/uploads/MOSSFAWorkshopReport2014.pdf
30206	Chemical and Physical Modeling and Behavior	Sinking Oil & MOSFFA	Develop research on MOSSFA timescales for formation, sinking, and incorporation into sediments.	Literature/Data Call	UNH Center for Spills in the Environment. (2013). *Marine oil snow sedimentation and flocculent accumulation (MOSSFA) workshop.* https://gulfresearchinitiative.org/wp-content/uploads/MOSSFAWorkshopReport2014.pdf
30206	Chemical and Physical Modeling and Behavior	Sinking Oil & MOSFFA	Research the factors that either enhance or diminish MOS production across a variety of environments to develop an understanding of the forcing factors that lead to MOSSFA events.	Literature/Data Call	Burd, A.B., Chanton, J.P., Daly, K.L., Gilbert, S., Passow, U., & Quigg, A. (2020). The science behind marine-oil snow and MOSSFA: Past, present, and future. *Progress in Oceanography, 187,* 102398. https://doi.org/10.1016/j.pocean.2020.102398
30206	Chemical and Physical Modeling and Behavior	Sinking Oil & MOSFFA	Research and determine which concentrations and conditions would optimally trigger MOS under various circumstances.	Literature/Data Call	Kostka, J.S. (2020). Microbial genomics of the global ocean system. *American Society for Microbiology.* https://asm.org/Reports/Microbial-Genomics-of-the-Global-Ocean-System-1
30206	Chemical and Physical Modeling and Behavior	Sinking Oil & MOSFFA	Investigate the interactions between MOS and photooxidation.	Literature/Data Call	Burd, A.B., Chanton, J.P., Daly, K.L., Gilbert, S., Passow, U., & Quigg, A. (2020). The science behind marine-oil snow and MOSSFA: Past, present, and future. *Progress in Oceanography, 187,* 102398. https://doi.org/10.1016/j.pocean.2020.102398
30206	Chemical and Physical Modeling and Behavior	Sinking Oil & MOSFFA	Research the factors controlling aggregate fractal structure, stickiness, and disaggregation rates to improve the model predictions and comparison with data.	Literature/Data Call	Gulf of Mexico Research Initiative. (2018). *Synthesis workshop I MOSSFA - Core area two.* https://gulfresearchinitiative.org/wp-content/uploads/MOSSFA-Workshop-Report-Nov2018-APRIL-2019-Final.pdf
30206	Chemical and Physical Modeling and Behavior	Sinking Oil & MOSFFA	Conduct laboratory experiments of resuspension and breakup of oil- particle aggregates (OPAs).	Literature/Data Call	Fitzpatrick, F.A., Boufadel, M.C., Johnson, R., Lee, K., Graan, T.P., Bejarano, A.C., Zhu, Z., Waterman, D., Capone, D.M., Hayter, E., Hamilton, S.K., Dekker, T., Garcia, M.H., & Hassan, J.S. (2015). *Oil-particle interactions and submergence from crude oil spills in marine and freshwater environments - Review of the science and future science needs.* U.S. Geological Survey. https://pubs.usgs.gov/of/2015/1076/
30301	Oil Spill Detection and Surveillance	Remote Detection	Advance and refine technologies that enable remote oil spill detection and mapping in low visibility conditions (e.g., night, fog, ice cover) to minimize false-positives and to accurately measure slick thickness.	SME Evaluations	N/A
30301	Oil Spill Detection and Surveillance	Remote Detection	Field test developed technologies for detecting and tracking oil under ice, encapsulated in ice, and floating within broken ice fields.	SME Evaluations	N/A
30301	Oil Spill Detection and Surveillance	Remote Detection	Identify specific characteristics of crude oil exposed to the full radiation spectrum (at hyperspectral intervals) and develop high resolution sensors for oil spill visualization, detection and quantification.	SME Evaluations	N/A
30301	Oil Spill Detection and Surveillance	Remote Detection	Integrate remote sensing and observational techniques to detect and track ice and oil to aid with contingency planning in the Arctic.	Public Listening Sessions	N/A
30301	Oil Spill Detection and Surveillance	Remote Detection	Conduct a field-scale experiment to determine airborne remote sensor detection parameters for oil in and under first-year sea ice..	Public Listening Sessions	N/A
30301	Oil Spill Detection and Surveillance	Remote Detection	Develop unmanned response vehicles to deploy remote sensing equipment.	Public Listening Sessions	N/A

The information in this database has not been processed or reviewed by the ICCOPR and is considered source/raw data. The approved final list of ICCOPR Research Needs can be found in Chapter 9 of the Oil Pollution Research and Technology Plan.

ICCOPR NUMBER	ICCOPR SRA	Subcategory	Research Need	Source	Citation
30301	Oil Spill Detection and Surveillance	Remote Detection	Develop technologies to accurately characterize, quantify, and measure the surface oil state (i.e., emulsified or not), oil volume, and oil thickness in the lab and in the field, above and below to surface.	Public Listening Sessions/data call	N/A
30301	Oil Spill Detection and Surveillance	Remote Detection	Develop miniaturized sensors for use on unmanned automatic systems (UAS) for remote detection and tracking of oil spill contaminates.	Public Listening Sessions	N/A
30301	Oil Spill Detection and Surveillance	Remote Detection	Expand capabilities for integration of unmanned aircraft/aerial systems for oil spill detection, tracking, and building derived products for decision support process.	Public Listening Sessions	N/A
30301	Oil Spill Detection and Surveillance	Remote Detection	Develop a standard protocols and data products that integrate data across all sensors for the interpretation and use of data from different sensors.	Literature/Data Call	DiPinto, L. (2020). *Three-dimensional mapping of dissolved hydrocarbons and oil droplets usin a REMUS-600 autonomous underwater vehicle* (Project No. 1100). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/three-dimensional-mapping-of-dissolved-hydrocarbons-and-oil-droplets-using-a-remus
30301	Oil Spill Detection and Surveillance	Remote Detection	Investigate a bio-degradable solution and/or steam for de-icing equipment and sensors.	Literature/Data Call	Yankielun, N.E., Barone, R., Cables, E., Locklear, C., & Wilson, K. (2013). *Great Lakes oil-in-ice demonstration 3 final report.* United States Coast Guard Research and Development Center. https://rrt5.org/Portals/0/docs/GreatLakesDemonstration3FinalReport.pdf
30301	Oil Spill Detection and Surveillance	Remote Detection	Develop better methods to identify false positives as part of overflight observation training.	Literature/Data Call	UNH Coastal Response Research Center. (2015). *Oil observing tools workshop.* https://crrc.unh.edu/oil_observing
30301	Oil Spill Detection and Surveillance	Remote Detection	Develop a tool for a quick validation of false positives from a handheld system or coordinated multi-sensor system.	Literature/Data Call	UNH Coastal Response Research Center. (2015). *Oil observing tools workshop.* https://crrc.unh.edu/oil_observing
30301	Oil Spill Detection and Surveillance	Remote Detection	Develop broadband systems for the transfer of data from Autonomous Underwater Vehicles (AUS).	Literature/Data Call	Nuka Research and Planning Group, LLC. (2015). *Final report: OSRR-funded project key findings and recommendations* (Project No. 1056). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/osrr-1056-catalog-osrr-funded-research-recommendations-and-key-findings
30301	Oil Spill Detection and Surveillance	Remote Detection	Update SMART protocols to include remote sensing operations.	Literature/Data Call	UNH Coastal Response Research Center. (2015). *Oil observing tools workshop.* https://crrc.unh.edu/oil_observing
30301	Oil Spill Detection and Surveillance	Remote Detection	Create database with several examples of mineral oils and look-alikes and validate in the field using a multi-sensor approach.	Literature/Data Call	Genovez, P.C., Jones, C.E., Saint'Anna, S.J., & Freitas, C.C. (2019). Oil slick characterization using a statistical region-based classifier applied to UAVSAR data. *Journal of Marine Science and Engineering, 7* (2), 36. https://doi.org/10.3390/jmse7020036
30301	Oil Spill Detection and Surveillance	Remote Detection	Develop workable combination packages of existing technologies and develop multiple platforms and sensor packages based on the most common response or assessment needs.	Literature/Data Call	UNH Coastal Response Research Center. (2015). *Oil observing tools workshop.* https://crrc.unh.edu/oil_observing
30301	Oil Spill Detection and Surveillance	Remote Detection	Develop a "go kit" multi sensor package (SAR, multispectral, infrared, high resolution imagery) for remote sensing operations.	Literature/Data Call	UNH Coastal Response Research Center. (2015). *Oil observing tools workshop.* https://crrc.unh.edu/oil_observing
30301	Oil Spill Detection and Surveillance	Remote Detection	Develop detailed and easily implemented alternatives for processing the data collected by the detection sensors and how this data is used during evaluation in real-world environments.	Literature/Data Call	Hansen, K.A., Guidroz, L., Hazel, B., Fitzpatrick, M., & Johnson, G.W. (2014). Sunken oil recovery system recommendations. *International Oil Spill Conference Proceedings, 2014* (1), 2014-2023. https://doi.org/10.7901/2169-3358-2014.1.2014
30301	Oil Spill Detection and Surveillance	Remote Detection	Evaluate the feasibility and integration to an autonomous underwater vehicle (AUV) payload system and demonstrate the deployment concept in a simulated control scenario.	Literature/Data Call	Gonzalez, G. & Lohe, R. (2018). *Autonomous underwater vehicle deployable oil spill igniter* (Project No. 1092). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/autonomous-underwater-oil-spill-igniter
30301	Oil Spill Detection and Surveillance	Remote Detection	Research and develop a response framework to determine the appropriate sensors to use during a response and how decision-makers will use data to determine the proper data format and other specifications.	Literature/Data Call	United States Coast Guard Research & Development Center. (2017). *Federal On-scene Coordinator (FOSC) guide for oil in ice.* U.S. Department of Homeland Security. https://homeport.uscg.mil/Lists/Content/Attachments/43701/USCG%20FOSC%20Guide%20-%20Oil%20in%20Ice.pdf
30302	Oil Spill Detection and Surveillance	Monitoring	Develop a refined SMART, or equivalent protocol, and operational procedures for use during subsea and surface responses.	SME Evaluations	N/A
30302	Oil Spill Detection and Surveillance	Monitoring	Advance technologies that analyze physio-chemical properties of spilled oil with automated algorithms to get near real time data (quick turnaround) during in situ burning (ISB) to improve decision making.	SME Evaluations	N/A
30302	Oil Spill Detection and Surveillance	Monitoring	Evaluate the efficacy of new technologies developed to improve oil, dispersant, and oil/dispersant detection in the water column and on the seafloor, and for monitoring dispersant effectiveness in the field.	SME Evaluations	N/A
30302	Oil Spill Detection and Surveillance	Monitoring	Develop a process, with Federal support, to obtain long-term permits for the use of unmanned aircraft systems (UAS).	Public Listening Sessions	N/A
30302	Oil Spill Detection and Surveillance	Monitoring	Advance Arctic mapping by using satellite and airborne imagery to capture the dynamic, rapidly changing Arctic coastline including ice thickness, concentration, and extent is essential for anticipating the likely behavior of oil in, under, and on ice.	Public Listening Sessions	N/A
30302	Oil Spill Detection and Surveillance	Monitoring	Determine the best technologies that facilitate the transfer of images captured from Aircraft of Opportunity (AOO) in support of remote sensing missions.	Public Listening Sessions	N/A
30302	Oil Spill Detection and Surveillance	Monitoring	Research ways to improve oil spill alarm systems using the acoustic based sonar system.	Literature/Data Call	Eriksen, P.K. (2013). Leakage and oil spill detection utilizing active acoustic systems. *2013 IEEE International Underwater Technology Symposium (UT),* 1-8. DOI: 10.1109/UT.2013.6519891
30302	Oil Spill Detection and Surveillance	Monitoring	Develop technology to monitor and assess the transport and fate of spreading oil in ice and below ice.	Literature/Data Call	Fitzpatrick, F.A., Boufadel, M.C., Johnson, R., Lee, K., Graan, T.P., Bejarano, A.C., Zhu, Z., Waterman, D., Capone, D.M., Hayter, E., Hamilton, S.K., Dekker, T., Garcia, M.H., & Hassan, J.S. (2015). *Oil-particle interactions and submergence from crude oil spills in marine and freshwater environments - Review of the science and future science needs.* U.S. Geological Survey. https://pubs.usgs.gov/of/2015/1076/
30302	Oil Spill Detection and Surveillance	Monitoring	Develop additional methods, models, and devices that can help to quantify the subsurface oil quantity and PAH concentrations.	Literature/Data Call	National Oceanic and Atmospheric Administration. (2018). *Deepwater Horizon lessons learned - Methodology and operational tools to assess future oil spills* (Project No. 1079). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/osrr-1079-deepwater-horizon-lessons-learned-methodology-and-operational-tools-to
30302	Oil Spill Detection and Surveillance	Monitoring	Evaluate Nuclear Magnetic Resonance (NMR) and ground penetrating radar (GPR) to identify oil in ice or snow.	Literature/Data Call	UNH Coastal Response Research Center. (2015). *Oil observing tools workshop.* https://crrc.unh.edu/oil_observing
30303	3303-Oil Spill Detection and Surveillance	Submerged Oil Detection	Evaluate the safety and effectiveness Light Detection and Ranging (LiDAR), during operations to detect submerged oil on the seafloor and in the water column.	SME Evaluation	N/A
30303	3303-Oil Spill Detection and Surveillance	Submerged Oil Detection	Develop new or improve existing chemical sensors for detecting submerged oil in deepwater (over 1,000 feet) and ultra-deepwater (over 5,000 feet).	SME Evaluation	N/A
30303	3303-Oil Spill Detection and Surveillance	Submerged Oil Detection	Develop methods to calibrate the degree of oiling on snare sampling systems with the amount of oil on the seafloor or in the water column.	SME Evaluation	N/A
30303	3303-Oil Spill Detection and Surveillance	Submerged Oil Detection	Assess infrared polarization remote sensing of sub-surface releases of fuel oils.	Public Listening Sessions	N/A
30303	3303-Oil Spill Detection and Surveillance	Submerged Oil Detection	Develop methods to use data, collected by an autonomous underwater vehicle (AUV) to indicate the locations and concentrations of submerged oil, in real time to guide the AUV in continued searching, leveraging a new-generation Bayesian statistic model for tracking submerged oil based on field data.	Public Listening Sessions	N/A
30303	3303-Oil Spill Detection and Surveillance	Submerged Oil Detection	Expand remote sensor oil detection capabilities to characterize crude oil in the water column and seafloor.	Public Listening Sessions	N/A
30303	3303-Oil Spill Detection and Surveillance	Submerged Oil Detection	Research and develop new methods of detecting, monitoring, containing, and recovering sunken or submerged oil.	Literature/Data Call	National Oceanic and Atomospheric Administration. (2013). *Transportation Alberta oil sands products: Defining the issues and assessing the risks.* https://crrc.unh.edu/sites/default/files/media/docs/noaa_oil_sands_report_09.2013.pdf
30303	3303-Oil Spill Detection and Surveillance	Submerged Oil Detection	Develop oil spill simulants to improve sunken oil detection methods.	Literature/Data Call	American Petroleum Institute. (2016). *Sunken oil detectiion and recovery* (Report No. 1154-1). http://www.oilspillprevention.org/-/media/Oil-Spill-Prevention/spillprevention/r-and-d/inland/sunken-oil-technical-report-pp2.pdf

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ICCOPR NUMBER	ICCOPR SRA	Subcategory	Research Need	Source	Citation
30303	3303-Oil Spill Detection and Surveillance	Submerged Oil Detection	Study the sensitivity of laser fluorosensors to sunken oil in the form of oil-particle aggregates mixed into bottom sediments.	Literature/Data Call	American Petroleum Institute. (2016). *Sunken oil detectiion and recovery* (Report No. 1154-1). http://www.oilspillprevention.org/-/media/Oil-Spill-Prevention/spillprevention/r-and-d/inland/sunken-oil-technical-report-pp2.pdf
30401	In- and On-water Containment and Recovery	Control/Recovery Technology	Operationalize new mechanical recovery methods/technologies for logistically challenging (e.g., cold water, ice, broken ice) Arctic conditions.	SME Evaluation	N/A
30401	In- and On-water Containment and Recovery	Control/Recovery Technology	Improve recovery tools and systems to make them more selective when recovering oil that is submerged, suspended in the water column, or on the seafloor.	SME Evaluation	N/A
30401	In- and On-water Containment and Recovery	Control/Recovery Technology	Develop control and recovery capabilities for oil in river conditions with pack ice and ice flows.	SME Evaluation	N/A
30401	In- and On-water Containment and Recovery	Control/Recovery Technology	Develop materials and technologies to improve oleophilic skimmer oil recovery rate and efficiency in thin oil slicks.	Public Listening Sessions	N/A
30401	In- and On-water Containment and Recovery	Control/Recovery Technology	Develop skimmers for very low sulfur fuel oil responses.	Public Listening Sessions	N/A
30401	In- and On-water Containment and Recovery	Control and Recovery Technology	Conduct open water controlled releases or oil to test and develop response technologies.	Public Listening Sessions	N/A
30401	In- and On-water Containment and Recovery	Control and Recovery Technology	Conduct controlled real-world field exercises to find and address specific gaps in current operational response capability of Arctic offshore oil spill detection and response.	Public Listening Sessions	N/A
30401	In- and On-water Containment and Recovery	Control and Recovery Technology	Expand the UAF test basin facility to include under ice capabilities.	Public Listening Sessions	N/A
30401	In- and On-water Containment and Recovery	Control and Recovery Technology	Study the limitations of mechanical recovery in both open water and ice.	Literature/Data Call	National Research Council. (2014). *Responding to Oil Spills in the U.S. Arctic Marine Environment.* Washington, DC: The National Academies Press. https://doi.org/10.17226/18625.
30401	In- and On-water Containment and Recovery	Control/Recovery Technology	Research techniques that can permit an ROV or other mechanism to reach under and recover oil that is under the ice.	Literature/Data Call	United States Coast Guard Research & Development Center. (2017). *Federal On-scene Coordinator (FOSC) guide for oil in ice.* U.S. Department of Homeland Security. https://homeport.uscg.mil/Lists/Content/Attachments/43701/USCG%20FOSC%20Guide%20-%20Oil%20in%20Ice.pdf
30401	In- and On-water Containment and Recovery	Control/Recovery Technology	Develop techniques that can clear a long length hose in extreme cold to prevent it from freezing during skimming operations.	Literature/Data Call	United States Coast Guard Research & Development Center. (2017). *Federal On-scene Coordinator (FOSC) guide for oil in ice.* U.S. Department of Homeland Security. https://homeport.uscg.mil/Lists/Content/Attachments/43701/USCG%20FOSC%20Guide%20-%20Oil%20in%20Ice.pdf
30401	In- and On-water Containment and Recovery	Control/Recovery Technology	Create a global standard definition for sorbent effectiveness.	Literature/Data Call	McCleney, A. B., Manders, J., Supak, K., Cortes, M., Green, S., Gutierrez, L., Marroquin, J., & McClusky, C. (2020). *Assessment of Innovative Sorbents - FINAL REPORT BSEE Contract No. 140E0119F0106* . Bureau of Safety and Environmental Enforcement (BSEE). https://www.bsee.gov/sites/bsee.gov/files/osrr-oil-spill-response-research/oil-spill-response/1118aa.pdf
30401	In- and On-water Containment and Recovery	Control/Recovery Technology	Study and increase the range of oil types that can be sorbed by sorbents.	Literature/Data Call	McCleney, A. B., Manders, J., Supak, K., Cortes, M., Green, S., Gutierrez, L., Marroquin, J., & McClusky, C. (2020). *Assessment of Innovative Sorbents - FINAL REPORT BSEE Contract No. 140E0119F0106* . Bureau of Safety and Environmental Enforcement (BSEE). https://www.bsee.gov/sites/bsee.gov/files/osrr-oil-spill-response-research/oil-spill-response/1118aa.pdf
30401	In- and On-water Containment and Recovery	Control/Recovery Technology	Research materials that can attract oil to the sorbent.	Literature/Data Call	McCleney, A. B., Manders, J., Supak, K., Cortes, M., Green, S., Gutierrez, L., Marroquin, J., & McClusky, C. (2020). *Assessment of Innovative Sorbents - FINAL REPORT BSEE Contract No. 140E0119F0106* . Bureau of Safety and Environmental Enforcement (BSEE). https://www.bsee.gov/sites/bsee.gov/files/osrr-oil-spill-response-research/oil-spill-response/1118aa.pdf
30401	In- and On-water Containment and Recovery	Control/Recovery Technology	Research natural materials to make sorbents that can be left to degrade in-situ.	Literature/Data Call	McCleney, A. B., Manders, J., Supak, K., Cortes, M., Green, S., Gutierrez, L., Marroquin, J., & McClusky, C. (2020). *Assessment of Innovative Sorbents - FINAL REPORT BSEE Contract No. 140E0119F0106* . Bureau of Safety and Environmental Enforcement (BSEE). https://www.bsee.gov/sites/bsee.gov/files/osrr-oil-spill-response-research/oil-spill-response/1118aa.pdf
30401	In- and On-water Containment and Recovery	Control/Recovery Technology	Develop mechanical response tools that are effective in spring broken ice and fall freeze-up conditions.	Literature/Data Call	UNH Coastal Response Research Center. (2012). *North Slope Borough Oil Spill Workshop: Natural Resource Damage Assessment (NRDA) & Environmental Response Management Application (ERMA ®).* University of New Hampshire. https://crrc.unh.edu/sites/crrc.unh.edu/files/media/docs/Workshops/nsb_12/NorthSlopeBorough_workshop_report_FINAL_appendix.pdf
30401	In- and On-water Containment and Recovery	Control/Recovery Technology	Develop ice management techniques for skimmers.	Literature/Data Call	Hansen, K. A. (2014). Responding to Oil Spills in Ice. *International Oil Spill Conference Proceedings* , *2014* (1), 1200–1214. https://doi.org/10.7901/2169-3358-2014.1.1200
30401	In- and On-water Containment and Recovery	Control/Recovery Technology	Develop recovery techniques for Marine Oil Snow Sedimentation and Flocculent Accumulation (MOSSFA).	Literature/Data Call	Jacketti, M., Beegle-Krause, C. J., & Englehardt, J. D. (2020). A review on the sinking mechanisms for oil and successful response technologies. *Marine Pollution Bulletin* , *160* , 111626. https://doi.org/10.1016/j.marpolbul.2020.111626
30402	In- and On-water Containment and Recovery	Recovery Operations and Testing	Develop/improve standardized testing protocols (especially for wave tanks) that yield accurate oil recovery limits that reflect response operations, specifically in rivers (swift water) and Arctic conditions.	SME Evaluation	N/A
30402	In- and On-water Containment and Recovery	Recovery Operations and Testing	Conduct field tests of cleanup techniques and create protocols for various habitats and conditions, including Arctic conditions.	SME Evaluation	N/A
30402	In- and On-water Containment and Recovery	Recovery Operations and Testing	Develop surrogates for different types of oil to be used for training and for research and development testing.	SME Evaluation	N/A
30402	In- and On-water Containment and Recovery	Recovery Operations and Testing	Develop methods to recover offshore oil from thin oil slicks or dispersed oil that are not recoverable by skimmers or containment barriers.	Public Listening Sessions	N/A
30402	In- and On-water Containment and Recovery	Recovery Operations and Testing	Develop oil collection and containment systems that can increase encounter and capture rate of surface oil slicks and ideally be integrated with existing Oil Spill Removal Organization equipment.	Public Listening Sessions	N/A
30402	In- and On-water Containment and Recovery	Recovery Operations and Testing	Develop a field scale test protocol for testing sorbents.	Public Listening Session	N/A

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ICCOPR NUMBER	ICCOPR SRA	Subcategory	Research Need	Source	Citation
30402	In- and On-water Containment and Recovery	Recovery Operations and Testing	Research how computational fluid dynamics modeling and physical scaled testing of oil containment booms may be used to verify expected performance of full scale boom systems.	Public Listening Session	N/A
30402	In- and On-water Containment and Recovery	Recovery Operations and Testing	Develop a surrogate or simulant that could be permitted for release offshore to allow oil containment booms to be field tested for failure mechanisms such as entrainment and drainage.	Public Listening Session	N/A
30402	In- and On-water Containment and Recovery	Recovery Operations and Testing	Develop methods and tools are needed to recover oil trapped under ice and to respond to subsea spills.	Literature/Data Call	UNH Coastal Response Research Center. (2012). *North Slope Borough Oil Spill Workshop: Natural Resource Damage Assessment (NRDA) & Environmental Response Management Application (ERMA ®).* University of New Hampshire. https://crrc.unh.edu/sites/crrc.unh.edu/files/media/docs/Workshops/nsb_12/NorthSlopeBorough_workshop_report_FINAL_appendix.pdf
30402	In- and On-water Containment and Recovery	Recovery Operations and Testing	Research and identify optimal surface parameters for oleophilic skimmers and develop methods to compare oleophilic skimmer performance.	Literature/Data Call	Nuka Research and Planning Group, LLC. (2015). *Final report: OSRR-funded project key findings and recommendations* (Project No. 1056). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/osrr-1056-catalog-osrr-funded-research-recommendations-and-key-findings
30402	In- and On-water Containment and Recovery	Recovery Operations and Testing	Finalize and test a permitting process for surrogate or simulant use.	Literature/Data Call	Nuka Research and Planning Group, LLC. (2015). *Permitting the use of oil spill simulants: Identifying options and building consensus final report* (Project No. 1032).. U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/osrr-1032-permitting-use-oil-spill-simulants-identifying-options-and-building
30402	In- and On-water Containment and Recovery	Recovery Operations and Testing	Develop an improved method to estimate mechanical recovery rates and efficiencies both nearshore and offshore.	Literature/Data Call	Genwest Systems, Inc. (2012). *EDRC project final report.* U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/osrr-673-effective-daily-recovery-capacity-edrc-project
30402	In- and On-water Containment and Recovery	Recovery Operations and Testing	Develop and execute targeted programs for the development of skimmers in operational environments of interest (i.e., arctic versus warm environments).	Literature/Data Call	Federici, C. & Mintz, J. (2014). *Oil properties and their impact on spill response options* . CNA Analysis & Solutions. https://www.bsee.gov/sites/bsee.gov/files/osrr-oil-spill-response-research/1017aa.pdf
30402	In- and On-water Containment and Recovery	Recovery Operations and Testing	Develop novel technologies customized to the specific characteristic of cold and harsh environment.	Literature/Data Call	Li, P., Cai, Q., Lin, W., Chen, B., & Zhang, B. (2016). Offshore oil spill response practices and emerging challenges. *Marine Pollution Bulletin, 110* (1), 6-27. https://doi.org/10.1016/j.marpolbul.2016.06.020
30402	In- and On-water Containment and Recovery	Recovery Operations and Testing	Refine state-of-knowledge regarding oil simulant or surrogate materials by documenting future use.	Literature/Data Call	Nuka Research and Planning Group, LLC. (2015). *Permitting the use of oil spill simulants: Identifying options and building consensus final report* (Project No. 1032).. U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/osrr-1032-permitting-use-oil-spill-simulants-identifying-options-and-building
30402	In- and On-water Containment and Recovery	Recovery Operations and Testing	Develop an environmentally benign oil simulant material.	Literature/Data Call	Nuka Research and Planning Group, LLC. (2015). *Permitting the use of oil spill simulants: Identifying options and building consensus final report* (Project No. 1032).. U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/osrr-1032-permitting-use-oil-spill-simulants-identifying-options-and-building
30402	In- and On-water Containment and Recovery	Recovery Operations and Testing	Develop sustainable physical and mechanical clean-up technologies and evaluate chemical dispersants for efficacy and toxicity.	Literature/Data Call	Wan, Z. & Chen, J. (2018, August 6). *Human errors are behind most oil-tanker spills.* Nature. https://www.nature.com/articles/d41586-018-05852-0
30500	Shore Containment and Recovery	No Subcategory	Study the effectiveness of a range of technologies for shoreline or nearshore cleanup; including dispersants, bioremediation agents, shoreline cleaners, and mechanical methods.	SME Evaluation	N/A
30500	Shore Containment and Recovery	No Subcategory	Study the effectiveness of surface washing for shoreline cleanup and develop standards for surface washing.	SME Evaluation	N/A
30500	Shore Containment and Recovery	No Subcategory	Conduct research to assess the ability of chemicals to prevent oil from reaching or sticking to shorelines.	SME Evaluation	N/A
30500	Shore Containment and Recovery	No Subcategory	Study if the effective use of dispersants reduce the impacts of the spill to shoreline and water surface resources without significantly increasing impacts to water-column and benthic resources.	Literature/Data Call	Venosa, A.D., Anastas, P.T., Barron, M.G., Conmy, R.N., Greenberg, M.S., & Wilson, G.J. (2014). Science-based decision making on the use of dispersants in the deepwater horizon oil spill. *Oil Spill Remediation.* https://doi.org/10.1002/9781118825662.ch1
30500	Shore Containment and Recovery	No Subcategory	Develop best practices for the use of drones in SCAT data collection.	Literature/Data Call	UNH Coastal Response Research Center. (2017). *SCAT for tomorrow.* University of New Hampshire. https://crrc.unh.edu/SCAT
30500	Shore Containment and Recovery	No Subcategory	Expand current capabilities of Oil Detection Canines (ODCs) to support shoreline spill response surveys and operations.	Literature/Data Call	API, 2016. Canine Oil Detection: Field Trials Report. American Petroleum Institute, Technical Report 1149-3, Washington DC, 48 pp.
30500	Shore Containment and Recovery	No Subcategory	Research shoreline cleaning agents for cleaner effectiveness using a variety of available cleaning agents to assist with pre-approvals should they be needed.	Literature/Data Call	Witt O'Brien's, Polaris Applied Sciences, & Western Canada Marine Response Corporation. (2013). *A study of fate and behavior of diluted bitumen oils on marine waters.* Trans Mountain Pipeline ULC (TMPL). https://s3-us-west-2.amazonaws.com/transmountain-craftcms/documents/1391734754-astudyoffateandbehaviourofdilutedbitumenoilsonmarinewater.pdf?mtime=20170721171558
30500	Shore Containment and Recovery	No Subcategory	Develop SCAT job-aids and manuals tailored to inland spill response and that provide assessment and response guidance to address contamination or potential contamination of drinking and groundwater sources.	Literature/Data Call	Whelan, A., Clark, J., Andrew, G., Michel, J., & Benggio, B. (2014). Developing cleanup endpoints for inland oil spills. *International Oil Spill Conference Proceedings, 2014* (1), 1267-1280. https://doi.org/10.7901/2169-3358-2014.1.1267
30500	Shore Containment and Recovery	No Subcategory	Develop more effective and environmentally friendly surface washing agents.	Literature/Data Call	Chen, Z., An, C., Boufadel, M., Owens, E., Chen, Z., Lee, K., Cao, Y., & Cai, M. (2020). Use of surface-washing agents for the treatment of oiled shorelines: Research advancemnts, technical applications and future challenges. *Chemical Engineering Journal, 391,* 123565. https://doi.org/10.1016/j.cej.2019.123565
30500	Shore Containment and Recovery	No Subcategory	Test the performance of surface washing agents under various environmental and operational conditions	Literature/Data Call	Chen, Z., An, C., Boufadel, M., Owens, E., Chen, Z., Lee, K., Cao, Y., & Cai, M. (2020). Use of surface-washing agents for the treatment of oiled shorelines: Research advancemnts, technical applications and future challenges. *Chemical Engineering Journal, 391,* 123565. https://doi.org/10.1016/j.cej.2019.123565
30500	Shore Containment and Recovery	No Subcategory	Determine an operational endpoint indicator based on the considerations of multiple surface washing agents performances such as removal efficiency and cost.	Literature/Data Call	Chen, Z., An, C., Boufadel, M., Owens, E., Chen, Z., Lee, K., Cao, Y., & Cai, M. (2020). Use of surface-washing agents for the treatment of oiled shorelines: Research advancemnts, technical applications and future challenges. *Chemical Engineering Journal, 391,* 123565. https://doi.org/10.1016/j.cej.2019.123565
30500	Shore Containment and Recovery	No Subcategory	Conduct further research using oil detection canines for the detection of sunken oil and shoreline assessments.		API, 2016. Canine Oil Detection: Field Trials Report. American Petroleum Institute, Technical Report 1149-3, Washington DC, 48 pp.
30500	Shore Containment and Recovery	No Subcategory	Develop an application guide for surface washing agent-aided shoreline treatment to consider all aspects to enhance the resilience of an oil spill decision and management system.	Literature/Data Call	Chen, Z., An, C., Boufadel, M., Owens, E., Chen, Z., Lee, K., Cao, Y., & Cai, M. (2020). Use of surface-washing agents for the treatment of oiled shorelines: Research advancemnts, technical applications and future challenges. *Chemical Engineering Journal, 391,* 123565. https://doi.org/10.1016/j.cej.2019.123565
30500	Shore Containment and Recovery	No Subcategory	Improve and develop new technology for near-shore and inland spills response.	Literature/Data Call	Whelan, A., Clark, J., Andrew, G., Michel, J., & Benggio, B. (2014). Developing Cleanup Endpoints for Inland Oil Spills. *International Oil Spill Conference Proceedings , 2014* (1), 1267–1280. https://doi.org/10.7901/2169-3358-2014.1.1267
30500	Shore Containment and Recovery	No Subcategory	Create a comprehensive index system considering multiple factors of surface washing agents that will help systematically analyze the socio-economic and environmental impacts of given surface washing agents and policies for a specific region.	Literature/Data Call	Chen, Z., An, C., Boufadel, M., Owens, E., Chen, Z., Lee, K., Cao, Y., & Cai, M. (2020). Use of surface-washing agents for the treatment of oiled shorelines: Research advancemnts, technical applications and future challenges. *Chemical Engineering Journal, 391,* 123565. https://doi.org/10.1016/j.cej.2019.123565
30500	Shore Containment and Recovery	No Subcategory	Further research the mechanisms responsible for surface washing agents toxicity to support the production of less toxic products.	Literature/Data Call	Chen, Z., An, C., Boufadel, M., Owens, E., Chen, Z., Lee, K., Cao, Y., & Cai, M. (2020). Use of surface-washing agents for the treatment of oiled shorelines: Research advancemnts, technical applications and future challenges. *Chemical Engineering Journal, 391,* 123565. https://doi.org/10.1016/j.cej.2019.123565
30601	Dispersants	Cold Weather and Ice Conditions	Understand the "window of opportunity" for potential deployment of all dispersants for different oil types and degrees of weathering over a range of realistic environmental conditions (including sea ice conditions) in the Arctic and sub-Arctic.	SME Evaluation	N/A
30601	Dispersants	Cold Weather and Ice Conditions	Study and compare the efficacy of all dispersants for different types of crude oil over a range of realistic environmental conditions, including ice infested waters.	SME Evaluation	N/A

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ICCOPR NUMBER	ICCOPR SRA	Subcategory	Research Need	Source	Citation
30601	Dispersants	Cold Weather and Ice Conditions	Study the fate and effects of subsea application of dispersants in Arctic waters, including in ice infested water and under ice.	SME Evaluation	N/A
30601	Dispersants	Cold Weather and Ice Conditions	Develop methods to handle the logistical operational challenges of applying dispersants in Arctic conditions.	SME comments	N/A
30601	Dispersants	Cold Weather and Ice Conditions	Study the effectiveness of dispersants on no emulsified oil at freezing seawater temperatures.	Public Listening Session	N/A
30601	Dispersants	Cold Weather and Ice Conditions	Develop chemical dispersants and chemical dispersant spray systems that are designed for cold environments.	Literature/Data Call	McCleney, A.B., Supak, K., Manders, J., & Cortes, M. (2018). *Determine the relative efficiency of various surface chemical dispersant delivery techniques/systems* (Project No. 1090). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/determine-the-relative-efficiency-of-various-surface-dispersant-delivery
30602	Dispersants	Behavior	Study the transport and detection of a variety of oil weathering states, oil types, dispersants, and oil/dispersants in different environmental conditions.	SME Evaluation	N/A
30602	Dispersants	Behavior	Study the impact of natural processes such as flocculation and hydrate encapsulation on a variety oil weathering states, oil types, and dispersed oil especially at depths greater than 1500 m.	SME Evaluation	N/A
30602	Dispersants	Behavior	Quantify the impact of photo weathering on the degradation rates of chemically dispersed, physically dispersed, and undispersed oil, including biodegradation kinetics.	SME Evaluation	N/A
30602	Dispersants	Behavior	Develop remote sensing to measure oil droplet size and gas bubble size in the water column for dispersant applications.	Public Listening Sessions	N/A
30602	Dispersants	Behavior	Continue to develop, refine, and communicate the response strategy for using aerial dispersants in conjunction with mechanical recovery and in situ burning to maximize the removal of oil from surface waters during a response.	Public Listening Sessions	N/A
30602	Dispersants	Behavior	Determine potential for aerosolization of chemically dispersed oil droplets under field conditions, i.e., aerial or boat spray application of dispersants on surface oil spills no sooner than 4 hours after slick formation.	Public Listening Sessions	N/A
30602	Dispersants	Behavior	Develop non-invasive methods for monitoring oil and dispersant chemistry.	Literature/Data Call	Bonheyo, G.T., Ruse, K., Bunn, A., Avila, A., Bays, T., Cullinan, V., Duran, R., Jeters, R., Kuo, L., Park, J., Velma, J., Winder, E., & Wingo, P. (2017). *Analysis of how environmental conditions affect dispersant performance during deep ocean application* (Project No. 1066). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/osrr-1066-analysis-how-environmental-conditions-affect-dispersant-performance-during
30602	Dispersants	Behavior	Study how dispersant-oil–sediment interactions alter the transport and weathering of oil.	Literature/Data Call	Gong, Y., Zhao, X., Cai, Z., O'Reilly, S.E., Hao, X., & Zhao, D. (2014). A review of oil, dispersed oil and sediment interactions in the aquatic environment: Influence on the fate, transport and remediation of oil spills. *Marine Pollution Bulletin, 79* (1-2), 16-33. https://doi.org/10.1016/j.marpolbul.2013.12.024
30602	Dispersants	Behavior	Evaluate surface and subsea spill scenarios using NEBA tools (i.e., CERA, SIMA, or CRA) do better define the range of conditions (e.g., oil type, sea state, depth, location, resources at risk) where dispersant use may be inappropriate and/or a feasible response option for reducing floating oil.	Literature/Data Call	National Academies of Sciences, Engineering, and Medicine. (2020). *The Use of Dispersants in Marine Oil Spill Response*. Washington, DC: The National Academies Press. https://doi.org/10.17226/25161.
30602	Dispersants	Behavior	Study the surface chemistry of oil droplets with/without dispersant.	Literature/Data Call	Bonheyo, G.T., Ruse, K., Bunn, A., Avila, A., Bays, T., Cullinan, V., Duran, R., Jeters, R., Kuo, L., Park, J., Velma, J., Winder, E., & Wingo, P. (2017). *Analysis of how environmental conditions affect dispersant performance during deep ocean application* (Project No. 1066). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/osrr-1066-analysis-how-environmental-conditions-affect-dispersant-performance-during
30602	Dispersants	Behavior	Study and improve windows of opportunity predictions to account for differences between dispersant types, oil weathering effects, multiple oil properties.	Literature/Data Call	McCleney, A.B., Supak, K., Manders, J., & Cortes, M. (2018). *Determine the relative efficiency of various surface chemical dispersant delivery techniques/systems* (Project No. 1090). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/determine-the-relative-efficiency-of-various-surface-dispersant-delivery
30602	Dispersants	Behavior	Conduct biodegradability chemical dispersant testing on the chemical dispersants that are stockpiled.	Literature/Data Call	McCleney, A.B., Supak, K., Manders, J., & Cortes, M. (2018). *Determine the relative efficiency of various surface chemical dispersant delivery techniques/systems* (Project No. 1090). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/determine-the-relative-efficiency-of-various-surface-dispersant-delivery
30603	Dispersants	Environmental Effects	Evaluate the protocols for testing toxicity of dispersants and other chemical agents for their ability to represent real world exposure scenarios.	SME Evaluation	N/A
30603	Dispersants	Environmental Effects	Study and evaluate dispersant and dispersed oil chronic and sub-lethal effects on a diversity of species and oils, and subsequent long-term ecological effects for varying real world exposure scenarios and durations.	SME Evaluation	N/A
30603	Dispersants	Environmental Effects	Study physiological impairments, such as sensory function, to species after exposure to oil and dispersants.	Public Listening Sessions	N/A
30603	Dispersants	Environmental Effects	Using dispersant spray card testing protocol as the study parameters, conduct a field study on land to define the actual operational dosage and exposure concentrations to humans and marine wildlife of aerially-applied dispersants at varying distances from the baseline application path.	Public Listening Sessions	N/A
30603	Dispersants	Environmental Effects	Evaluate the toxicity of dispersants and chemically dispersed oil on key Arctic marine species, with appropriate experimental design and incorporation of real-world conditions and concentrations observed in the field.	Public Listening Sessions	N/A
30603	Dispersants	Environmental Effects	Study dispersant bioaccumulation in aquatic organisms.	Literature/Data Call	Venosa, A.D., Anastas, P.T., Barron, M.G., Conmy, R.N., Greenberg, M.S., & Wilson, G.J. (2014). Science-based decision making on the use of dispersants in the deepwater horizon oil spill. *Oil Spill Remediation.* https://doi.org/10.1002/9781118825662.ch1
30603	Dispersants	Environmental Effects	Investigate the adverse effects of oil dispersants and combined effects of oil and dispersant exposures on humans.	Literature/Data Call	Krishnamurthy, J., Engel, L.S., Wang, L., Schwartz, E.G., Christenbury, K., Kondrup, B., Barrett, J., & Rusiecki, J.A. (2019). Neurological symptoms associated with oil spill response exposures: Results from the Deepwater Horizon Oil Spill Coast Guard Cohort Study. *Environmental International, 131,* 104963. https://doi.org/10.1016/j.envint.2019.104963
30603	Dispersants	Environmental Effects	Study the health effects of dispersants to determine an allowable exposure threshold to further inform exposure limits for setback distances.	Literature/Data Call	AMOG Consulting, Inc. (2016). *OSSR program develop an innovative dispersant spray drift model* (Project No. 1070). U.S. Bureau of Safety and Environemental Enforcement. https://www.bsee.gov/research-record/osrr-1070-developing-innovative-dispersant-spray-drift-model
30603	Dispersants	Environmental Effects	Research the long-term effects of short-term dispersed oil exposure, and those long-term studies on the fate of dispersed oil span include laboratory, test tank, and field investigations.	Literature/Data Call	Fingas, M. (2017). *A review of literature related to oil spill dispersants.* Prince William Sound Regional Citizens' Advisory Council. https://www.pwsrcac.org/wp-content/uploads/filebase/programs/environmental_monitoring/dispersants/A%20Review%20of%20Literature%20Related%20to%20Oil%20Spill%20Dispersants,%20September%202017.pdf
30603	Dispersants	Environmental Effects	Study the comparative ecotoxicological effects of dispersants in surface and deep-sea injection exposure versus shoreline.	Literature/Data Call	Venosa, A.D., Anastas, P.T., Barron, M.G., Conmy, R.N., Greenberg, M.S., & Wilson, G.J. (2014). Science-based decision making on the use of dispersants in the deepwater horizon oil spill. *Oil Spill Remediation.* https://doi.org/10.1002/9781118825662.ch1
30603	Dispersants	Environmental Effects	Study the order in which microorganisms biodegrade various dispersant components versus petroleum hydrocarbons present in crude oil, including the tendency for preferential biodegradation of certain components to occur.	Literature/Data Call	UNH Coastal Response Research Center. (2017). *2017 state-of the science of dispersants and dispersed oil (DDO) in U.S. Arctic waters: Degradation and fate.* https://scholars.unh.edu/crrc/3
30603	Dispersants	Environmental Effects	Study the impact of chemical dispersants/dispersion on microbial activities (i.e., oil biodegradation).	Literature/Data Call	UNH Coastal Response Research Center. (2017). *2017 state-of the science of dispersants and dispersed oil (DDO) in U.S. Arctic waters: Degradation and fate.* https://scholars.unh.edu/crrc/3
30603	Dispersants	Environmental Effects	Research the ecotoxicological effects of oil dispersant products and chemically dispersed oil.	Literature/Data Call	Venosa, A.D., Anastas, P.T., Barron, M.G., Conmy, R.N., Greenberg, M.S., & Wilson, G.J. (2014). Science-based decision making on the use of dispersants in the deepwater horizon oil spill. *Oil Spill Remediation.* https://doi.org/10.1002/9781118825662.ch1
30603	Dispersants	Environmental Effects	Study how dispersants and dispersed oil impact the water-repellency of fur and feathers.	Literature/Data Call	Fingas, M. (2017). *A review of literature related to oil spill dispersants.* Prince William Sound Regional Citizens' Advisory Council. https://www.pwsrcac.org/wp-content/uploads/filebase/programs/environmental_monitoring/dispersants/A%20Review%20of%20Literature%20Related%20to%20Oil%20Spill%20Dispersants,%20September%202017.pdf

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ICCOPR NUMBER	ICCOPR SRA	Subcategory	Research Need	Source	Citation
30603	Dispersants	Environmental Effects	Study if oil dispersant products be toxic to aquatic species when injected at the surface or underwater to mitigate spill impacts from deep-sea blowouts.	Literature/Data Call	Venosa, A.D., Anastas, P.T., Barron, M.G., Conmy, R.N., Greenberg, M.S., & Wilson, G.J. (2014). Science-based decision making on the use of dispersants in the deepwater horizon oil spill. *Oil Spill Remediation.* https://doi.org/10.1002/9781118825662.ch1
30603	Dispersants	Environmental Effects	Investigate the impacts of dispersants on microbial communities.	Literature/Data Call	UNH Coastal Response Research Center. (2017). *2017 state-of the science of dispersants and dispersed oil (DDO) in U.S. Arctic waters: Degradation and fate.* https://scholars.unh.edu/crrc/3
30604	Dispersants	Efficacy and Effectiveness	Develop methods to determine the relative effectiveness of surface dispersant delivery techniques/systems in the field.	SME Evaluation	N/A
30604	Dispersants	Efficacy and Effectiveness	Study the effects of subsea dispersant application with different oil types, with and without gas to better assess the subsequent impacts on oil recovery.	SME Evaluation	N/A
30604	Dispersants	Efficacy and Effectiveness	Develop methods to quantify the factors needed to scale results of laboratory and wave tank experiments so that they become more accurate indicators of real world effectiveness.	SME Evaluation	N/A
30604	Dispersants	Efficacy and Effectiveness	Study and test commercially available remote sensors to determine each sensor's ability to detect the operational effectiveness of surface applied dispersants to an oil slick to enhance existing SMART protocols.	Public Listening Sessions	N/A
30604	Dispersants	Efficacy and Effectiveness	Review and update SMART monitoring protocol for oil spill dispersant operations, specifically by improving the challenges associated with the boat-based use of fluorometers.	Public Listening Session	N/A
30604	Dispersants	Efficacy and Effectiveness	Study and test the effectiveness of dispersants on a range of oil types, temperatures, oil viscosity, and salinities under realistic environmental conditions.	Literature/Data Call	UNH Center for Spills in the Environment. (2014). *Dispersants forum: Gulf of Mexico oil spill & ecosystem science conference.* University of New Hampshire. https://crrc.unh.edu/sites/crrc.unh.edu/files/2014.05.12_gomri_dispersants_session_report_total.pdf
30604	Dispersants	Efficacy and Effectiveness	Develop a standardized testing methodology that confirms the accuracy and uncertainty of the efficiency of the technologies.	Literature/Data Call	McCleney, A.B., Supak, K., Manders, J., & Cortes, M. (2018). *Determine the relative efficiency of various surface chemical dispersant delivery techniques/systems* (Project No. 1090). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/determine-the-relative-efficiency-of-various-surface-dispersant-delivery
30604	Dispersants	Efficacy and Effectiveness	Develop standard, routine equipment maintenance practices that provide manufactures feedback from responders on how their equipment is functioning.	Literature/Data Call	McCleney, A.B., Supak, K., Manders, J., & Cortes, M. (2018). *Determine the relative efficiency of various surface chemical dispersant delivery techniques/systems* (Project No. 1090). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/determine-the-relative-efficiency-of-various-surface-dispersant-delivery
30604	Dispersants	Efficacy and Effectiveness	Conduct field testing of the technologies since results from laboratory testing does not necessarily relate closely to the expected effectiveness of the technology in the field, creating varying degrees of success for equipment performance.	Literature/Data Call	McCleney, A.B., Supak, K., Manders, J., & Cortes, M. (2018). *Determine the relative efficiency of various surface chemical dispersant delivery techniques/systems* (Project No. 1090). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/determine-the-relative-efficiency-of-various-surface-dispersant-delivery
30604	Dispersants	Efficacy and Effectiveness	Develop technologies to measure and monitor chemical dispersant effectiveness that is not subject to human bias..	Literature/Data Call	McCleney, A.B., Supak, K., Manders, J., & Cortes, M. (2018). *Determine the relative efficiency of various surface chemical dispersant delivery techniques/systems* (Project No. 1090). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/determine-the-relative-efficiency-of-various-surface-dispersant-delivery
30604	Dispersants	Efficacy and Effectiveness	Develop a more direct indicator of dispersant effectiveness.	Literature/Data Call	Nedwed, T., Mitchell, D., Konkel, W., & Coolbaugh, T. (2020). *Abstracts for poster presentations.* Gulf of Mexico Oil Spill & Ecosystem Science Conference, Tampa, FL. https://gulfresearchinitiative.org/gulf-mexico-oil-spill-ecosystem-science-conference/
30604	Dispersants	Efficacy and Effectiveness	Investigate the range of oil and dispersant types and flow rates, the importance of oil drop re-coalescence and devolution, the importance of oil temperature, high-pressure dispersant effectiveness testing	Literature/Data Call	Nuka Research and Planning Group, LLC. (2015). *Final report: OSRR-funded project key findings and recommendations* (Project No. 1056). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/osrr-1056-catalog-osrr-funded-research-recommendations-and-key-findings
30604	Dispersants	Efficacy and Effectiveness	Research what green chemistry methods are available to use as effective dispersants.	Literature/Data Call	Venosa, A.D., Anastas, P.T., Barron, M.G., Conmy, R.N., Greenberg, M.S., & Wilson, G.J. (2014). Science-based decision making on the use of dispersants in the deepwater horizon oil spill. *Oil Spill Remediation.* https://doi.org/10.1002/9781118825662.ch1
30604	Dispersants	Efficacy and Effectiveness	Investigate what dispersants can be produced that have a "lighter" environmental footprint than petroleum based products.	Literature/Data Call	Venosa, A.D., Anastas, P.T., Barron, M.G., Conmy, R.N., Greenberg, M.S., & Wilson, G.J. (2014). Science-based decision making on the use of dispersants in the deepwater horizon oil spill. *Oil Spill Remediation.* https://doi.org/10.1002/9781118825662.ch1
30604	Dispersants	Efficacy and Effectiveness	Demonstration of response strategies using icebreakers in conjunction with dispersant application.	Literature/Data Call	Dickins, D. (2017). *Arctic oil spill response technology joint industry programme synthesis report.* Arctic Response Technology Oil Spill Preparedness. http://www.arcticresponsetechnology.org/wp-content/uploads/2017/09/synthesis-report-final-report-to-the-iogp-arctic-oil-spill-response-technology-joint-industry-programme-1.pdf
30604	Dispersants	Efficacy and Effectiveness	Develop methods to distinguish between water-dissolved dispersant and dispersant sequestered to oil droplets in dispersed oil solutions.	Literature/Data Call	Adams, J.E., Madison, B.N., Charbonneau, K., Sereneo, M., Baillon, L., Langlois, V.S., Brown, R.S., & Hodson, P.V. (2020). Effects on trout alevins of chronic exposures to chemically dispersed access western blend and cold lake blend diluted bitumens. *Environmental Toxicology and Chemistry, 39* (8), 1620-1633. https://doi.org/10.1002/etc.4747
30604	Dispersants	Efficacy and Effectiveness	Investigate the influence of various crude oils and dispersant formulations on dispersant effectiveness as a function of energy dissipation rates.	Literature/Data Call	Li, Z., Lee, K., King, T., Boufadel, M.C., & Venosa, A.D. (2008). Assessment of chemical dispersant effectiveness in a wave tank under regular non-breaking and breaking wave conditions. *Marine Pollution Bulletin, 56,* 903-912. https://crrc.unh.edu/sites/crrc.unh.edu/files/mpbchemical_dispersants.pdf
30604	Dispersants	Efficacy and Effectiveness	Develop equipment for simulating blowouts and oil suspensions in closed cells and methods for measuring and monitoring the evolution of DSDs within pressure cells.	Literature/Data Call	Bonheyo, G.T., Ruse, K., Bunn, A., Avila, A., Bays, T., Cullinan, V., Duran, R., Jeters, R., Kuo, L., Park, J., Velma, J., Winder, E., & Wingo, P. (2017). *Analysis of how environmental conditions affect dispersant performance during deep ocean application* (Project No. 1066). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/osrr-1066-analysis-how-environmental-conditions-affect-dispersant-performance-during
30604	Dispersants	Efficacy and Effectiveness	Conduct field tests in the open ocean to reduce some uncertainties regarding the correlation and scaling of laboratory tests with real world scenarios.	Literature/Data Call	Bonheyo, G.T., Ruse, K., Bunn, A., Avila, A., Bays, T., Cullinan, V., Duran, R., Jeters, R., Kuo, L., Park, J., Velma, J., Winder, E., & Wingo, P. (2017). *Analysis of how environmental conditions affect dispersant performance during deep ocean application* (Project No. 1066). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/osrr-1066-analysis-how-environmental-conditions-affect-dispersant-performance-during
30605	Dispersants	Fate	Study the differences in the effects of photolysis on undispersed, chemically dispersed, and physically dispersed oil droplets.	SME Evaluation	N/A
30605	Dispersants	Fate	Study the adhesiveness of physically and chemically dispersed oil on organisms and habitats, including how adhesion changes over time and with oil type.	SME Evaluation	N/A
30605	Dispersants	Fate	Study the longer-term fate of less-labile components of Corexit 9500 (DOSS, DGBE, and solvents) and the metabolic processes underlying oil and Corexit codegradation in seawater following chemical dispersion of oil to better understand the fate of dispersants and mechanisms of their biodegradation.	Literature/Data Call	Gofstein, T.R., Perkins, M., Field, J., & Leigh, M.B. (2020). The interactive effects of crude oil and Corexit 9500 on their biodegradation in Arctic seawater. *Applied Environmental Microbiology, 86* (21). doi: 10.1128/AEM.01194-20
30605	Dispersants	Fate	Study the environmental fate and transport of dispersed oil and dispersants from surface, subsurface, and deepwater scenarios.	Literature/Data Call	Venosa, A.D., Anastas, P.T., Barron, M.G., Conmy, R.N., Greenberg, M.S., & Wilson, G.J. (2014). Science-based decision making on the use of dispersants in the deepwater horizon oil spill. *Oil Spill Remediation.* https://doi.org/10.1002/9781118825662.ch1
30605	Dispersants	Fate	Study the impact of photo-oxidation on a dispersant effectiveness with a broad range of oils (light to heavy, sweet to sour) and dispersant mixtures.	Literature/Data Call	Ward, C.P. & Overton, E.B. (2020). How the 2010 Deepwater Horizon spill reshaped our understanding of crude oil photochemical weathering at sea: a past, present, and future perspective. *Environmental Science: Processes & Impacts, 22* (5), 1101-1308. https://doi.org/10.1039/D0EM00027B
30605	Dispersants	Fate	Investigate the microbial response oil and Corexit when present together in Arctic seawater to better understand their fate and interactions in the context of a dispersed oil plume.	Literature/Data Call	McFarlin, K.M., Perkins, M.J., Field, J.A., & Leigh, M.B. (2018). Bioderadation of crude oil and Corexit 9500 in Arctic seawater. *Frontiers in Microbiology, 9.* https://doi.org/10.3389/fmicb.2018.01788

The information in this database has not been processed or reviewed by the ICCOPR and is considered source/raw data. The approved final list of ICCOPR Research Needs can be found in Chapter 9 of the Oil Pollution Research and Technology Plan.

ICCOPR NUMBER	ICCOPR SRA	Subcategory	Research Need	Source	Citation
30605	Dispersants	Fate	Research new dispersant effectiveness, impacts, and how they are distributed.	Literature/Data Call	UNH Center for Spills in the Environment. (2014). *Dispersants forum: Gulf of Mexico oil spill & ecosystem science conference.* University of New Hampshire. https://crrc.unh.edu/sites/crrc.unh.edu/files/2014.05.12_gomri_dispersants_session_report_total.pdf
30605	Dispersants	Fate	Research what methods are available to track dispersed oil in the deep sea.	Literature/Data Call	Venosa, A.D., Anastas, P.T., Barron, M.G., Conmy, R.N., Greenberg, M.S., & Wilson, G.J. (2014). Science-based decision making on the use of dispersants in the deepwater horizon oil spill. *Oil Spill Remediation.* https://doi.org/10.1002/9781118825662.ch1
30605	Dispersants	Fate	Study how rapidly dispersant components are degraded in the sea.	Literature/Data Call	Prince, R.C. (2015). Oil spill dispersants: Boon or bane?. *Environmental Science & Technology, 49* (11), 6376-6384. https://doi.org/10.1021/acs.est.5b00961
30605	Dispersants	Fate	Conduct sublethal research to determine the effects of dispersants and dispersed oil on the reproduction and growth of open ocean zooplankton, particularly fish larvae, that have previously shown to be quite sensitive to low concentrations of dispersed oil.	Literature/Data Call	Lee, R. (2013). *Ingestion and effects of dispersed oil on marine zooplankton.* Prince William Sound Regional Citizens' Advisory Council (PWSRCAC). https://www.pwsrcac.org/wp-content/uploads/filebase/programs/environmental_monitoring/dispersants/Ingestion%20and%20Effects%20of%20Dispersed%20Oil%20on%20Marine%20Zooplankton%20-%20January%202013.pdf
30605	Dispersants	Fate	Conduct comparative studies with the same groups of different species, using different dispersants, and particularly with emphasis on Corexit 9527 and 9500 because these two have become the most extensively used to determine toxicity.	Literature/Data Call	Wise, J. & Wise, J.P., Sr. (2011). A review of the toxicity of chemical dispersants. R*eviews on Environmental Health, 26* (4), 281–300. https://doi.org/10.1515/reveh.2011.035
30605	Dispersants	Fate	Develop cost-effective methods for measuring particulate and dissolved oil and free and sequestered dispersant concentrations in toxicity test solutions.	Literature/Data Call	Hodson, P.V., Adams, J., & Brown, R.S. (2018). Oil toxicity test methods must be improved. *Environmental Toxicology and Chemistry, 38* (2), 302-311. https://doi.org/10.1002/etc.4303
30606	Dispersants	Subsurface	Research on subsurface transport of oil constituents and exposure of deep-water organisms.	SME Evaluation	N/A
30606	Dispersants	Subsurface	Construct a large scale test facility with the capability to simulate ultra-deep water pressures and use live oil to investigate the effects of in situ chemistry and physics on the efficacy of sub-surface dispersant injection (SSDI).	Public Listening Session	N/A
30606	Dispersants	Subsurface	Further investigate the effects of sub-surface dispersant injection (SSDI) use on the fate of oil constituents, such as VOC concentrations, at the sea surface.	Public Listening Session	N/A
30606	Dispersants	Subsurface	Conduct large-scale experiments that mimic real world conditions to investigate the is size of droplets emanating from a blowout both before and after application of dispersants.	Public Listening Session	N/A
30606	Dispersants	Subsurface	Determine the effectiveness, systems design, and short- and long-term impacts of subsea dispersant delivery.	Public Listening Session	N/A
30606	Dispersants	Subsurface	Quantify relationships between oil properties and dispersant effectiveness in different conditions related to subsea injections	Literature/Data Call	Nuka Research and Planning Group, LLC. (2015). *Final report: OSRR-funded project key findings and recommendations* (Project No. 1056). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/osrr-1056-catalog-osrr-funded-research-recommendations-and-key-findings
30606	Dispersants	Subsurface	Construct a large-scale high pressure facility capable of using gas-saturated oil at simulated operating depths of the ultra-deep industry.	Literature/Data Call	Murawski, S.A., Schlüter, M., Paris, C.B., & Aman, Z.M. (2019). Resolving the dilemma of dispersant use for deep oil spill response. *Environmental Research Letters, 14* (9), 1002. https://iopscience.iop.org/article/10.1088/1748-9326/ab3aa0
30606	Dispersants	Subsurface	Investigate the potential effects if DOSS and other dispersant components under the conditions found in the GOM.	Literature/Data Call	Gray, J.L., Kanagy, L.K., Furlong, E.T., Kanagy, C.J., McCoy, J.W., Mason, A., & Lauenstein, G. (2014). Presence of the Corexit component dioctyl sodium sulfosuccinate in Gulf of Mexico waters after the 2010 Deepwater Horizon oil spill. *Chemosphere, 95,* 124-130. https://doi.org/10.1016/j.chemosphere.2013.08.049
30606	Dispersants	Subsurface	Investigate subsea dispersant application to determine what the most effective dispersants are for subsea use, when they should be used, what the most effective application methods and rates are.	Literature/Data Call	UNH Center for Spills in the Environment. (2014). *Dispersants forum: Gulf of Mexico oil spill & ecosystem science conference.* University of New Hampshire. https://crrc.unh.edu/sites/crrc.unh.edu/files/2014.05.12_gomri_dispersants_session_report_total.pdf
30606	Dispersants	Subsurface	Study the fate of dispersants and dispersed oil when used on deep-sea applications to better understand the coalescence and resurfacing of dispersed oil droplets to develop models for tracking the movement of dispersed oil plumes at the surface, in the subsurface, and in the deep sea	Literature/Data Call	Venosa, A.D., Anastas, P.T., Barron, M.G., Conmy, R.N., Greenberg, M.S., & Wilson, G.J. (2014). Science-based decision making on the use of dispersants in the deepwater horizon oil spill. *Oil Spill Remediation.* https://doi.org/10.1002/9781118825662.ch1
30701	In Situ Burning (ISB)	Effectiveness and Impacts	Develop improved pre- and post-spill plume modeling to determine whether an in situ burn should be conducted and facilitate decisions on measures to protect local\ populations, including the potential effect of "fall-out" from a smoke plume that goes over land-based subsistence resources.	SME Evaluation	N/A
30701	In Situ Burning (ISB)	Effectiveness and Impacts	Study in situ burning residues including toxicity, physical properties, and bioavailability of contaminants contained within the residue matrix, especially regarding potential benthic community effects.	SME Evaluation	N/A
30701	In Situ Burning (ISB)	Effectiveness and Impacts	Develop techniques and technologies to improve *in situ* burning effectiveness in the Arctic and other extreme environments.	SME Evaluation	N/A
30701	In Situ Burning (ISB)	Effectiveness and Impacts	Research the behavior of unburned oil and burn residue on ice and snow, especially with respect to the role of albedo and its impact on the integrity of the ice for spill mitigation operations.	SME Comments	N/A
30701	In Situ Burning (ISB)	Effectiveness and Impacts	Research the conditions leading to boil over to encourage this phenomenon during open-ocean *in situ* burns to increase burn efficiency and reduce burn residues.	Public Listening Sessions	N/A
30701	In Situ Burning (ISB)	Effectiveness and Impacts	Research fundamental thermochemistry of water-in-oil emulsions and limitations in increased burn efficiency.	Public Listening Sessions	N/A
30701	In Situ Burning (ISB)	Effectiveness and Impacts	Study how emulsions behave during accelerant ignition, burning, and extinction to determine if and how these processes could expand ignition envelopes, increase burning rates, and delay extinction.	Public Listening Sessions	N/A
30701	In Situ Burning (ISB)	Effectiveness and Impacts	Develop deployable methods to measure the burn rate efficiency in the field during ISB to determine the amount of oil removed from the environment and how much remains.	Public Listening Sessions	N/A
30701	In Situ Burning (ISB)	Effectiveness and Impacts	Study alternate techniques including booming and ignition strategies to enhance burn efficiencies.	Public Listening Sessions	N/A
30701	In Situ Burning (ISB)	Effectiveness and Impacts	Research burn residue containment or recovery methods that would reduce or eliminate potential fishery impacts associated with sinking residue.	Literature/Data Call	Shigenaka, G., Overton, E., Meyer, B., Gao, H., & Miles, S. (2015). *Comparison of physical and chemical characteristics of in-situ burn residue and other environmental oil samples collected during the Deepwater Horizon spill response.* U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/sites/bsee.gov/files/osrr-oil-spill-response-research/1010ac.pdf
30701	In Situ Burning (ISB)	Effectiveness and Impacts	Study the toxicity and environmental hazards of burn residues on aquatic and arctic organisms with different types of oil.	Literature/Data Call	Fritt-Rasmussen, J., Wegeberg, S., & Gustavson, K. (2015). Review of burn residues from in situ burning of oil spills in relation to Arctic waters. *Water, Air, & Soil Pollution, 226.* https://doi.org/10.1007/s11270-015-2593-1
30701	In Situ Burning (ISB)	Effectiveness and Impacts	Investigate the smothering effects of more viscous burn residues on birds and other organisms related to the sea surface.	Literature/Data Call	Fritt-Rasmussen, J., Wegeberg, S., & Gustavson, K. (2015). Review of burn residues from in situ burning of oil spills in relation to Arctic waters. *Water, Air, & Soil Pollution, 226.* https://doi.org/10.1007/s11270-015-2593-1
30701	In Situ Burning (ISB)	Effectiveness and Impacts	Develop a laboratory measurement apparatus and procedure for determining effects of oil chemical properties on burn rates and efficiencies.	Literature/Data Call	Panetta, P.D., Byrne, R., & Du, H. (2018). *Quantitative measurement of in-situ burn (ISB) efficiency and rate.* U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/sites/bsee.gov/files/research-reports/1074aa.pdf
30701	In Situ Burning (ISB)	Effectiveness and Impacts	Conduct a study of heat transfer mechanics, both in small and large scale experiments, to understand the burning efficiency of in-situ burning of crude oils on water.	Literature/Data Call	Gelderen, L.V., Malmquist, L.M.V., & Jomaas, G. (2017). Vaporization order and burning efficiency of crude oils during in-situ burning on water. *Fuel, 191,* 528-537. https://doi.org/10.1016/j.fuel.2016.11.109
30701	In Situ Burning (ISB)	Effectiveness and Impacts	Conduct ISB field trials to compare to predictive models and additional chronic toxicity testing on potential impacts from burn residue.	Literature/Data Call	Bullock, R.J., Perkins, R.A., & Aggarwal, S. (2019). In-situ burning with chemical herders for Arctic oil spill response: Meta-analysis and review. *Science of The Total Environment, 675,* 705-716. https://doi.org/10.1016/j.scitotenv.2019.04.127
30701	In Situ Burning (ISB)	Effectiveness and Impacts	Conduct studies on the quantification of the burn residue as a function of the weathered level of the crude to full characterization of sunken burn residues.	Literature/Data Call	Rojas-Alva, U., Andersen, B.S., & Jomaas, G. (2019). Chemical herding of weathered crude oils for in-situ burning. *Journal of Environmental Management, 250,* 109470. https://doi.org/10.1016/j.jenvman.2019.109470
30702	In Situ Burning (ISB)	Planning and Technology	Conduct a comparative study of in situ burning vs. mechanical, chemical and natural attenuation methods in cleanup of wetlands or marshy areas.	SME Evaluation	N/A
30702	In Situ Burning (ISB)	Planning and Technology	Develop enhanced designs for containment of burning oil, such as reusable and high seas capable booms.	SME Evaluation	N/A
30702	In Situ Burning (ISB)	Planning and Technology	Develop methods to improve and sustain combustion of emulsions.	SME Evaluation	N/A

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ICCOPR NUMBER	ICCOPR SRA	Subcategory	Research Need	Source	Citation
30702	In Situ Burning (ISB)	Planning and Technology	Develop a deployable system to measure open water burns.	Literature/Data Call	N/A
30702	In Situ Burning (ISB)	Planning and Technology	Research the limitations and burning behaviors of crude oil in the Arctic.	Public Listening Sessions	N/A
30702	In Situ Burning (ISB)	Planning and Technology	Develop a model to estimate the ignitability and burning efficiency of oils based on pre-determined parameters.	Literature/Data Call	Nuka Research and Planning Group, LLC. (2015). *Final report: OSRR-funded project key findings and recommendations* (Project No. 1056). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/osrr-1056-catalog-osrr-funded-research-recommendations-and-key-findings
30702	In Situ Burning (ISB)	Planning and Technology	Develop operational, reliable UAS systems with sufficient payload capacity and endurance to apply herders and ignite spills in ice and at sea.	Literature/Data Call	Dickins, D. (2017). *Arctic oil spill response technology joint industry programme synthesis report.* Arctic Response Technology Oil Spill Preparedness. http://www.arcticresponsetechnology.org/wp-content/uploads/2017/09/synthesis-report-final-report-to-the-iogp-arctic-oil-spill-response-technology-joint-industry-programme-1.pdf
30702	In Situ Burning (ISB)	Planning and Technology	Develop an oil-burning barge that could also deploy a skimmer if oil becomes un-burnable.	Literature/Data Call	Nuka Research and Planning Group, LLC. (2015). *Final report: OSRR-funded project key findings and recommendations* (Project No. 1056). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/osrr-1056-catalog-osrr-funded-research-recommendations-and-key-findings
30702	In Situ Burning (ISB)	Planning and Technology	Develop cross-boundary research, training, and collaboration on *in situ* burning and herders.	Literature/Data Call	Bullock, R.J., Perkins, R.A., & Aggarwal, S. (2019). In-situ burning with chemical herders for Arctic oil spill response: Meta-analysis and review. *Science of The Total Environment, 675,* 705-716. https://doi.org/10.1016/j.scitotenv.2019.04.127
30702	In Situ Burning (ISB)	Planning and Technology	Research technologies to improve the window of opportunity for *in situ* burning.	Literature/Data Call	Nuka Research and Planning Group, LLC. (2015). *Final report: OSRR-funded project key findings and recommendations* (Project No. 1056). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/osrr-1056-catalog-osrr-funded-research-recommendations-and-key-findings
30702	In Situ Burning (ISB)	Planning and Technology	Quantify the combustion efficiency of the atomization and combustion of emulsified crude oil process .	Literature/Data Call	Nuka Research and Planning Group, LLC. (2015). *Final report: OSRR-funded project key findings and recommendations* (Project No. 1056). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/osrr-1056-catalog-osrr-funded-research-recommendations-and-key-findings
30702	In Situ Burning (ISB)	Planning and Technology	Conduct field trials of aerial application of herders and ignition in real drift ice conditions offshore to better estimate the efficiencies and weather windows of herders to act on the oil slick.	Literature/Data Call	Potter, S., Buist, I., Cooper, D., Aggarwal, S., Schnabel, W., Garron, J., Bullock, R., Perkins, R., & Lane, P. (2017). Aerial application of herding agents can enhance in-situ burning in partial ice cover. *International Oil Spill Conference Proceedings, 2017* (1), 2955–2975. https://doi.org/10.7901/2169-3358-2017.1.2955
30702	In Situ Burning (ISB)	Planning and Technology	Research if in-situ burn residue containment or recovery efforts feasible and if so, what are the recovery options.	Literature/Data Call	Shigenaka, G., Meyer, B., Overton, E., & Miles, M.S. (2017). Physical and chemical characterization of in-situ burn residue encountered by a deep-water fishery in the Gulf of Mexico. *International Oil Spill Conference Proceedings, 2017* (1), 1020-1040. https://doi.org/10.7901/2169-3358-2017.1.1020
30702	In Situ Burning (ISB)	Planning and Technology	Develop models of the physical processes to predict potential movements of sinking residues.	Literature/Data Call	Shigenaka, G., Meyer, B., Overton, E., & Miles, M.S. (2017). Physical and chemical characterization of in-situ burn residue encountered by a deep-water fishery in the Gulf of Mexico. *International Oil Spill Conference Proceedings, 2017* (1), 1020-1040. https://doi.org/10.7901/2169-3358-2017.1.1020
30800	Alternative Chemical Countermeasures	No Subcategory	Study the potential use of chemical herders use to enhance response capabilities of *in situ* burning or recovery of oil in confined/covered spaces.	SME Evaluation	N/A
30800	Alternative Chemical Countermeasures	No Subcategory	Study the value and impact of chemical herders regarding the timing for deployment of various countermeasures, particularly with respect to a second stage recovery effort during ice melt to target oil that had previously been entrained in sea ice.	SME Evaluation	N/A
30800	Alternative Chemical Countermeasures	No Subcategory	Conduct laboratory and field tests of chemical agents for breaking or inhibiting emulsions.	SME Evaluation	N/A
30800	Alternative Chemical Countermeasures	No Subcategory	Evaluate the effectiveness and toxicity of oil spill response chemicals on the National Contingency Plan (NCP).	Public Listening Sessions	N/A
30800	Alternative Chemical Countermeasures	No Subcategory	Characterize the differences in biodegradation and toxicity of burnt oil residues, native crude oil, and chemical herders.	Public Listening Sessions	N/A
30800	Alternative Chemical Countermeasures	No Subcategory	Study the characterization, treatment, fate, and transport of oil emulsions.	Public Listening Sessions	N/A
30800	Alternative Chemical Countermeasures	No Subcategory	Perform controlled laboratory and field in-situ burn experiments to understand how herder and oil properties influence herding and burn efficiency under varying environmental factors (salinity, temperature, and ice-coverage).	Public Listening Sessions	N/A
30800	Alternative Chemical Countermeasures	No Subcategory	Study the effectiveness of herder application in various environments and sea states using methods that directly measure the thickness of the oil.	Public Listening Sessions	N/A
30800	Alternative Chemical Countermeasures	No Subcategory	Research the effectiveness of herding surfactants and emulsion breakers in conjunction with in situ burning.	Literature/Data Call	Nuka Research and Planning Group, LLC. (2015). *Final report: OSRR-funded project key findings and recommendations* (Project No. 1056). U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/osrr-1056-catalog-osrr-funded-research-recommendations-and-key-findings
30800	Alternative Chemical Countermeasures	No Subcategory	Study the effectiveness of applications of herders in cold weather conditions.	Literature/Data Call	Aggarwal, S., Schnabel, W., Buist, I., Garron, J., Bullock, R., Perkins, R., Potter, S., & Cooper, D. (2017). Aerial application of herding agents to advance in-situ burning for oil spill response in the Arctic: A pilot study. *Cold Regions Science and Technology, 135* , 97-104. https://doi.org/10.1016/j.coldregions.2016.12.010
30800	Alternative Chemical Countermeasures	No Subcategory	Study the impact of photooxidation on the effectiveness of chemical agents used in oil spill response operations (e.g., herders and surface-washing agents) other than dispersants.	Literature/Data Call	Ward, C.P., Reddy, C.M., & Overton, E.B. (2020, April 28). *Why sunlight matters for marine oil spills.* EOS, 101. https://doi.org/10.1029/2020EO143427.
30800	Alternative Chemical Countermeasures	No Subcategory	Develop a standard definition to define solidifiers and to distinguish solidifying agents from sorbents.	Literature/Data Call	Federici, C. & Mintz, J. (2014). *Oil properties and their impact on spill response options* . CNA Analysis & Solutions. https://www.bsee.gov/sites/bsee.gov/files/osrr-oil-spill-response-research/1017aa.pdf
30800	Alternative Chemical Countermeasures	No Subcategory	Test herders with different types of oil.	Literature/Data Call	Bullock, R.J., Perkins, R.A., & Aggarwal, S. (2019). In-situ burning with chemical herders for Arctic oil spill response: Meta-analysis and review. *Science of The Total Environment, 675,* 705-716. https://doi.org/10.1016/j.scitotenv.2019.04.127
30800	Alternative Chemical Countermeasures	No Subcategory	Determine the efficiency of herders in different sea states and determine value and opportunities for residue recovery types	Literature/Data Call	Bullock, R.J., Perkins, R.A., & Aggarwal, S. (2019). In-situ burning with chemical herders for Arctic oil spill response: Meta-analysis and review. *Science of The Total Environment, 675,* 705-716. https://doi.org/10.1016/j.scitotenv.2019.04.127
30800	Alternative Chemical Countermeasures	No Subcategory	Determine how herders can be deployed to improve offshore skimming encounter rates in suitable open water conditions.	Literature/Data Call	S.L. Ross Environmental Research Ltd. (2012). *Research on using oil herding agents for rapid response in situ burning of oil slicks on open water.* U.S. Bureau of Safety and Environmental Enforcement. https://www.bsee.gov/research-record/osrr-683-using-oil-herding-agents-rapid-response-situ-burning-oil-spills-open-water
30800	Alternative Chemical Countermeasures	No Subcategory	Research herder chemical characteristics and toxicological information on Arctic species of concern for ISB with herders.	Literature/Data Call	Bullock, R.J., Perkins, R.A., & Aggarwal, S. (2019). In-situ burning with chemical herders for Arctic oil spill response: Meta-analysis and review. *Science of The Total Environment, 675,* 705-716. https://doi.org/10.1016/j.scitotenv.2019.04.127
30800	Alternative Chemical Countermeasures	No Subcategory	Further research into the use of herders in combination with ignition as a response option to oil releases in Arctic waters, using multiple fuels and higher rates of ice coverage, need to be evaluated.	Literature/Data Call	Bullock, R.J., Aggarwal, S., Perkins, R.A., & Schnabel, W. (2017). Scale-up considerations for surface collecting agent assisted in-situ burn crude oil spill response experiments in the Arctic: Laboratory to field-scale investigations. *Journal of Environmental Management, 190,* 266-273. https://doi.org/10.1016/j.jenvman.2016.12.044
30800	Alternative Chemical Countermeasures	No Subcategory	Evaluate herder degradation mechanisms and develop a test to measure herders in burn residue.	Literature/Data Call	Bullock, R.J., Perkins, R.A., & Aggarwal, S. (2019). In-situ burning with chemical herders for Arctic oil spill response: Meta-analysis and review. *Science of The Total Environment, 675,* 705-716. https://doi.org/10.1016/j.scitotenv.2019.04.127
30800	Alternative Chemical Countermeasures	No Subcategory	Conduct field tests with herder and ISB in drift ice and open waters and continue to test herder fate and toxicity.	Literature/Data Call	Bullock, R.J., Perkins, R.A., & Aggarwal, S. (2019). In-situ burning with chemical herders for Arctic oil spill response: Meta-analysis and review. *Science of The Total Environment, 675,* 705-716. https://doi.org/10.1016/j.scitotenv.2019.04.127
30800	Alternative Chemical Countermeasures	No Subcategory	Conduct field trails to determine the fate of herders and potential environmental impacts in Arctic waters.	Literature/Data Call	Bullock, R.J., Perkins, R.A., & Aggarwal, S. (2019). In-situ burning with chemical herders for Arctic oil spill response: Meta-analysis and review. *Science of The Total Environment, 675,* 705-716. https://doi.org/10.1016/j.scitotenv.2019.04.127
30800	Alternative Chemical Countermeasures	No Subcategory	Develop standard test methods and performance metrics to quantify the effectiveness of solidifiers.	Literature/Data Call	Federici, C. & Mintz, J. (2014). *Oil properties and their impact on spill response options* . CNA Analysis & Solutions. https://www.bsee.gov/sites/bsee.gov/files/osrr-oil-spill-response-research/1017aa.pdf

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ICCOPR NUMBER	ICCOPR SRA	Subcategory	Research Need	Source	Citation
30800	Alternative Chemical Countermeasures	No Subcategory	Study the long-term fate and stability of solidifiers, solidified oil, and un-reacted solidifying agents in the environment.	Literature/Data Call	Fingas, M. (2013). *Review of Solidifiers: An Update 2013* . Prince William Sound Regional Citizens' Advisory Council. https://www.pwsrcac.org/wp-content/uploads/filebase/programs/environmental_monitoring/non-dispersing_response_technologies/Review%20of%20Solidifiers%20An%20Update%202013%20by%20Merv%20Fingas.pdf
30800	Alternative Chemical Countermeasures	No Subcategory	Research disposal methods for used solidifiers and solidified mass of oil.	Literature/Data Call	Fingas, M. (2013). *Review of solidifiers: An update 2013.* Prince William Sound Regional Citizens' Advisory Council (PWSRCAC). https://www.pwsrcac.org/wp-content/uploads/filebase/programs/environmental_monitoring/non-dispersing_response_technologies/Review%20of%20Solidifiers%20An%20Update%202013%20by%20Merv%20Fingas.pdf
30900	Oily and Oil Waste Disposal	No Subcategory	Test developed systems for oil/water separation decanting to verify performance and optimize operational use for various oil types.	SME Evaluation	N/A
30900	Oily and Oil Waste Disposal	No Subcategory	Investigate operational feasibility of using reusable sorbent materials to reduce secondary waste during nearshore oil spill response.	SME Evaluation	N/A
30900	Oily and Oil Waste Disposal	No Subcategory	Develop methods to temporarily store or dispose of recovered oil/pollutants in remote or harsh environments.	SME Evaluation	N/A
30900	Oily and Oil Waste Disposal	No Subcategory	Research how to optimize and operationalize portable incinerator units to reduce secondary waste from sorbents.	SME comments	N/A
30900	Oily and Oil Waste Disposal	No Subcategory	Investigate the fundamental mechanisms and theories of special wettable materials for oil/water separation.	Literature/Data Call	Xue, Z., Cao, Y., Liu, N., Feng, L., & Jiang, L. (2014). Special wettable materials for oil/water separation. *Journal of Materials Chemistry A, 2* (8), 2445-2460. https://doi.org/10.1039/C3TA13397D
30900	Oily and Oil Waste Disposal	No Subcategory	Further research/develop/design temporary storage and transportation concepts for recovered oil.	Literature/Data Call	United States Coast Guard. (2013). *Great Lakes oil-in-ice demonstration 3 final report.* U.S. Department of Homeland Security. https://rrt5.org/Portals/0/docs/GreatLakesDemonstration3FinalReport.pdf
30900	Oily and Oil Waste Disposal	No Subcategory	Evaluate alternative methods for independent waste treatment for oil-polluted matter that needs to be handled on site.	Literature/Data Call	Ly, J.M. (2017). Worst case preparation - Environmental risk based dimensioning of oil spill response. *International Oil Spill Conference Proceedings, 2017* (1), 802-821. https://doi.org/10.7901/2169-3358-2017.1.802
30900	Oily and Oil Waste Disposal	No Subcategory	Conduct in-depth studies on oily wastewater degradation mechanisms to improve oily wastewater treatment efficiency and reduce processing costs.	Literature/Data Call	Yu, L., Han, M., & He, F. (2017). A review of treating oily wastewater. *Arabian Journal of Chemistry, 10* (2), S1913-S1922. https://doi.org/10.1016/j.arabjc.2013.07.020
30900	Oily and Oil Waste Disposal	No Subcategory	Conduct qualitative and quantitative studies of the interactions between materials and oil/water mixtures to provide better guidance for the development of novel materials.	Literature/Data Call	Xue, Z., Cao, Y., Liu, N., Feng, L., & Jiang, L. (2014). Special wettable materials for oil/water separation. *Journal of Materials Chemistry A, 2* (8), 2445-2460. https://doi.org/10.1039/C3TA13397D
30900	Oily and Oil Waste Disposal	No Subcategory	Research and develop stimuli-responsive special wettable materials for controllable oil/water separation.	Literature/Data Call	Xue, Z., Cao, Y., Liu, N., Feng, L., & Jiang, L. (2014). Special wettable materials for oil/water separation. *Journal of Materials Chemistry A, 2* (8), 2445-2460. https://doi.org/10.1039/C3TA13397D
31000	Bioremediation and Biodegradation	No Subcategory	Study the relative effectiveness and environmental impacts of bioremediation technologies under realistic field conditions.	SME Evaluation	N/A
31000	Bioremediation and Biodegradation	No Subcategory	Study the factors controlling bioavailability of petroleum hydrocarbons in estuarine and freshwater sediments to assess the effectiveness of bioremediation.	SME Evaluation	N/A
31000	Bioremediation and Biodegradation	No Subcategory	Create a complete glossary of terms used in both biodegradation research, and bioremediation technologies.	SME Comments	N/A
31000	Bioremediation and Biodegradation	No Subcategory	Determine the rate at which indigenous bacteria in Arctic waters degrade oil.	Public Listening Sessions	N/A
31000	Bioremediation and Biodegradation	No Subcategory	Evaluate spatial heterogeneity of oil degraders and oil degrading pathways in Arctic marine environments.	Public Listening Sessions	N/A
31000	Bioremediation and Biodegradation	No Subcategory	Evaluate the oil biodegradation potential in high-latitude benthic environments.	Public Listening Sessions	N/A
31000	Bioremediation and Biodegradation	No Subcategory	Conduct long-term studies to determine microbial rates of hydrocarbon degradation over time and to assess the recovery rate of benthic communities.	Literature/Data Call	Daly, K.L., Passow, U., Chanton, J., & Hollander, D. (2016). Assessing the impacts of oil-associated marine snow formation and sedimentation during and after the Deepwater Horizon oil spill. *Anthropocene, 13* , 18-33. https://doi.org/10.1016/j.ancene.2016.01.006
31000	Bioremediation and Biodegradation	No Subcategory	Study the dominant factors controlling the persistence and degradation of hydrocarbons in sediments	Literature/Data Call	Daly, K.L., Passow, U., Chanton, J., & Hollander, D. (2016). Assessing the impacts of oil-associated marine snow formation and sedimentation during and after the Deepwater Horizon oil spill. *Anthropocene, 13* , 18-33. https://doi.org/10.1016/j.ancene.2016.01.006
31000	Bioremediation and Biodegradation	No Subcategory	Study how the density of dispersed oil changes as the biodegradation proceeds.	Literature/Data Call	Prince, R.C. (2015). Oil spill dispersants: Boon or bane?. *Environmental Science & Technology, 49* (11), 6376-6384. https://doi.org/10.1021/acs.est.5b00961
31000	Bioremediation and Biodegradation	No Subcategory	Research the effectiveness of natural and enhanced biodegradation on dilbits to provide information on guidelines for cleanup and remediation.	Literature/Data Call	Witt O'Brien's, Polaris Applied Sciences, & Western Canada Marine Response Corporation. (2013). *A study of fate and behavior of diluted bitumen oils on marine waters.* Trans Mountain Pipeline ULC (TMPL). https://s3-us-west-2.amazonaws.com/transmountain-craftcms/documents/1391734754-astudyoffateandbehaviourofdilutedbitumenoilsonmarinewater.pdf?mtime=20170721171558
31000	Bioremediation and Biodegradation	No Subcategory	Research pressure effects on the physiology of deep sea hydrocarbon-degrading microorganisms.	Literature/Data Call	Kostka, J.E., Joye, S.B., Overholt, W., Bubenheim, P., Hackbusch, S., Larter, S.R., Liese, A., Lincoln, S.A., Marietou, A., Müller, R., Noirungsee, N., Oldenburg, T.B.P., Radović, J.R., & Viamonte, J. (2020). Biodegradation of petroleum hydrocarbons in the deep sea. In: Murawski, S., Ainsworth, C.H., Gilbert, S., Hollander, D.J., Paris, C.B., Schlüter, M., & Wetzel, D.L. (Eds.), *Deep oil spills* (pp. 107-124). Springer, Cham. https://doi.org/10.1007/978-3-030-11605-7_7
31000	Bioremediation and Biodegradation	No Subcategory	Study the lag time associated with the onset of biodegradation in laboratory experiments and whether/how it relates to microbial growth on dissolved and droplet oil in the field.	Literature/Data Call	Socolofsky, S.A., Gros, J., North, E., Boufadel, M.C., Parkerton, T.F., & Adams, E.E. (2019). The treatment of biodegradation in models of sub-surface oil spills: A review and sensitivity study. *Marine Pollution Bulletin, 143,* 204-219. https://doi.org/10.1016/j.marpolbul.2019.04.018
31000	Bioremediation and Biodegradation	No Subcategory	Research the microbial degraded of diluted bitumen under various conditions (e.g., different levels of nitrogen and phosphorus), and how these conditions impact the microbial ecology of hydrocarbon degrading bacteria in natural settings.	Literature/Data Call	Deshpande, R. S., Sundaravadivelu, D., Techtmann, S., Conmy, R. N., Santo Domingo, J. W., & Campo, P. (2018). Microbial degradation of Cold Lake Blend and Western Canadian select dilbits by freshwater enrichments. *Journal of Hazardous Materials* , *352* , 111–120. https://doi.org/10.1016/j.jhazmat.2018.03.030
31000	Bioremediation and Biodegradation	No Subcategory	Validate the effect of temperature on biodegradation rates.	Literature/Data Call	Torlapati, J., Geng, X., King, T., Boufadel, M., & Lee, K. (2014). Shoreline bioremediation model (SBM) - A graphical user interface for simulating the biodegradation of beached oil.
31000	Bioremediation and Biodegradation	No Subcategory	Assess marine colloids relative role in biodegradations vs. photo-degradation vs. photo-flocculation vs. colloid aggregation through electrostatic and hydrophobic interactions vs. self-assembly contributing to the observed size distribution and properties of marine colloids and particles.	Literature/Data Call	Santschi, P.H. (2018). Marine colloids, agents of the self-cleansing capacity of aquatic systems: Historical perspective and new discoveries. *Marine Chemistry, 207,* 124-135. https://doi.org/10.1016/j.marchem.2018.11.003
31000	Bioremediation and Biodegradation	No Subcategory	Study and quantify biodegradation rates and to elucidate the scales of seasonal and interannual variability such as those observed in other ecosystem components	Literature/Data Call	McFarlin, K.M., Questel, J.M., Hopcroft, R.R., & Leigh, M.B. (2017). Bacterial community structure and functional potential in the northeastern Chukchi Sea. *Continental Shelf Research, 136,* 20-28. https://doi.org/10.1016/j.csr.2017.01.018
31000	Bioremediation and Biodegradation	No Subcategory	Investigate the composition of oil spill degradation intermediates and their potential risks to disrupt biological processes in both human and ecological receptors.	Literature/Data Call	Bekins, B.A., Brennan, J.C., Tillitt, D.E., Cozzarelli, I.M., Illig, J.M., & Martinović-Weigelt, D. (2020). Biological effects of hydrocarbon degradation intermediates: Is the total petroleum hydrocarbon analytical method adequate for risk assessment?. *Environmental Science & Technology, 54* (18), 11396-11404. https://doi.org/10.1021/acs.est.0c02220
31000	Bioremediation and Biodegradation	No Subcategory	Study biodegradation rates in offshore Arctic oil lease areas to address the behavior and biodegradation of oil spilled in ice covered waters.	Literature/Data Call	McFarlin, K.M., Prince, R.C., Perkins, R., & Leigh, M.B. (2014). Biodegradation of dispersed oil in Arctic seawater at -1°C. *PLoS ONE, 9* (1), e84297. https://doi.org/10.1371/journal.pone.0084297
31000	Bioremediation and Biodegradation	No Subcategory	Study the mechanism of oil photo-oxidation and how it may vary for different types of oil.	Literature/Data Call	Ward, C.P. & Overton, E.B. (2020). How the 2010 Deepwater Horizon spill reshaped our understanding of crude oil photochemical weathering at sea: a past, present, and future perspective. *Environmental Science: Processes & Impacts, 22* (5), 1101-1308. https://doi.org/10.1039/D0EM00027B

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ICCOPR NUMBER	ICCOPR SRA	Subcategory	Research Need	Source	Citation
31000	Bioremediation and Biodegradation	No Subcategory	Investigate which microbes mediate degradation of individual classes of hydrocarbon carbon compounds and how oil impacts important ecosystem services provided by microbes, such as organic matter mineralization and nutrient cycling.	Literature/Data Call	Kostka, J.E., Overholt, W.A., Rodriguez-R, L.M., Huettel, M., & Konstantinidis, K. (2019). Toward a predictive understanding of the benthic microbial community response to oiling on the Northern Gulf of Mexico coast. In: Murawski, S., Ainsworth, C.H., Gilbert, S., Hollander, D.J., Paris, C.B., Schlüter, M., & Wetzel, D.L. (Eds.), *Scenarios and responses to future deep oil spills* (pp. 182-202). Springer, Cham. https://doi.org/10.1007/978-3-030-12963-7_11
31000	Bioremediation and Biodegradation	No Subcategory	Develop and calibrate models that treat biodegradation of liquid oil as a function of the area of the oil/water interface	Literature/Data Call	Socolofsky, S.A., Gros, J., North, E., Boufadel, M.C., Parkerton, T.F., & Adams, E.E. (2019). The treatment of biodegradation in models of sub-surface oil spills: A review and sensitivity study. *Marine Pollution Bulletin, 143,* 204-219. https://doi.org/10.1016/j.marpolbul.2019.04.018
31000	Bioremediation and Biodegradation	No Subcategory	Study the relationship between light attenuation and photo-oxidation in the water column.	Literature/Data Call	Vergeynst, L., Greer, C.W., Mosbech, A., Gustavson, K., Meire, L., Poulsen, K.G., & Christensen, J.H. (2019). Biodegradation, photo-oxidation, and dissolution of petroleum compounds in an Arctic fjord during summer. *Environmental Science & Technology, 53* (21), 12197-12206. https://doi.org/10.1021/acs.est.9b03336
31000	Bioremediation and Biodegradation	No Subcategory	Study fate, transport, and ecotoxicity of oil contaminates and their degradation intermediates for the effective remediation of site impacted by heavy oil spills.	Literature/Data Call	Cai, B., Ma, J., Yan, G., Dai, X., Li, M., & Guo, S. (2016). Comparison of phytoremediation, bioaugmentation and natural attenuation for remediating saline soil contaminated by heavy crude oil. *Biochemical Engineering Journal, 112,* 170-177. https://doi.org/10.1016/j.bej.2016.04.018
INJURY ASSESSMENT & RESTORATION (40000 SERIES)					
40001	Environmental Impacts and Ecosystem Recovery	Species Impacts	Study the effect of exposure to oil on: physiological functions of organisms (immune, reproductive, and other vital systems); potential impacts on individual fitness; and population vitality rates, abundance and trends.	SME Evaluation	N/A
40001	Environmental Impacts and Ecosystem Recovery	Species Impacts	Develop an increased understanding of the environmental effects of in situ burning, chemical dispersants and herding agents on Arctic ecology, with emphasis on sensitivity differences between Arctic organisms and more commonly used test organisms.	SME Evaluation	N/A
40001	Environmental Impacts and Ecosystem Recovery	Species Impacts	Interpret existing data and conduct research to identify specific metrics and methods for evaluating oil exposure and impacts on organisms, populations, and habitats in the Arctic to support future NRDA activities in Arctic areas that are at high risk for oil spills.	SME Evaluation	N/A
40001	Environmental Impacts and Ecosystem Recovery	Species Impacts	Conduct studies on the dynamics of oil exposure concentrations (temporal and spatial variable) to water column organisms.	Public Listening Sessions	N/A
40001	Environmental Impacts and Ecosystem Recovery	Species Impacts	Conduct studies on the distribution of water column organisms and whether and how long biota were exposed to oil.	Public Listening Sessions	N/A
40001	Environmental Impacts and Ecosystem Recovery	Species Impacts	Study the differences in biological response to acute exposures and long-term exposures of both naturally occurring and human-introduced hydrocarbons.	Literature/Data Call	Portnoy, D.S., Fields, A.T., Greer, J.B., & Schlenk, D. (2019). Genetics and oil: Transcriptomics, epigenetics, and population genomics as tools to understand animal responses to exposure across different time scales. In: Murawski, S., Ainsworth, C.H., Gilbert, S., Hollander, D.J., Paris, C.B., Schlüter, M., & Wetzel, D.L. (Eds.), Deep oil spills (pp. 515-532). Springer, Cham. https://doi.org/10.1007/978-3-030-11605-7_30
40001	Environmental Impacts and Ecosystem Recovery	Species Impacts	Conduct long-term and short-term monitoring impacts of oil spills on recreational and commercial fish.	Literature/Data Call	Murawski, S. A., Kilborn, J. P., Bejarano, A. C., Chagaris, D., Donaldson, D., Hernandez, F. J., MacDonald, T. C., Newton, C., Peebles, E., & Robinson, K. L. (2021). A Synthesis of Deepwater Horizon Impacts on Coastal and Nearshore Living Marine Resources. *Frontiers in Marine Science* , *7* . https://doi.org/10.3389/fmars.2020.594862
40001	Environmental Impacts and Ecosystem Recovery	Species Impacts	Study the mechanisms by which crude oil changes feather properties and the relationship between oiling and the power requirement/output during takeoff in oiled birds.	Literature/Data Call	Maggini, I., Kennedy, L.V., Elliott, K.H., Dean, K.M., MacCurdy, R., Macmillan, A., Pritsos, C.A., & Guglielmo, C.G. (2017). Reprint of: Trouble on takeoff: Crude oil on feathers reduces escape performance of shorebirds. *Ecotoxicology and Environmental Safety, 146,* 111-117. https://doi.org/10.1016/j.ecoenv.2017.05.018
40001	Environmental Impacts and Ecosystem Recovery	Species Impacts	Study the effects of dispersant and dispersed crude oil on key zooplankton groups that are currently understudied (e.g. copepod nauplii, meroplankton, ciliates, etc.) to better understand the impact of dispersants and dispersed crude oil on planktonic communities.	Literature/Data Call	Almeda, R., Baca, S., Hyatt, C., & Buskey, E.J. (2014). Ingestion and sublethal effects of physically and chemically dispersed crude oil on marine planktonic copepods. *Ecotoxicology, 23,* 988-1003. https://doi.org/10.1007/s10646-014-1242-6
40001	Environmental Impacts and Ecosystem Recovery	Species Impacts	Study UV exposure and examine oil toxicity to tropical organisms in shallow, clear-water environments.	Literature/Data Call	Negri, A. P., Brinkman, D. L., Flores, F., Botté, E. S., Jones, R. J., & Webster, N. S. (2016). Acute ecotoxicology of natural oil and gas condensate to coral reef larvae. *Scientific Reports* , *6* (1). https://doi.org/10.1038/srep21153
40001	Environmental Impacts and Ecosystem Recovery	Species Impacts	Research the effects of petroleum hydrocarbons on more tropical reef organisms, including potential interactions with ultraviolet radiation (UVR) and other stressors, is needed to more effectively quantify these risks.	Literature/Data Call	Nordborg, F. M., Flores, F., Brinkman, D. L., Agustí, S., & Negri, A. P. (2018). Phototoxic effects of two common marine fuels on the settlement success of the coral Acropora tenuis. *Scientific Reports, 8* (1). https://doi.org/10.1038/s41598-018-26972-7
40001	Environmental Impacts and Ecosystem Recovery	Species Impacts	Determine the impacts on populations of key Arctic species and their implications on resilience and recovery, and ecological processes (i.e., trophic level impacts).	Literature/Data Call	Bejarano, A. C., Gardiner, W. W., Barron, M. G., & Word, J. Q. (2017). Relative sensitivity of Arctic species to physically and chemically dispersed oil determined from three hydrocarbon measures of aquatic toxicity. *Marine Pollution Bulletin* , *122* (1-2), 316–322. https://doi.org/10.1016/j.marpolbul.2017.06.064
40001	Environmental Impacts and Ecosystem Recovery	Species Impacts	Research on how oiling affects sea turtles, particularly about the types and concentrations of chemicals contained in the air directly above an oil spill, because sea turtles (and marine mammals and birds) breathe in close proximity to the seawater–air interface.	Literature/Data Call	Beyer, J., Trannum, H. C., Bakke, T., Hodson, P. V., & Collier, T. K. (2016). Environmental effects of the Deepwater Horizon oil spill: A review. *Marine Pollution Bulletin* , *110* (1), 28–51. https://doi.org/10.1016/j.marpolbul.2016.06.027
40001	Environmental Impacts and Ecosystem Recovery	Species Impacts	Conduct long-term and short-term monitoring impacts of oil spills on birds.	Literature/Data Call	Coastal Response Research Center (CRRC). (2016). 2016 NRPT: Addressing Public Concerns During Spill Response. *Coastal Response Research Center* . https://scholars.unh.edu/crrc/9/
40001	Environmental Impacts and Ecosystem Recovery	Species Impacts	Examine the effects of photo-induced toxicity using a lower range of ultraviolet intensities to represent depths down to 20 m, because these types of toxicity studies focus almost exclusively on the risk posed to organisms at or near the surface.	Literature/Data Call	Bridges, K. N., Lay, C. R., Alloy, M. M., Gielazyn, M. L., Morris, J. M., Forth, H. P., Takeshita, R., Travers, C. L., Oris, J. T., & Roberts, A. P. (2018). Estimating incident ultraviolet radiation exposure in the northern Gulf of Mexico during the Deepwater Horizon oil spill. *Environmental Toxicology and Chemistry* , *37* (6), 1679–1687. https://doi.org/10.1002/etc.4119
40002	Environmental Impacts and Ecosystem Recovery	Toxicological and Sub-lethal Impacts	Study oil-specific biomarkers of exposure and injury, establish mechanistic linkages between biomarkers and effects, and develop guidelines for using transcriptional and other biomarker methods for a range of species, including timing for sample collection and use and interpretation of data.	SME Evaluation	N/A
40002	Environmental Impacts and Ecosystem Recovery	Toxicological and Sub-lethal Impacts	Conduct research on key species to determine the long-term, sub-lethal, and latent mortality effects of short-term exposure to oil Synthesize existing research to support extrapolation to population, community and ecosystem effects.	SME Evaluation	N/A
40002	Environmental Impacts and Ecosystem Recovery	Toxicological and Sub-lethal Impacts	Study the bioavailability and toxicity of oil sands products, including process water and crude oil constituents, to birds and mammals.	SME Evaluation	N/A
40002	Environmental Impacts and Ecosystem Recovery	Toxicological and Sub-lethal Impacts	Conduct further research into rapid impact assessment tool kits that provide an early indication of potential toxic effects and impacts of an oil spill.	Public Listening Sessions	N/A
40002	Environmental Impacts and Ecosystem Recovery	Toxicological and Sub-lethal Impacts	Determine the effects of ultraviolet radiation (UVR) on the toxicity of oil on shallow water species (e.g., coral reefs).	Public Listening Sessions	N/A
40002	Environmental Impacts and Ecosystem Recovery	Toxicological and Sub-lethal Impacts	Conduct toxicity testing of species common among known sensitive taxa (e.g., crustaceans) and test different life stages of the same species.	Literature/Data Call	Bejarano, A. C., Clark, J. R., & Coelho, G. M. (2014). Issues and challenges with oil toxicity data and implications for their use in decision making: A quantitative review. *Environmental Toxicology and Chemistry* , *33* (4), 732–742. https://doi.org/10.1002/etc.2501
40002	Environmental Impacts and Ecosystem Recovery	Toxicological and Sub-lethal Impacts	Develop minimum criteria and data quality requirements to provide more toxicological data points suitable for inclusion in toxicity models.	Literature/Data Call	Mitchelmore, C. L., Griffitt, R. J., Coelho, G. M., & Wetzel, D. L. (2019). Modernizing Protocols for Aquatic Toxicity Testing of Oil and Dispersant. *Scenarios and Responses to Future Deep Oil Spills* , 239–252. https://doi.org/10.1007/978-3-030-12963-7_14

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ICCOPR NUMBER	ICCOPR SRA	Subcategory	Research Need	Source	Citation
40002	Environmental Impacts and Ecosystem Recovery	Toxicological and Sub-lethal Impacts	Research the toxic effects on un-resolved and unidentified hydrocarbons in crude oils.	Literature/Data Call	Hong, S., Khim, J. S., Ryu, J., Kang, S.-G., Shim, W. J., & Yim, U. H. (2014). Environmental and ecological effects and recoveries after five years of the Hebei Spirit oil spill, Taean, Korea. *Ocean & Coastal Management*, *102*, 522–532. https://doi.org/10.1016/j.ocecoaman.2014.01.006
40002	Environmental Impacts and Ecosystem Recovery	Toxicological and Sub-lethal Impacts	Develop standard methods for unambiguous measures of oil toxicity that will improve the understanding of why oil toxicity changes under site-specific conditions.	Literature/Data Call	Hodson, P. V., Adams, J., & Brown, R. S. (2018). Oil toxicity test methods must be improved. *Environmental Toxicology and Chemistry*, *38* (2), 302–311. https://doi.org/10.1002/etc.4303
40002	Environmental Impacts and Ecosystem Recovery	Toxicological and Sub-lethal	Evaluate the toxicity of surface washing and bioremediation agents.	Literature/Data Call	Chen, Z., An, C., Boufadel, M., Owens, E., Chi, Z., Lee, K., Cao, Y., & Cai, M. (2020). Use of surface-washing agents for the treatment of oiled shorelines: Research advancements, technical applications and future challenges. *Chemical Engineering Journal*, *391*, 123565. https://doi.org/10.1016/j.cej.2019.123565
40002	Environmental Impacts and Ecosystem Recovery	Toxicological and Sub-lethal	Study dilbit toxicity to a greater diversity of both native and standard test species to understand the chemical and physical effects of dilbits in sediments.	Literature/Data Call	Barron, M. G., Conmy, R. N., Holder, E. L., Meyer, P., Wilson, G. J., Principe, V. E., & Willming, M. M. (2018). Toxicity of Cold Lake Blend and Western Canadian Select dilbits to standard aquatic test species. *Chemosphere*, *191*, 1–6. https://doi.org/10.1016/j.chemosphere.2017.10.014
40002	Environmental Impacts and Ecosystem Recovery	Toxicological and Sub-lethal	Examine how environmentally-persistent PAHs from dilbit influence the chronic toxicity of different blends of dilbit that weather at varied rates.	Literature/Data Call	Madison, B. N., Hodson, P. V., & Langlois, V. S. (2017). Cold Lake Blend diluted bitumen toxicity to the early development of Japanese medaka. *Environmental Pollution*, *225*, 579–586. https://doi.org/10.1016/j.envpol.2017.03.025
40002	Environmental Impacts and Ecosystem Recovery	Toxicological and Sub-lethal	Research the toxicity and environmental fate of unweathered and weathered dilbits to allow for more informed hazard assessments in case of dilbit spills in aquatic and terrestrial environments.	Literature/Data Call	Barron, M. G., Conmy, R. N., Holder, E. L., Meyer, P., Wilson, G. J., Principe, V. E., & Willming, M. M. (2018). Toxicity of Cold Lake Blend and Western Canadian Select dilbits to standard aquatic test species. *Chemosphere*, *191*, 1–6. https://doi.org/10.1016/j.chemosphere.2017.10.014
40002	Environmental Impacts and Ecosystem Recovery	Toxicological and Sub-lethal Impacts	Research and collect omics data for deep ocean species so that biomarkers of toxicant exposure and toxicity can be established.	Literature/Data Call	Chiasson, S., A. Bejarano, and M. Barron. (2020). Ecotoxicology of Deep Ocean Spills. *Society of Environmental Toxicology and Chemistry (SETAC), Fort Worth, Texas*. https://cfpub.epa.gov/si/si_public_record_Report.cfm?dirEntryId=350822&Lab=CEMM
40002	Environmental Impacts and Ecosystem Recovery	Toxicological and Sub-lethal Impacts	Research more environmentally relevant exposures i.e. longer-term, chronic, sublethal endpoints and examine changing exposure characteristics (chemistry, etc.) over time.	Literature/Data Call	Mitchelmore, C. L., Bejarano, A. C., & Wetzel, D. L. (2019). A Synthesis of DWH Oil: Chemical Dispersant and Chemically Dispersed Oil Aquatic Standard Laboratory Acute and Chronic Toxicity Studies. *Deep Oil Spills*, 480–496. https://doi.org/10.1007/978-3-030-11605-7_28
40002	Environmental Impacts and Ecosystem Recovery	Toxicological and Sub-lethal Impacts	Conduct toxicity studies for deep ocean fish and invertebrates.	Literature/Data Call	Buskey, E. J., White, H. K., & Esbaugh, A. J. (2016). Impact of Oil Spills on Marine Life in the Gulf of Mexico: EFFECTS ON PLANKTON, NEKTON, AND DEEP-SEA BENTHOS. *Oceanography*, *29* (3), 174–181. http://www.jstor.org/stable/24862719
40002	Environmental Impacts and Ecosystem Recovery	Toxicological and Sub-lethal Impacts	Research the relationships between toxicity and the chemical composition and physical properties of spill response agents.	Literature/Data Call	Barron, M. G., Bejarano, A. C., Conmy, R. N., Sundaravadivelu, D., & Meyer, P. (2020). Toxicity of oil spill response agents and crude oils to five aquatic test species. *Marine Pollution Bulletin*, *153*, 110954. https://doi.org/10.1016/j.marpolbul.2020.110954
40002	Environmental Impacts and Ecosystem Recovery	Toxicological and Sub-lethal Impacts	Research and quantify sublethal endpoints of dispersants as well as the potential modulating role of pressure and colder temperatures on toxicity at depth.	Literature/Data Call	McConville, M. M., Roberts, J. P., Boulais, M., Woodall, B., Butler, J. D., Redman, A. D., Parkerton, T. F., Arnold, W. R., Guyomarch, J., LeFloch, S., Bytingsvik, J., Camus, L., Volety, A., & Brander, S. M. (2018). The sensitivity of a deep-sea fish species (Anoplopoma fimbria) to oil-associated aromatic compounds, dispersant, and Alaskan North Slope crude oil. *Environmental Toxicology and Chemistry*, *37* (8), 2210–2221. https://doi.org/10.1002/etc.4165
40002	Environmental Impacts and Ecosystem Recovery	Toxicological and Sub-lethal Impacts	Determine how the characteristics of dilbit and the methodology to prepare solutions for dilbit toxicity testing, may alter the interpretation of toxicity.	Literature/Data Call	Adams, J. E., Madison, B. N., Charbonneau, K., Sereneo, M., Baillon, L., Langlois, V. S., Brown, R. S., & Hodson, P. V. (2020). Effects on Trout Alevins of Chronic Exposures to Chemically Dispersed Access Western Blend and Cold Lake Blend Diluted Bitumens. *Environmental Toxicology and Chemistry*, *39* (8), 1620–1633. https://doi.org/10.1002/etc.4747
40002	Environmental Impacts and Ecosystem Recovery	Toxicological and Sub-lethal Impacts	Study the effect of pressure on the aquatic toxicity of hydrocarbons.	Literature/Data Call	Broje, V., Gala, W., Nedwed, T., & Twomey, J. (2014). A Consensus on the State of the Knowledge and Research Recommendations on the Fate and Effects of Deep Water Releases of Oil, Dispersants and Dispersed Oil. *International Oil Spill Conference Proceedings*, *2014* (1), 225–237. https://doi.org/10.7901/2169-3358-2014.1.225
40002	Environmental Impacts and Ecosystem Recovery	Toxicological and Sub-lethal Impacts	Study under what conditions would C1-C4 hydrocarbons cause significant toxicity to deep sea and shallow water species following a wellhead release.	Literature/Data Call	Broje, V., Gala, W., Nedwed, T., & Twomey, J. (2014). A Consensus on the State of the Knowledge and Research Recommendations on the Fate and Effects of Deep Water Releases of Oil, Dispersants and Dispersed Oil. *International Oil Spill Conference Proceedings*, *2014* (1), 225–237. https://doi.org/10.7901/2169-3358-2014.1.225
40002	Environmental Impacts and Ecosystem Recovery	Toxicological and Sub-lethal Impacts	Conduct experiments to assess temperature stresses role in toxicity at both high and low ends of environmentally relevant temperatures for the Gulf of Mexico.	Literature/Data Call	Nordborg, F. M., Jones, R., Oelgemoller, M., & Negri, A. (2020). The effects of ultraviolet radiation and climate on oil toxicity to coral reef organisms – A review. *Science of the Total Environment*, *720*, 137486. https://doi.org/10.1016/j.scitotenv.2020.137486
40002	Environmental Impacts and Ecosystem Recovery	Toxicological and Sub-lethal Impacts	Determine which environmental variables affect dilbit, synbit, and dilsynbit toxicity to establish species sensitivities.	Literature/Data Call	Dew, W. A., Hontela, A., Rood, S. B., & Pyle, G. G. (2015). Biological effects and toxicity of diluted bitumen and its constituents in freshwater systems. *Journal of Applied Toxicology*, *35* (11), 1219–1227. https://doi.org/10.1002/jat.3196
40002	Environmental Impacts and Ecosystem Recovery	Toxicological and Sub-lethal Impacts	Study the acute and chronic toxicity associated with OSP in the environment and particularly for threatened and endangered species.	Literature/Data Call	The Center for Spills in the Environment. (2013). *Alberta Oil Sands Workshop for Washington State Department of Ecology, the Regional Response Team 10 and the Pacific States/British Columbia Oil Spill Task Force*. University of New Hampshire. https://crrc.unh.edu/sites/crrc.unh.edu/files/media/docs/Workshops/oil_sands_washington/OilSandsProductsWorkshopReport_Washington%20TOTAL.pdf
40002	Environmental Impacts and Ecosystem Recovery	Toxicological and Sub-lethal Impacts	Investigate the links between embryo toxicity and effects on adult fish, and the role of weathering in the results of dilbit toxicity tests.	Literature/Data Call	Alsaadi, F. M., Madison, B. N., Brown, R. S., Hodson, P. V., & Langlois, V. S. (2018). Morphological and molecular effects of two diluted bitumens on developing fathead minnow (Pimephales promelas). *Aquatic Toxicology*, *204*, 107–116. https://doi.org/10.1016/j.aquatox.2018.09.003
40003	Environmental Impacts and Ecosystem Recovery	Sunken and Submerged Oil Impacts	Develop an understanding of the exposure pathways of submerged oil to benthic communities.	SME Evaluation	N/A
40003	Environmental Impacts and Ecosystem Recovery	Sunken and Submerged Oil Impacts	Determine the degradation rates of oil components and oil mixture changes 5 or more years after termination of oil spill cleanup efforts.	SME Evaluation	N/A
40003	Environmental Impacts and Ecosystem Recovery	Sunken and Submerged Oil Impacts	Conduct controlled studies on the long term effects of species contact with sediments containing oil and oily residues.	SME Evaluation	N/A
40003	Environmental Impacts and Ecosystem Recovery	Sunken and Submerged Oil Impacts	Study the biodegradation of hydrocarbons in marine snow and any residual toxicity and bioavailability if any alongside distribution at seabed to understand concentrations and potential impacts	Public Listening Sessions	N/A
40003	Environmental Impacts and Ecosystem Recovery	Sunken and Submerged Oil Impacts	Study how long nutrient freshwater ecosystems are affected by diluted bitumen.	Literature/Data Call	Cederwall, J., Black, T. A., Blais, J. M., Hanson, M. L., Hollebone, B. P., Palace, V. P., Rodriguez-Gil, J. L., Greer, C. W., Maynard, C., Ortmann, A. C., Rooney, R. C., & Orihel, D. M. (2020). Life under an oil slick: response of a freshwater food web to simulated spills of diluted bitumen in field mesocosms. *Canadian Journal of Fisheries and Aquatic Sciences*, *77* (5), 779–788. https://doi.org/10.1139/cjfas-2019-0224
40003	Environmental Impacts and Ecosystem Recovery	Sunken and Submerged Oil Impacts	Study if sunken diluted bitumen smother sediment biota and negatively affect the development of zooplankton eggs and benthic invertebrates.	Literature/Data Call	Cederwall, J., Black, T. A., Blais, J. M., Hanson, M. L., Hollebone, B. P., Palace, V. P., Rodriguez-Gil, J. L., Greer, C. W., Maynard, C., Ortmann, A. C., Rooney, R. C., & Orihel, D. M. (2020). Life under an oil slick: response of a freshwater food web to simulated spills of diluted bitumen in field mesocosms. *Canadian Journal of Fisheries and Aquatic Sciences*, *77* (5), 779–788. https://doi.org/10.1139/cjfas-2019-0224
40003	Environmental Impacts and Ecosystem Recovery	Sunken and Submerged Oil Impacts	Research the effects of MOS and MOSSFA on ecosystems and food webs in a variety of oceanographic regimes to develop a better understanding of the complexities of this dynamic material.	Literature/Data Call	Burd, A. B., Chanton, J. P., Daly, K. L., Gilbert, S., Passow, U., & Quigg, A. (2020). The science behind marine-oil snow and MOSSFA: Past, present, and future. *Progress in Oceanography*, *187*. https://doi.org/10.1016/j.pocean.2020.102398
40003	Environmental Impacts and Ecosystem Recovery	Sunken and Submerged Oil Impacts	Study the effects of MOS and MOSSFA on pelagic and deep-sea organisms.	Literature/Data Call	Burd, A. B., Chanton, J. P., Daly, K. L., Gilbert, S., Passow, U., & Quigg, A. (2020). The science behind marine-oil snow and MOSSFA: Past, present, and future. *Progress in Oceanography*, *187*. https://doi.org/10.1016/j.pocean.2020.102398

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ICCOPR NUMBER	ICCOPR SRA	Subcategory	Research Need	Source	Citation
40003	Environmental Impacts and Ecosystem Recovery	Sunken and Submerged Oil Impacts	Determine the impact of MOSSFA on humans, including socio-economic impacts.	Literature/Data Call	Gulf of Mexico Research Initiative. (2018). *Gulf of Mexico Research Initiative Synthesis Workshop I MOSSFA -Core Area Two* . Gulf of Mexico Research Initiative. https://gulfresearchinitiative.org/wp-content/uploads/MOSSFA-Workshop-Report-Nov2018-APRIL-2019-Final.pdf
40003	Environmental Impacts and Ecosystem Recovery	Sunken and Submerged Oil Impacts	Develop models and simulations of fate and transport of oil and oil- particle aggregates (OPAs) in freshwater and cold climate environments with a range of oil and sediment types.	Literature/Data Call	U.S. Geological Survey. (2015). *Oil-Particle Interactions and Submergence from Crude Oil Spills in Marine and Freshwater Environments- Review of the Science and Future Science Needs* . U.S. Department of the Interior. https://pubs.usgs.gov/of/2015/1076/pdf/ofr2015-1076.pdf
40003	Environmental Impacts and Ecosystem Recovery	Sunken and Submerged Oil Impacts	Conduct field trials in cold climates using realist field conditions of oil- particle aggregate (OPA) formation during oil spills, especially study freshwater environments in and around the Great Lakes coastal environments and river mouths.	Literature/Data Call	U.S. Geological Survey. (2015). *Oil-Particle Interactions and Submergence from Crude Oil Spills in Marine and Freshwater Environments- Review of the Science and Future Science Needs* . U.S. Department of the Interior. https://pubs.usgs.gov/of/2015/1076/pdf/ofr2015-1076.pdf
40003	Environmental Impacts and Ecosystem Recovery	Sunken and Submerged Oil Impacts	Research how to sample to capturing sediment surface floc (e.g., slurp guns, sediment traps) or water column marine snow event.	Literature/Data Call	Gulf of Mexico Research Initiative. (2018). *Gulf of Mexico Research Initiative Synthesis Workshop I MOSSFA -Core Area Two* . Gulf of Mexico Research Initiative. https://gulfresearchinitiative.org/wp-content/uploads/MOSSFA-Workshop-Report-Nov2018-APRIL-2019-Final.pdf
40003	Environmental Impacts and Ecosystem Recovery	Sunken and Submerged Oil Impacts	Research the role of dispersants in the MOSSFA process, including different dispersant types and concentrations.	Literature/Data Call	Gulf of Mexico Research Initiative. (2018). *Gulf of Mexico Research Initiative Synthesis Workshop I MOSSFA -Core Area Two* . Gulf of Mexico Research Initiative. https://gulfresearchinitiative.org/wp-content/uploads/MOSSFA-Workshop-Report-Nov2018-APRIL-2019-Final.pdf
40003	Environmental Impacts and Ecosystem Recovery	Sunken and Submerged Oil Impacts	Conduct research on the biological and chemical factors involved in the persistence and degradation of oil/marine snow in sediments.	Literature/Data Call	Gulf of Mexico Research Initiative. (2018). *Gulf of Mexico Research Initiative Synthesis Workshop I MOSSFA -Core Area Two* . Gulf of Mexico Research Initiative. https://gulfresearchinitiative.org/wp-content/uploads/MOSSFA-Workshop-Report-Nov2018-APRIL-2019-Final.pdf
40003	Environmental Impacts and Ecosystem Recovery	Sunken and Submerged Oil Impacts	Conduct research on the long-term toxicity (including sublethal impacts) of oil and oil/flocs in sediments, including both laboratory and feild testing.	Literature/Data Call	Gulf of Mexico Research Initiative. (2018). *Gulf of Mexico Research Initiative Synthesis Workshop I MOSSFA -Core Area Two* . Gulf of Mexico Research Initiative. https://gulfresearchinitiative.org/wp-content/uploads/MOSSFA-Workshop-Report-Nov2018-APRIL-2019-Final.pdf
40003	Environmental Impacts and Ecosystem Recovery	Sunken and Submerged Oil Impacts	Investigate oil-particulate aggregate (OPA) toxicity and physical effects on different habitats, specifically freshwater benthic organisms.	Literature/Data Call	U.S. Geological Survey. (2015). *Oil-Particle Interactions and Submergence from Crude Oil Spills in Marine and Freshwater Environments- Review of the Science and Future Science Needs* . U.S. Department of the Interior. https://pubs.usgs.gov/of/2015/1076/pdf/ofr2015-1076.pdf
40003	Environmental Impacts and Ecosystem Recovery	Sunken and Submerged Oil Impacts	Develop a long-term monitoring programs to collect samples of marine snow/oil in sediments over time	Literature/Data Call	Gulf of Mexico Research Initiative. (2018). *Gulf of Mexico Research Initiative Synthesis Workshop I MOSSFA -Core Area Two* . Gulf of Mexico Research Initiative. https://gulfresearchinitiative.org/wp-content/uploads/MOSSFA-Workshop-Report-Nov2018-APRIL-2019-Final.pdf
40003	Environmental Impacts and Ecosystem Recovery	Sunken and Submerged Oil Impacts	Evaluate existing data from field and laboratory studies to develop timescales for MOSSFA processes and develop additional laboratory studies to provide more data	Literature/Data Call	Gulf of Mexico Research Initiative. (2018). *Gulf of Mexico Research Initiative Synthesis Workshop I MOSSFA -Core Area Two* . Gulf of Mexico Research Initiative. https://gulfresearchinitiative.org/wp-content/uploads/MOSSFA-Workshop-Report-Nov2018-APRIL-2019-Final.pdf
40003	Environmental Impacts and Ecosystem Recovery	Sunken and Submerged Oil Impacts	Research the biodegrading of oil in MOS aggregates.	Literature/Data Call	Gulf of Mexico Research Initiative. (2018). *Gulf of Mexico Research Initiative Synthesis Workshop I MOSSFA -Core Area Two* . Gulf of Mexico Research Initiative. https://gulfresearchinitiative.org/wp-content/uploads/MOSSFA-Workshop-Report-Nov2018-APRIL-2019-Final.pdf
40003	Environmental Impacts and Ecosystem Recovery	Sunken and Submerged Oil Impacts	Develop research programs for tracking degradation and flux of oil marine snow in sediments.	Literature/Data Call	Gulf of Mexico Research Initiative. (2018). *Gulf of Mexico Research Initiative Synthesis Workshop I MOSSFA -Core Area Two* . Gulf of Mexico Research Initiative. https://gulfresearchinitiative.org/wp-content/uploads/MOSSFA-Workshop-Report-Nov2018-APRIL-2019-Final.pdf
40004	Environmental Impacts and Ecosystem Recovery	Ecosystem and Habitat Impacts	Develop and define relevant exposure conditions (spatially and temporally) and examine connections between exposure and ecological effects.	SME Evaluation	N/A
40004	Environmental Impacts and Ecosystem Recovery	Ecosystem and Habitat Impacts	Develop an understanding of different trophic and habitat linkages among organisms to incorporate into models predicting cascading effects using different types of oils.	SME Evaluation	N/A
40004	Environmental Impacts and Ecosystem Recovery	Ecosystem and Habitat Impacts	Develop an understanding of the difference between oil effects and natural stressors by assessing community structure and function for different habitats.	SME Evaluation	N/A
40004	Environmental Impacts and Ecosystem Recovery	Ecosystem and Habitat Impacts	Conduct experiments (e.g. mesocosms) mimicking the natural environment (e.g. natural microbial assemblages, sunlight, turbulence, etc.) to better understand the effects of oil spills on zooplankton communities and the transfer of petroleum hydrocarbon in marine food webs.	Literature/Data Call	Almeda, R., Wambaugh, Z., Wang, Z., Hyatt, C., Liu, Z., & Buskey, E. J. (2013). Interactions between Zooplankton and Crude Oil: Toxic Effects and Bioaccumulation of Polycyclic Aromatic Hydrocarbons. *PLoS ONE* , *8* (6), e67212. https://doi.org/10.1371/journal.pone.0067212
40004	Environmental Impacts and Ecosystem Recovery	Ecosystem and Habitat Impacts	Study the mid- and long-term response of tropical marine ecosystem exposed to accidental oil spills.	Literature/Data Call	Soto, L. A., Botello, A. V., Licea-DurÃ¡n, S., LizÃ¡rraga-Partida, M. L., & YÃ¡Ã±ez-Arancibia, A. (2014). The environmental legacy of the Ixtoc-I oil spill in Campeche Sound, southwestern Gulf of Mexico. *Frontiers in Marine Science* , *1* . https://doi.org/10.3389/fmars.2014.00057
40004	Environmental Impacts and Ecosystem Recovery	Ecosystem and Habitat Impacts	Research the extent to which oil is transferred to the next trophic level, and how dispersants influenced the degree of impacts on zooplankton under field conditions.	Literature/Data Call	Beyer, J., Trannum, H. C., Bakke, T., Hodson, P. V., & Collier, T. K. (2016). Environmental effects of the Deepwater Horizon oil spill: A review. *Marine Pollution Bulletin* , *110* (1), 28–51. https://doi.org/10.1016/j.marpolbul.2016.06.027
40004	Environmental Impacts and Ecosystem Recovery	Ecosystem and Habitat Impacts	Develop long time scale ecosystem-based management efforts of the deep-pelagic ocean.	Literature/Data Call	Sutton, T. T., Frank, T., Judkins, H., & Romero, I. C. (2019). As Gulf Oil Extraction Goes Deeper, Who Is at Risk? Community Structure, Distribution, and Connectivity of the Deep-Pelagic Fauna. *Scenarios and Responses to Future Deep Oil Spills* , 403–418. https://doi.org/10.1007/978-3-030-12963-7_24
40004	Environmental Impacts and Ecosystem Recovery	Ecosystem and Habitat Impacts	Study the ecological impacts of subsea oil releases and Arctic oil spills on Arctic food webs and dynamics at different trophic levels.	Literature/Data Call	Barron, M. G., Vivian, D. N., Heintz, R. A., & Yim, U. H. (2020). Long-Term Ecological Impacts from Oil Spills: Comparison of Exxon Valdez, Hebei Spirit, and Deepwater Horizon. *Environmental Science & Technology* , *54* (11), 6456–6467. https://doi.org/10.1021/acs.est.9b05020
40004	Environmental Impacts and Ecosystem Recovery	Ecosystem and Habitat Impacts	Continue to study the long-term impacts of the oil spill.	Literature/Data Call	Barron, M. G., Vivian, D. N., Heintz, R. A., & Yim, U. H. (2020). Long-Term Ecological Impacts from Oil Spills: Comparison of Exxon Valdez, Hebei Spirit, and Deepwater Horizon. *Environmental Science & Technology* , *54* (11), 6456–6467. https://doi.org/10.1021/acs.est.9b05020
40005	Environmental Impacts and Ecosystem Recovery	Recovery	Study recovery of injured habitats using different types of oils and methods including synthesis of research on individual species (e.g., previous spills, mesocosm, field studies).	SME Evaluation	N/A
40005	Environmental Impacts and Ecosystem Recovery	Recovery	Develop conceptual models of service loss and recovery from key habitats, and gather the information necessary to parameterize recovery models with appropriate timeframe incorporated.	SME Evaluation	N/A
40005	Environmental Impacts and Ecosystem Recovery	Recovery	Conduct a study comparing environmental injury footprints and ecosystem recovery times after implementation of various response technologies and techniques.	SME Evaluation	N/A
40005	Environmental Impacts and Ecosystem Recovery	Recovery	Conduct follow up studies from historical spills to evaluate the recovery rates of various resources exposed and the effectiveness of the mitigation techniques used.	Public Listening Sessions	N/A
40005	Environmental Impacts and Ecosystem Recovery	Recovery	Evaluate the recovery rates of various biota species in laboratory and mesocosm experiments.	Public Listening Sessions	N/A
40005	Environmental Impacts and Ecosystem Recovery	Recovery	Study the recovery potential of pelagic fish resources from offshore spills and collect abundance, distribution, and movement ecology information from a broader cross-section of these open-ocean species.	Literature/Data Call	Paris, C.B., Murawski, S.A., Olascoaga, M.J., Vaz, A.C., Berenshtein, I., Miron, P., & Beron-Vera, F.J. (2019). Connectivity of the Gulf of Mexico Continental Shelf Fish Populations and Implications of Simulated Oil Spills. *Scenarios and Response to Future Deep Oil Spills. Springer, Cham.* 369-389. https://doi.org/10.1007/978-3-030-12963-7_22

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ICCOPR NUMBER	ICCOPR SRA	Subcategory	Research Need	Source	Citation
40006	Environmental Impacts and Ecosystem Recovery	Risk Assessment and Impact Metrics	Develop models to estimate injury to natural resources encompassing a range of exposure scenarios to biota at different life stages.	SME Evaluation	N/A
40006	Environmental Impacts and Ecosystem Recovery	Risk Assessment and Impact Metrics	Conduct research to determine the best metrics for assessing injury and damages to natural resources.	SME Evaluation	N/A
40006	Environmental Impacts and Ecosystem Recovery	Risk Assessment and Impact Metrics	Conduct single species toxicity research in different regions to understand the mechanisms of toxicity and the impacts of a broader suite of polycyclic aromatic compounds (PACs).	SME Evaluation	N/A
40006	Environmental Impacts and Ecosystem Recovery	Risk Assessment and Impact Metrics	Study the influence of oil exposure duration and its effects on endpoints.	Public Listening Sessions	N/A
40006	Environmental Impacts and Ecosystem Recovery	Risk Assessment and Impact Metrics	Develop microcosm and mesocosm systems that mimic natural conditions to conduct research that links omics information to functional measures.	Literature/Data Call	Microbial Genomics of the Global Ocean System: Report on an American Academy of Microbiology (Academy), The American Geophysical Union (AGU), and The Gulf of Mexico Research Initiative (GoMRI) Colloquium held on 9 and 10 April 2019. (2020). *American Society for Microbiology* . https://doi.org/10.1128/aamcol.apr.2019
40006	Environmental Impacts and Ecosystem Recovery	Risk Assessment and Impact Metrics	Develop standardized decision support tools in the Gulf of Mexico that are sensitive to chronic and acute stressors.	Literature/Data Call	O'Malley, B. J., Schwing, P. T., Martínez-Colón, M., Spezzaferri, S., Machain-Castillo, M. L., Larson, R. A., Brooks, G. R., Ruiz-Fernández, A. C., & Hollander, D. J. (2021). Development of a benthic foraminifera based marine biotic index (Foram-AMBI) for the Gulf of Mexico: A decision support tool. *Ecological Indicators* , *120* , 106916. https://doi.org/10.1016/j.ecolind.2020.106916
40006	Environmental Impacts and Ecosystem Recovery	Risk Assessment and Impact Metrics	Research the translation of genomics data into an integrative biogeochemical model for hydrocarbon degradation.	Literature/Data Call	Microbial Genomics of the Global Ocean System: Report on an American Academy of Microbiology (Academy), The American Geophysical Union (AGU), and The Gulf of Mexico Research Initiative (GoMRI) Colloquium held on 9 and 10 April 2019. (2020). *American Society for Microbiology* . https://doi.org/10.1128/aamcol.apr.2019
40006	Environmental Impacts and Ecosystem Recovery	Risk Assessment and Impact Metrics	Establish a multi-model approach for ecosystem modeling efforts in the GOM that consists of using several ecosystem models that differ greatly in their structure and assumptions to tackle the same research questions.	Literature/Data Call	Gruss, A., Rose, K., Simons, J., Ainsworth, C., Babcock, E., Chagaris, D., De Mutsert, K., Froeschke, J., Himchak, P., Kaplan, I., O'Farrell, H., & Zetina Rejon, M. (2017). Recommendations on the Use of Ecosystem Modeling for Informing Ecosystem-Based Fisheries Management and Restoration Outcomes in the Gulf of Mexico. *Marine and Coastal Fisheries* , *9* (1), 281–295. https://doi.org/https://doi.org/10.1080/19425120.2017.1330786
40006	Environmental Impacts and Ecosystem Recovery	Risk Assessment and Impact Metrics	Research appropriate wildlife response techniques and develop wildlife response plans to include key indicators of environmental health, and prioritize research strategies.	Literature/Data Call	Transportation Research Board and National Research Council. (2014). *Responding to Oil Spills in the U.S. Arctic Marine Environment* . National Academies Press. https://doi.org/10.17226/18625
40006	Environmental Impacts and Ecosystem Recovery	Risk Assessment and Impact Metrics	Research and determine if dedicated equipment kits and facility modules (mobile units) should be developed for Arctic wildlife response.	Literature/Data Call	Nijkamp, H., Sessions, S., Blanc, P., & Autret, Y. (2014). Arctic Oiled Wildlife Response: Exploring Potential and Limitations. *International Oil Spill Conference Proceedings* , *2014* (1), 1569–1582. https://doi.org/10.7901/2169-3358-2014.1.1569
40006	Environmental Impacts and Ecosystem Recovery	Risk Assessment and Impact Metrics	Clarify the roles, responsibilities, and coordination between response activities and NRDA activities.	Literature/Data Call	Wilkin, S. M., Rowles, T. K., Stratton, E., Adimey, N., Field, C. L., Wissmann, S., Shigenaka, G., Fougères, E., Mase, B., Network, S. R. S., & Ziccardi, M. H. (2017). Marine mammal response operations during the Deepwater Horizon oil spill. *Endangered Species Research* , *33* , 107–118. https://doi.org/10.3354/esr00811
40006	Environmental Impacts and Ecosystem Recovery	Risk Assessment and Impact Metrics	Develop a marine biotic index (e.g., foraminifera- and/or macrofauna-based AMBI) for the entire Gulf of Mexico that would provide an easy to interpret benthic habitat suitability and ecological health status tool that can be operationalized by living resource managers.	Literature/Data Call	Schwing, P. T., Montagna, P. A., Machain-Castillo, M. L., Escobar-Briones, E., & Rohal, M. (2019). Benthic Faunal Baselines in the Gulf of Mexico: A Precursor to Evaluate Future Impacts. *Scenarios and Responses to Future Deep Oil Spills* , 96–108. https://doi.org/10.1007/978-3-030-12963-7_6
40006	Environmental Impacts and Ecosystem Recovery	Risk Assessment and Impact Metrics	Develop research tools to bridge the gap between omics and quantitative measures of ecosystem function.	Literature/Data Call	Microbial Genomics of the Global Ocean System: Report on an American Academy of Microbiology (Academy), The American Geophysical Union (AGU), and The Gulf of Mexico Research Initiative (GoMRI) Colloquium held on 9 and 10 April 2019. (2020). *American Society for Microbiology* . https://doi.org/10.1128/aamcol.apr.2019
40006	Environmental Impacts and Ecosystem Recovery	Risk Assessment and Impact Metrics	Improve components of ecosystem modeling capabilities in the GOM such as the collection of data for model development (e.g., parameterizing trophic interactions from diet studies), calibration (e.g., fitting model predictions of biomass to observed biomass trends), and validation (e.g., comparing model predictions of biomass with observed trends).	Literature/Data Call	O'Farrell, H., Grüss, A., Sagarese, S. R., Babcock, E. A., & Rose, K. A. (2017). Ecosystem modeling in the Gulf of Mexico: current status and future needs to address ecosystem-based fisheries management and restoration activities. *Reviews in Fish Biology and Fisheries* , *27* (3), 587–614. https://doi.org/10.1007/s11160-017-9482-1
40100	Environmental Restoration Methods and Technologies	No Subcategory	Develop methods for restoration assessment (including establishing indicators and applying performance metrics) and estimation of restoration cost.	SME Evaluation	N/A
40100	Environmental Restoration Methods and Technologies	No Subcategory	Conduct comparative analysis of restoration vs. natural attenuation.	SME Evaluation	N/A
40100	Environmental Restoration Methods and Technologies	No Subcategory	Study the factors associated with long-term restoration success.	SME Evaluation	N/A
40100	Environmental Restoration Methods and Technologies	No Subcategory	Conduct long-term monitoring of oil concentrations at recovery sites to understand the long-term trajectory of recovery.	Literature/Data Call	Turner, R. E., Overton, E. B., Meyer, B. M., Miles, M. S., McClenachan, G., Hooper-Bui, L., Engel, A. S., Swenson, E. M., Lee, J. M., Milan, C. S., & Gao, H. (2014). Distribution and recovery trajectory of Macondo (Mississippi Canyon 252) oil in Louisiana coastal wetlands. *Marine Pollution Bulletin* , 87(1-2), 57–67. https://doi.org/10.1016/j.marpolbul.2014.08.011
40100	Environmental Restoration Methods and Technologies	No Subcategory	Develop monitoring protocols to determine how much cleanup is enough and the manner in which natural attenuation may ameliorate effects in the future.	Literature/Data Call	Hassan, F. A. F., Michel C. Boufadel, Rex Johnson, Kenneth Lee, Thomas P. Graan, Adriana C. Bejarano, Zhenduo Zhu, David Waterman, Daniel M. Capone, Earl Hayter, Stephen K. Hamilton, Timothy Dekker, Marcelo H. Garcia, and Jacob S. (2015). Oil-Particle Interactions and Submergence from Crude Oil Spills in Marine and Freshwater Environments—Review of the Science and Future Science Needs: *U.S. Geological Survey Open-File Report 2015-1076* , 33. https://pubs.usgs.gov/of/2015/1076/
40100	Environmental Restoration Methods and Technologies	No Subcategory	Determine the combined effects of oiling at the marsh edge to inland sediments, functional (i.e. metabolic) changes at the microbial level, and the confounding effects of physical changes to the marshes over time, such as from flooding and marsh erosion.	Literature/Data Call	Hooper-Bui, L. M., Rabalais, N. N., Engel, A. S., Turner, R. E., McClenachan, G., Roberts, B., Overton, E. B., Justic, D., Strudivant, K., Brown, K., & Conover, J. (2014). Overview of Research into the Coastal Effects of the Macondo Blowout from the Coastal Waters Consortium: A GoMRI Consortium. *International Oil Spill Conference Proceedings, 2014* (1), 604–617. https://doi.org/10.7901/2169-3358-2014.1.604
40201	Human Safety and Health	Safety	Develop technologies, methods, and standards for protecting on-scene personnel, including the incorporation of training, adequate supervision, information databases, protective equipment, maximum exposure limits, and decontamination procedures.	SME Evaluation	N/A
40201	Human Safety and Health	Safety	Study the levels of oil constituents, including Volatile Organic Compounds (VOCs), throughout the water column under different dispersant application scenarios (e.g., subsea, surface) and establish their contribution to long term potential worker health and safety issues.	SME Evaluation	N/A
40201	Human Safety and Health	Safety	Study methods to detect levels of agents of concern at the source and being able to then prepare any communities and/or responders as the plume drifts.	Public Listening Sessions	N/A
40201	Human Safety and Health	Safety	Study and develop procedures for rescue and medical aid in man-overboard situations in ice-infested waters.	Literature/Data Call	United States Coast Guard. (2013). *Great Lakes Oil-in-Ice Demonstration 3 Final Report* . U.S. Department of Homeland Security. https://rrt5.org/Portals/0/docs/GreatLakesDemonstration3FinalReport.pdf
40201	Human Safety and Health	Safety	Research the correlation between personal protective equipment (PPE) and exposure opportunity among oil cleanup responders.	Literature/Data Call	Alexander, M., Engel, L. S., Olaiya, N., Wang, L., Barrett, J., Weems, L., Schwartz, E. G., & Rusiecki, J. A. (2018). The deepwater horizon oil spill coast guard cohort study: A cross-sectional study of acute respiratory health symptoms. *Environmental Research* , *162* , 196–202. https://doi.org/10.1016/j.envres.2017.11.044
40201	Human Safety and Health	Safety	Develop a quantitative job exposure matrix for Corexit™ exposure that takes into account the chemical and physical properties of the chemicals and external information on patterns of use may allow evaluation of exposure–response relationships in the future.	Literature/Data Call	McGowan, C. J., Kwok, R. K., Engel, L. S., Stenzel, M. R., Stewart, P. A., & Sandler, D. P. (2017). Respiratory, Dermal, and Eye Irritation Symptoms Associated with Corexit™ EC9527A/EC9500A following the Deepwater Horizon Oil Spill: Findings from the GuLF STUDY. *Environmental Health Perspectives* , *125* (9), 097015. https://doi.org/10.1289/ehp1677

The information in this database has not been processed or reviewed by the ICCOPR and is considered source/raw data. The approved final list of ICCOPR Research Needs can be found in Chapter 9 of the Oil Pollution Research and Technology Plan.

ICCOPR NUMBER	ICCOPR SRA	Subcategory	Research Need	Source	Citation
40201	Human Safety and Health	Safety	Conduct long-term toxic health studies of oil spill responders.	Literature/Data Call	D'Andrea, M. A., & Reddy, G. K. (2018). The Development of Long-Term Adverse Health Effects in Oil Spill Cleanup Workers of the Deepwater Horizon Offshore Drilling Rig Disaster. *Frontiers in Public Health*, *6*. https://doi.org/10.3389/fpubh.2018.00117
40201	Human Safety and Health	Safety	Evaluate personal protective equipment (PPE) specifically used for dispersant-related work.	Literature/Data Call	Alexander, M., Engel, L. S., Olaiya, N., Wang, L., Barrett, J., Weems, L., Schwartz, E. G., & Rusiecki, J. A. (2018). The deepwater horizon oil spill coast guard cohort study: A cross-sectional study of acute respiratory health symptoms. *Environmental Research*, *162*, 196–202. https://doi.org/10.1016/j.envres.2017.11.044
40201	Human Safety and Health	Safety	Develop personal protective equipment (PPE) for cold weather, adapted for easy decontamination.	Literature/Data Call	United States Coast Guard. (2017). *Federal On-Scene Coordinator (FOSC) Guide for Oil in Ice*. ; U.S. Department of Homeland Security. https://homeport.uscg.mil/Lists/Content/Attachments/43701/USCG%20FOSC%20Guide%20-%20Oil%20in%20Ice.pdf
40201	Human Safety and Health	Safety	Study the potential toxicity of PAHs to human health and incorporate them into human health risk assessments and characterizations.	Literature/Data Call	Wickliffe, J., Overton, E., Frickel, S., Howard, J., Wilson, M., Simon, B., Echsner, S., Nguyen, D., Gauthe, D., Blake, D., Miller, C., Elferink, C., Ansari, S., Fernando, H., Trapido, E., & Kane, A. (2014). Evaluation of Polycyclic Aromatic Hydrocarbons Using Analytical Methods, Toxicology, and Risk Assessment Research: Seafood Safety after a Petroleum Spill as an Example. *Environmental Health Perspectives*, *122* (1), 6–9. https://doi.org/10.1289/ehp.1306724
40202	Human Safety and Health	Human Exposure	Evaluate and implement developed frameworks viability for conducting rapid research response on human exposure during oil spills.	SME Evaluation	N/A
40202	Human Safety and Health	Human Exposure	Study the long-term impacts to humans from exposure to contaminants from oil spills (e.g., dermal, oral (through seafood), and respiratory).	SME Evaluation	N/A
40202	Human Safety and Health	Human Exposure	Study the toxicological effects and the causal or correlative relationships between chemical (i.e., oil and dispersants) exposure and human health.	SME Evaluation	N/A
40202	Human Safety and Health	Human Exposure	Continue research on the long-term safety of seafood following a spill or fisheries closure and develop methods to communicate these to the public.	SME Evaluation	N/A
40202	Human Safety and Health	Human Exposure	Develop improved and more economically efficient methods of assessing and mitigating sub-slab home heating oil spills in cold regions.	Public Listening Sessions	N/A
40202	Human Safety and Health	Human Exposure	Develop infrastructure to rapidly collect data and assess exposure post-disasters.	Literature/Data Call	Peres, L. C., Trapido, E., Rung, A. L., Harrington, D. J., Oral, E., Fang, Z., Fontham, E., & Peters, E. S. (2016). The Deepwater Horizon Oil Spill and Physical Health among Adult Women in Southern Louisiana: The Women and Their Children's Health (WaTCH) Study. *Environmental Health Perspectives*, *124* (8), 1208–1213. https://doi.org/10.1289/ehp.1510348
40202	Human Safety and Health	Human Exposure	Investigate mental health impacts from oil spill response and develop practices for how to manage it.	Literature/Data Call	Grattan, L. M., Roberts, S., Mahan, W. T., McLaughlin, P. K., Otwell, W. S., & Morris, J. G. (2011). The Early Psychological Impacts of the Deepwater Horizon Oil Spill on Florida and Alabama Communities. *Environmental Health Perspectives*, *119* (6), 838–843. https://doi.org/10.1289/ehp.1002915
40202	Human Safety and Health	Human Exposure	Research depression among fishers in the Gulf Coast and create interventions specific to this group similar to strategies for law enforcement.	Literature/Data Call	Ramchand, R., Seelam, R., Parks, V., Ghosh-Dastidar, B., Lee, M. R., & Finucane, M. (2019). Exposure to the Deepwater Horizon Oil Spill, Associated Resource Loss, and Long-Term Mental and Behavioral Outcomes. *Disaster Medicine and Public Health Preparedness*, *13* (5-6), 889–897. https://doi.org/10.1017/dmp.2019.3
40202	Human Safety and Health	Human Exposure	Study the human health and safety associated with an oil sands products (OSP) spill.	Literature/Data Call	The Center for Spills in the Environment. (2013). *Alberta Oil Sands Workshop for Washington State Department of Ecology, the Regional Response Team 10 and the Pacific States/British Columbia Oil Spill Task Force*. University of New Hampshire. https://crrc.unh.edu/sites/crrc.unh.edu/files/media/docs/Workshops/oil_sands_washington/OilSandsProductsWorkshopReport_Washington%20TOTAL.pdf
40202	Human Safety and Health	Human Exposure	Conduct culturally tailored dietary assessments targeting risks and benefits of seafood consumption.	Literature/Data Call	Lichtveld, M., Sherchan, S., Gam, K. B., Kwok, R. K., Mundorf, C., Shankar, A., & Soares, L. (2016). The Deepwater Horizon Oil Spill Through the Lens of Human Health and the Ecosystem. *Current Environmental Health Reports*, *3* (4), 370–378. https://doi.org/10.1007/s40572-016-0119-7
40202	Human Safety and Health	Human Exposure	Research the ambient oil concentrations at which bioaccumulation rate leads to seafood contamination above the level of concern.	Literature/Data Call	Berenshtein, I., Perlin, N., Murawski, S. A., Joye, S. B., & Paris, C. B. (2019). Evaluating the Effectiveness of Fishery Closures for Deep Oil Spills Using a Four-Dimensional Model. *Scenarios and Responses to Future Deep Oil Spills*, 390–402. https://doi.org/10.1007/978-3-030-12963-7_23
40202	Human Safety and Health	Human Exposure	Establish a monitoring program to assess the well-being of coastal counties in the Gulf of Mexico that were affected by the Deepwater Horizon oil spill that extends well-being data collection into the future with additional post-DWH time points.	Literature/Data Call	Goedeke, T. (2013). *Evaluating Changes in Health and Well-being in Communities Affected by the Deepwater Horizon Disaster*. NCCOS Coastal Science Website. https://coastalscience.noaa.gov/project/evaluating-changes-communities-affected-deepwater-horizon/
40301	Sociological and Economic Impacts	Community and Economic Impacts	Evaluate the effectiveness of developed models/frameworks for community/stakeholder involvement in oil spill planning, response and restoration.	SME Evaluation	N/A
40301	Sociological and Economic Impacts	Community and Economic Impacts	Evaluate the effectiveness of developed methods for communicating risk tradeoffs to various audiences.	SME Evaluation	N/A
40301	Sociological and Economic Impacts	Community and Economic Impacts	Study the long term impacts on community vulnerability and resilience to past spills, including social impacts.	SME Evaluation	N/A
40301	Sociological and Economic Impacts	Community and Economic Impacts	Develop protocols for effective and affordable treatment of petroleum-contaminated soils in remote locations, such as rural Alaska.	Public listening sessions	N/A
40301	Sociological and Economic Impacts	Community and Economic Impacts	Analyze the effectiveness of previous programs used to ameliorate the effects of oil spills on communities and determine if alternatives should be investigated.	Public listening sessions	N/A
40301	Sociological and Economic Impacts	Community and Economic Impacts	Investigate vulnerability and risk of the remote and/or ice-edge communities affected by oil spills.	Literature/Data Call	Li, P., Cai, Q., Lin, W., Chen, B., & Zhang, B. (2016). Offshore oil spill response practices and emerging challenges. *Marine Pollution Bulletin*, *110* (1), 6–27. https://doi.org/10.1016/j.marpolbul.2016.06.020
40301	Sociological and Economic Impacts	Community and Economic Impacts	Develop strategies for dealing with the individual and community impact of future natural and man-made disasters.	Literature/Data Call	Morris, J. G., Grattan, L. M., Mayer, B. M., & Blackburn, J. K. (2013). Psychological Responses and Resilience of People and Communities Impacted by The Deepwater Horizon Oil Spill. *Transactions of the American Clinical and Climatological Association*, *124*, 191–201. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3715935/
40301	Sociological and Economic Impacts	Community and Economic Impacts	Review disaster laws, policies, and regulations to identify opportunities to strengthen public health preparedness and responses including for stress-related impacts, better engage affected communities, and enhance provision of health services.	Literature/Data Call	Sandifer, P. A., & Walker, A. H. (2018). Enhancing Disaster Resilience by Reducing Stress-Associated Health Impacts. *Frontiers in Public Health*, *6*. https://doi.org/10.3389/fpubh.2018.00373
40301	Sociological and Economic Impacts	Community and Economic Impacts	Improve existing disaster behavioral and physical health programs to better address, leverage, and coordinate resources for stress reduction, relief, and treatment in disaster planning and response.	Literature/Data Call	Sandifer, P. A., & Walker, A. H. (2018). Enhancing Disaster Resilience by Reducing Stress-Associated Health Impacts. *Frontiers in Public Health*, *6*. https://doi.org/10.3389/fpubh.2018.00373
40301	Sociological and Economic Impacts	Community and Economic Impacts	Develop and institute equitable processes pre-disaster for dealing with damage assessments, litigation, payments, and housing with community participation.	Literature/Data Call	Sandifer, P. A., & Walker, A. H. (2018). Enhancing Disaster Resilience by Reducing Stress-Associated Health Impacts. *Frontiers in Public Health*, *6*. https://doi.org/10.3389/fpubh.2018.00373
40301	Sociological and Economic Impacts	Community and Economic Impacts	Conduct pre-disaster baseline data for communities at risk for disaster emergencies (e.g., man-made or natural).	Literature/Data Call	Croisant, S., Lin, Y., Shearer, J., Prochaska, J., Phillips-Savoy, A., Gee, J., Jackson, D., Panettieri, R., Howarth, M., Sullivan, J., Black, B., Tate, J., Nguyen, D., Anthony, A., Khan, A., Fernando, H., Ansari, G., Rowe, G., Howrey, B., & Singleton, C. (2017). The Gulf Coast Health Alliance: Health Risks Related to the Macondo Spill (GC-HARMS) Study: Self-Reported Health Effects. *International Journal of Environmental Research and Public Health*, *14* (11), 1328. https://doi.org/10.3390/ijerph14111328
40301	Sociological and Economic Impacts	Community and Economic Impacts	Study the long-term impacts of economic development in the Arctic region and on Arctic citizens including the overuse of resources and pollution.	Literature/Data Call	Johannsdottir, L., & Cook, D. (2019). Systemic risk of maritime-related oil spills viewed from an Arctic and insurance perspective. *Ocean & Coastal Management*, *179*, 104853. https://doi.org/10.1016/j.ocecoaman.2019.104853
40301	Sociological and Economic Impacts	Community and Economic Impacts	Research methods to improve communication and trust among community residents, especially those identified as community leaders, NGOs, researchers, and public agencies.	Literature/Data Call	Reams, M.A., Harding, A.K., Subra, W., Lam, N.S., O'Connell, S.G., Tidwell, L., & Anderson, K.A. (2017). Response, Recovery, and Resilience to Oil Spill and Environmnetal Disasters: Exploration and Use of Novel Approaches to Enhance Community Resilience. *Journal of Environmental Health.* 80(2): 8 - 15. https://www.neha.org/sites/default/files/jeh/JEH9.17-Feature-Response-Recovery-Resilience-to-Oil-Spills.pdf

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ICCOPR NUMBER	ICCOPR SRA	Subcategory	Research Need	Source	Citation
40302	Sociological and Economic Impacts	Human Impacts	Research and determine subsistence losses and culturally-significant natural resource injuries associated with a spill.	SME Evaluation	N/A
40302	Sociological and Economic Impacts	Human Impacts	Develop and evaluate response protocols to improve and proactively mitigate human dimension impacts from a spill.	Public Listening Sessions	N/A
40302	Sociological and Economic Impacts	Human Impacts	Update the Oil Spill Prevention Act of 1990 (OPA 90) to include coverage for direct, indirect, and long-term effects of oil spills on the mental and physical health of humans.	Literature/Data Call	Eklund, R. L., Knapp, L. C., Sandifer, P. A., & Colwell, R. C. (2019). Oil Spills and Human Health: Contributions of the Gulf of Mexico Research Initiative. *GeoHealth* , *3* (12), 391–406. https://doi.org/10.1029/2019gh000217
40302	Sociological and Economic Impacts	Human Impacts	Study the influence of communication strategies to establish a full understanding of how the nation views Gulf caught seafood.	Literature/Data Call	Gorham, L.M., Rumble, J.N., Pounds, K.L., Lindsey, A.B., & Irani, T. (2016). The Role of Dissonance and Schema: An Exploration of Florida Public Perception after the DWH Oil Spill. *Journal of Applied Communications.* 100 (2). https://doi.org/10.4148/1051-0834.1034
40302	Sociological and Economic Impacts	Human Impacts	Develop infrastructure for tracking public fears, understanding, and behavior in real-time regarding oil spills.	Literature/Data Call	Parker, A. M., Edelman, A. F., Carman, K. G., & Finucane, M. L. (2019). On the Need for Prospective Disaster Survey Panels. *Disaster Medicine and Public Health Preparedness* , *14* (3), 299–301. https://doi.org/10.1017/dmp.2019.94
40302	Sociological and Economic Impacts	Human Impacts	Improve methods for disaster crisis and risk communication with the general public.	Literature/Data Call	Reams, M., Harding, A., Subra, W., Lam, N., O'Connell, S., Tidwell, L., & Anderson, K. (2017). Response, Recovery, and Resilience to Oil Spills and Environmental Disasters: Exploration and Use of Novel Approaches to Enhance Community Resilience. *Advancement of the Science* , *80* (2). https://neha.org/sites/default/files/jeh/JEH9.17-Feature-Response-Recovery-Resilience-to-Oil-Spills.pdf
40302	Sociological and Economic Impacts	Human Impacts	Develop protocols and approaches to mitigate stress-related impacts from disasters, which can be incorporated into preparedness and response plans.	Literature/Data Call	Sandifer, P.A., & Walker, A.H. (2018). Enhancing Disaster Resilience by Reducing Stress-Associated Health Impacts. *Frontiers in Public Health.* 6: 373. 10.3389/fpubh.2018.00373
40302	Sociological and Economic Impacts	Human Impacts	Develop standards to objectively assess county-level well-being after an oil spill.	Literature/Data Call	Goedeke, T. (2013). *Evaluating Changes in Health and Well-being in Communities Affected by the Deepwater Horizon Disaster* . NCCOS Coastal Science Website. https://coastalscience.noaa.gov/project/evaluating-changes-communities-affected-deepwater-horizon/

Appendix C

Survey Technical Report

Subject Matter Expert (SME) Survey Technical Report

1.0 Survey Instrument Development

The University of New Hampshire Survey Center (UNHSC), in collaboration with the University of New Hampshire Coastal Response Research Center (CRRC) and the Interagency Coordinating Committee on Oil Pollution Research (ICCOPR), developed criteria to establish the importance of individual Research Needs in three domains: importance, complexity of research question, and timeliness. In addition to the three domains, Subject Matter Experts (SMEs) were asked to provide examples of additional Research Needs were not included.

The survey instrument was programmed using Qualtrics surveys and was extensively tested by the UNHSC staff, as well as by select members from the ICCOPR research team, for accuracy and ease of use.

The University of New Hampshire Institutional Review Board approved the survey instrument and methodology for this study. Respondents were provided assurances of confidentiality and that identifiable information would not be included in any report. The full consent language can be found in Attachment 1 which includes a final version of the consent and survey instrument.

2.0 How the SME Sample Was Selected

The ICCOPR Research and Technology (R&T) Workgroup, CRRC and ICCOPR members selected the sample of Subject Matter Experts (SMEs) for the survey. For each of the SRAs and Subcategories the R&T Workgroup and CRRC identified federal SMEs that were knowledgeable about each of the research areas. In addition, the R&T Workgroup contacted other ICCOPR members and members of their individual agencies to expand the number of SMEs. In some areas, it was determined that there was a need to include state agency, academic and industry experts to find the right expertise to evaluate the Research Needs. The R&T Workgroup determined however, that in no SRA category or subgroup would non-federal employees exceed 40% of the SMEs. A total of 97 non-federal employees were used (only 23.7 % of the SME surveyed).

A sample of 410 SMEs was identified to participate in survey on 28 SRAs. Some SRAs were further broken down into multiple Subcategories. With the addition of the Subcategories, a total of 58 individual surveys were created to organize the list of Research Needs. A list of all 58 SRAs and Subcategories and the number of selected SMEs for each can be found in Appendix A. If a selected SME either requested not to participate or did not consider themselves expert in the field, they were replaced by another identified expert (N=25).

4.0 Survey Initiation

The survey was invitation was sent on February 17, 2021, with three reminders sent on February 22, March 1, and March 8, 2021. The survey was closed on May 17, 2021. The invitation and reminders can be found in Attachment 2.

5.0 Response Rates

Of the 410 identified SMEs, 25 of them declined to participate in the survey, and interviews were completed with 212 selected SMEs. This resulted in an overall response rate of 55%, this is a high response rate for surveys of this type.

Table 1: Response Rates by SRA series

SRA Series	Sample Size	Not Qualified[1]	Valid sample	Completed	Response Rate
1000 Series	118	10	108	56	52%
2000 Series	31	2	29	16	55%
3000 Series	173	9	164	101	62%
4000 Series	88	4	84	39	46%
Total	**410**	**25**	**385**	**212**	**55%**

[1] Not Qualified consists of undeliverable, not an expert in area, unavailable during survey period.

6.0 Calculating a Score

The survey instrument was designed to allow researchers to calculate a composite score based on the three domains listed above. Each domain is scored from 0 to 100. Where a zero would place the Research Need *lower* in importance and 100 places the Research Need *higher* in importance.

The composite score consisted of three domains: importance, and complexity of research question and timeliness. The possible range for the composite score is zero to 300.

Each respondent's composite score was calculated by adding the three domain scores for a total score within the range of zero to 300. Finally, all respondents' scores for the specified Research Need were averaged to get an average composite score (and a standard deviation) for the Research Need with a range of zero to 300.

7.0 Weighting of Data

The composite score is based on all domains being considered equally influential on the importance of a Research Need. Therefore, the research team developed a weight system to give higher weights to domains that are more influential on the importance of Research Needs. Domain 1 (importance) is weighted to make up 60% of the score; domain 2 (complexity of research) is weighted to make up 30% of the score and; and domain 3 (timeliness) is weighted to make up 10% of the score. Each domain score was multiplied by the associated proportional weight and then added together. The sum was multiplied by three to make the weighted score range consistent with the unweighted score range of zero – 300. Finally, all respondents' weighted scores for the specified Research Need were averaged to get an average weighted composite score (and a standard deviation) for the Research Need with a range of zero to 300.

8.0 Selecting Decision Making Measures

As described in Chapter 6 of the OPRTP, the R&T Workgroup's iterative process to select the recommended priorities consisted of the following steps:

- Review statistical ranking and analysis of survey results (i.e., the raw and weighted means and the standard deviations). The R&T Workgroup used these initial rankings to start their discussions.

- Review missing Research Needs. Several SMEs identified potentially missing Research Needs in their responses to Question 4. The R&T Workgroup reviewed the suggestions and determined whether a different SRA or Subcategory already included the Research Need. The R&T Workgroup added newly identified Research Needs to the appropriate SRA or Subcategory and assigned an appropriate rank based on the members' expert opinions.

- Consolidate Research Needs. In many cases, an SRA or Subcategory listed similar Research Needs. The R&T Workgroup reviewed these similarities and consolidated them, where appropriate. The draft ranking was adjusted to reflect the importance of the consolidated Research Need.

- Determine top three recommended priority Research Needs. The R&T Workgroup agreed upon the top three suggested priority Research Needs for each SRA and Subcategory.

- Develop the final description of each recommended priority Research Need. The R&T Workgroup reviewed the language of each SRA, and the associated priority Research Needs to ensure they were clearly articulated and consistent with the definition.

- Obtain ICCOPR member feedback. The R&T Workgroup sent its draft list of priorities to all ICCOPR members for review and comment. The R&T Workgroup adjudicated the comments through discussions with commenting members and a meeting of the R&T Workgroup. ICCOPR adopted the top three priority Needs for each SRA and Subcategory as presented in Chapter 9.

CRRC 2022 ICCOPR

Start of Block: CRRC INTRO

INTRO

Interagency Coordinating Committee on Oil Pollution Research (ICCOPR) Research & Technology Plan Research Needs Survey

Your input as subject matter expert (SME) is critical to the success of this project. We know that you are extremely busy, but please take between 10 and 45 minutes required to complete the online survey. We are surveying up to 370 SMEs in numerous fields across many federal agencies to capture a range of perspectives. This research is funded by a NOAA award, entitled "Update to Interagency Coordinating Committee on Oil Pollution Research (ICCOPR) Research and Technology Plan for FY2022-2027."

Note that by completing the survey, you are consenting to participate in this research. Participation is expected to present minimal risk to you. While you may not receive any direct benefits from participating in this study, the anticipated benefits of the knowledge gained include determining future priorities of oil spill research.

Although we hope that you will answer every question, you are certainly free to skip any you do not want to answer. Your participation is voluntary, and you may withdraw your consent and discontinue participation at any time. The UNH Survey Center and Coastal Response Research Center (CRRC) seek to maintain the confidentiality of all data and records associated with your participation in this research. However, any communication via the Internet poses minimal risk of a breach of confidentiality. Data will be shared with ICCOPR; however, your responses will be combined with others in such a way that individuals cannot be identified when data is reported or published.

Thank you in advance for completing this survey. If you have any questions pertaining to:

- content and/or definition of the research needs, contact Nancy Kinner, CRRC 603-862-1422 or nancy.kinner@unh.edu
- the mechanism or "how-to" of completing this survey, contact Tracy Keirns, UNH Survey Center, tracy.keirns@unh.edu
- information on ICCOPR (Interagency Coordinating Committee on Oil Pollution Research), contact LCDR Clifton Graham, U.S. Coast Guard at clifton.j.graham@uscg.mil
- your rights as a research participant, you may contact Melissa McGee in UNH Research Integrity Services, melissa.mcgee@unh.edu or 603-862-2005 to discuss them (IRB #8459).

By clicking "Next" you are agreeing to participate in the research.

Page Break

INTRO2 You have been selected as a Subject Matter Expert in the area of ***${e://Field/SRA} ${e://Field/SRA_Sub}***

The following questions will focus on evaluation of *all identified research needs* in your subject matter area.

You will be asked a set of 3 questions for each research need in your subject matter area. These questions will ask you to rate a statement on a scale of 0 to 100. In order to do this, select the slider bar and move the bar to the number between 0 and 100 that comes closest to your opinion. The last question will ask you to identify additional research needs that you feel need to be addressed but were not included in the survey.

If at any time you need to leave the survey, simply close your browser and all of your answers will be saved. To continue the survey just click the original link you were provided and continue the survey. Do not use the browser's back button, but if you would like to navigate through the survey you may use the "Back" and "Next" buttons at the bottom of each page of the survey.

While you are not required to answer every question, priority research needs can only be identified with complete data.

Page Break

NumNeeds
You will be asked 3 questions for the following number of Research Needs:

____

End of Block: CRRC INTRO

Start of Block: Sub Intro

sub_intro As a Subject Matter Expert (SME) you are being asked to answer questions regarding an important oil spill related Subject Research Area (SRA). Because there were a large number of identified research and technology needs in your SRA, we have divided the SRA into subcategories to reduce the number of questions you need to address.

If you would like to see all of the identified R&D needs in the SRA, click here for a comprehensive list. This may help you at the end of the survey when evaluating whether all the important R&D needs are included in the overall survey.

End of Block: Sub Intro

Start of Block: core questions

Q1
Research Need: ${lm://Field/2}

1. How important is it that we solve this Research Need to the advancement of ${e://Field/ResearchClass}?

	Low Importance	Medium Importance	High Importance
	0 10 20 30	40 50 60 70	80 90 100
. ()			

Q2 **Research Need:** **${lm://Field/2}**

2. Using the definitions below, please estimate where this Research Need fits in this spectrum of basic to applied research?

Applied Research seeks to answer specific questions to solve practical, real world problems. The knowledge acquired may have commercial objectives (e.g., products, procedures, services).

Basic Research seeks to answer *why, what, or how* questions to increase the understanding of fundamental principles. The goal is to expand knowledge and the research may not result in a solution to a practical problem.

	Basic Research	Applied Research
	0 10 20 30 40 50 60 70 80 90 100	
. ()		

Q3 **Research Need:** **${lm://Field/2}**

3. How likely is it that this Research Need can be completely addressed within the next six years?

	Not At All Likely	Very Likely
	0 10 20 30 40 50 60 70 80 90 100	
. ()		

End of Block: core questions

Start of Block: Additional Needs

Q4.1
Are there any research needs related to this subject area that you feel need to be addressed, but were not on this list?

____

____

Display This Question:

If If Are there any research needs related to this subject area that you feel need to be addressed, but... Text Response Is Not Empty

Q4.2
Are there any research needs related to this subject area that you feel need to be addressed, but were not on this list?

____

____

Display This Question:

If If Are there any research needs related to this subject area that you feel need to be addressed, but... Text Response Is Not Empty

Q4.3
Are there any research needs related to this subject area that you feel need to be addressed, but were not on this list?

____

____

End of Block: Additional Needs

Start of Block: THANK1

Thank
Thank you taking for the time to complete this survey. Click "Submit" below to exit.

End of Block: THANK1

Sample of Survey Data Results
Count = 3

	Score		ScoreW	
	Mean	SD	Mean	SD
Need1	166.0	126.6	184.2	129.6
Need2	111.7	104.1	122.5	113.4
Need3	180.3	156.7	191.6	165.9
Need4	133.7	125.9	141.3	137.4
Need5	153.3	133.0	139.9	121.8
Need6	219.7	63.8	219.5	64.1
Need7	260.3	15.0	261.5	11.5
Need8	149.0	85.7	167.7	93.3
Need9	117.3	127.5	111.1	124.1
Need10	195.3	97.2	203.7	89.2

Appendix D

Potential Impacts to
Spill Response Options

Environmental Conditions	Potential Impacts to Spill Response Options							
	All Response Technologies		Mechanical Recovery		In-Situ Burning (ISB)		Dispersants	
	Limitations	Advantages	Limitations	Advantages	Limitations	Advantages	Limitations	Advantages
Sea Ice	• Oil (fresh or weathered) that is trapped in or under ice can result in a secondary release when the ice melts.[3] • Sea ice can damage vessels and inhibit navigation, including access to spill sites.[14] • Ice-class vessels may be required for response operations.[14] • Ice conditions may change suddenly creating unsafe conditions.[16] • Lack of infrastructure (e.g., ports, airports, roads) in Arctic locations can delay response operations.[14] • Response methods are generally more effective in ice-free environments.[18] •Response personnel, including vessel operators and pilots, must be familiar with ice conditions.[14]	Oil weathering (i.e., evaporation, emulsification, and natural dispersion) are slowed.[8]	• Booms cannot be used if there is total ice coverage greater than 3/10 or if oil is encapsulation within ice. [2] • Recovered material is likely to be mostly oiled snow and ice, having a low density of oil, requiring appropriately scaled storage/melt disposal facilities.[2] • Encounter rate is reduced in the presence of concentrated sea ice.[4] • Access to equipment and logistical support (e.g., housing, food, fuel) in remote locations is difficult.[4] • Slush ice can clog skimmers and reduce efficiency.[14] • Limited maneuverability may prevent or delay accurate deployment.[16]	• Ice may contain the oil to allow for smaller batch recovery operations.[2] • Technological advances for mechanical recovery equipment have made them more efficient in sea ice conditions.[11]	• Effectiveness of ISB varies depending on ice condition (i.e., broken ice, percent ice coverage).[11] • The environmental effects of burn residues and smoke in the presence of ice need to be further studied and characertized.[12] • Toxicity of chemical herders on Arctic species is unknown.[6] • Limited access to equipment and logistical support (e.g., fire booms, igniters).[16] • Fire booms used to increase slick thickness are less effective and are difficult to deploy in sea ice.[5]	• Ice provides a containment for burning and reduces the spreading of oil above a 7/10 ice coverage.[5] • Chemical herders may increase slick thickness in ice conditions.[6] • Increased ISB "window of opportunity" in the presence of sea ice.[11]	• Sea ice reduces wave action therefore reducing mixing energy.[2] • Sea ice slows the mixing of dispersed oil in the upper water column.[2] • Unknown if oil trapped in or under ice will be dispersible when the ice melts and releases the oil.[3] • The effectiveness of dispersants on ice-infested waters needs to be further investigated.[3]	Colder temperatures and the presence sea ice have the potential to reduce oil weathering (i.e., evaporation) and may expand the "window of opportunity" to apply dispersants.[3]
High Winds	• Operating vessels and deploying on-water equipment is unsafe in high winds.[16] • Aircraft can only fly under certain wind conditions.[1] • High winds drive sea state, and may enhance wave height and create strong currents.[16] • High winds and cold temperatures can result in freezing sea spray that can ice vessels/equipment leading to unsafe operating conditions.[11]	• Strong winds may concentrate oil in confined areas of sea ice (e.g., polynyas, leads).16 • Strong winds may move oil away from environmentally sensitive areas.16	• Difficult to keep vessels and equipment in place.[16] • Booms and skimmers are unstable in high winds, therefore not effectively containing oil.[10] • High winds limit mechanical recovery operations and equipment deployment.[8]	No known advantages. However, mechanical recovery equipment continues to improve so that it can operate at higher wind speeds.[11]	• Difficult to ignite and sustain burns in high winds.[15] • Burning in high winds increase the risk of hazards.[15] • Aircraft ignited methods cannot deploy in high winds.[1] • The toxicity of the smoke from ISB is still being studied. High winds have the potential to carry smoke to environmentally sensitive areas and nearby communities endangering human-health.[11]	No known advantages.	• High winds limit dispersant application operations from vessels.[8] • Aerial operations (for application and monitoring) are limited to specific wind speeds to ensure aircraft safety.[1]	• Dispersants are more tolerant of wind and waves compared to other response options.[17] • Effective mixing of dispersants and oil in high wind/wave environments due to increased turbulance.[1]
Cold Temperature	• Extreme cold conditions are unsafe for responders to work.[6] • Cold temperatures can cause equipment to break and freeze up.[8] • High winds and cold temperatures can result in freezing sea spray which can ice vessels/equipment leading to unsafe operating conditions.[11]	• Cold temperatures increase oil viscosity and slow oil weathering, increasing response windows.[9]	• Cold temperatures may freeze up skimmers, pumps, and increase oil viscosity making it harder to recover.[7] • Cold temperatures can freeze skimmer hoses, making them unusable.[14]	No known advantages.	• Oil is more difficult to ignite.[2]	No known advantages.	• Cold temperatures increase oil's viscosity making it more difficult to disperse and dispersants less effective.[11]	• Low-medium viscosity oils can be dispersed in cold (freezing temperature) seawater.[3] • Colder temperatures and the presence of sea ice reduce oil weathering (i.e., evaporation) and may expand the "window of opportunity" to apply dispersants.[3]
Limited Visibility	• Efficacy of all response methods depends on aerial and vessel surveillance of the spill which may be restricted during limited visibility conditions.[11] • Low visibility conditions prevent direct observation and tracking of oil and response methods.[8]	No known advantages.	• Less effective at finding actionable oil during low visibility conditions.[1] • Limited visibility reduces the operational hours.[1]	No known advantages.	• High visibility and aerial direction are important for successful ISB operations.[11] • Limited visibility reduces operational hours.[1]	No known advantages.	• Aerial and vessel operations are limited to specific visibility ranges to ensure safety.[1] • Limited visibility makes it difficult to identify slicks and accurately apply dispersant on actionable oil.[1]	No known advantages.

Environmental Conditions	Potential Impacts to Spill Response Options							
	All Response Technologies		Mechanical Recovery		In-Situ Burning (ISB)		Dispersants	
	Limitations	Advantages	Limitations	Advantages	Limitations	Advantages	Limitations	Advantages
High Sea State (i.e., high waves, strong tides)	• Inhibit some vessel operations.[8] • High sea state can impact crew's effectiveness and safety (i.e., seasickness, fatigue, slippery surfaces).[8]	Waves may increase mixing, improving the effectiveness of chemical aids.[1]	Booms and skimmers are less effective in moderate to high sea states.[1]	No known advantages.	• High sea state may affect the ability to contain oil for burning.[18] • Ineffective and potentially unsafe in high sea states.[1]	No known advantages.	Vessel-based application has operational limits with high sea states to ensure personnel safety.[1]	More effective in high sea state due to increased mixing energy.[1]

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