Bureau of Safety and Environmental Enforcement
Oil Spill Preparedness Division

Shoreline Oil Spill Response Knowledge Gaps and Technological Development Opportunities

A WORKSHOP REPORT

August 2023

(Photo: NOAA shoreline)

Coastal Response Research Center, NOAA Office of Response and Restoration, BSEE Oil Spill Response Division

US Department of the Interior
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CITATION

Shoreline Oil Spill Response Knowledge Gaps and Technological Development Opportunities Workshop, May 9-11, 2023, NOAA's Western Regional Center, Seattle, WA; Coastal Response Research Center

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- Steven Buschang, BSEE
- Troy Baker, NOAA OR&R ARD
- Alexander Balsley, USCG Research & Development Center
- Marion Lewandowski, USCG Research & Development Center
- Lisa DiPinto, NOAA OR&R
- James Hanzalik, Clean Gulf Associates
- Nancy Kinner, CRRC
- Greg McGowan, California Oil Spill Prevention and Response (OSPR)

This summit was facilitated by Nancy Kinner (www.crrc.unh.edu). CRRC is known globally as an independent intermediary that brings all stakeholders to the table to develop and implement viable and trusted solutions to complex problems related to environmental disasters. CRRC has conducted 90+ workshops that bring together practitioners, researchers, and scientists of diverse backgrounds (e.g., industry, academia, government, NGOs) to discuss and develop solutions to marine pollution and disaster problems. We would like to thank each of the speakers for their participation in the workshop:

- Doug Helton, NOAA OR&R Emergency Response Division (ERD) Regional Operations Supervisor
- Elliott Taylor, Polaris Applied Sciences, Inc.
- Angela Vallier, National Strike Force Coordination Center (NSFCC)
- Tim Nedwed, ExxonMobil Upstream Research Company
- Ed Owens, Owens Coastal Consultants Ltd
- Lisa DiPinto, NOAA OR&R
- Michel Boufadel, New Jersey Institute of Technology (NJIT)
- Prabakar Clement, The University of Alabama, Civil, Construction & Environmental Engineering
- Chris Hall, Alaska Clean Seas
- Carl Childs, NOAA OR&R ERD
- Brent Koza, Texas General Land Office, Research & Development, State SSC
- Karolien Debusschere, Louisiana Oil Spill Coordinator's Office
- Maria Hartley, Chevron
- Elizabeth Petras, U.S. Coast Guard, ICCOPR
- LCDR Clifton Graham, U.S. Coast Guard

- Jeff Morris, Abt Associates
- Greg McGowan, California DFW, Office of Spill Prevention & Response (OSPR)
- Pauline Gerrard, IISD Experimental Lakes Area
- Charlie Henry, NOAA OR&R Disaster Preparedness Program, Gulf of Mexico Disaster Response Center
- Scott Pegau, Alaska Oil Spill Recovery Institute
- Marion Lewandowski, U.S. Coast Guard Research and Development Center (RDC)
- Jacqui Michel, Research Planning, Inc

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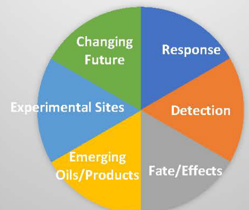
GRAPHICAL ABSTRACT

Shoreline Oil Spill Response Knowledge Gaps & Technological Development Opportunities

Topics/Participants

- Two-day workshop to identify research gaps (Federal, State, OSRO*, Industry)



- Literature review of state-of-science
- Prioritized 3 research gaps for each topic

*Oil Spill Response Organizations (OSROs)

Workshop Findings

- Focus on crude oils and dielectrics from offshore facilities
- Several North American facilities available for response research
- Clean-up in nearshore waters is best approach before spill impacts shoreline

Workshop Recommendations

- Collaborate: Among agencies and with OSROs (e.g., field test prototypes)

- Develop database on chemistry of emerging oils and contaminants
- Form working group on shoreline spill response

Report Reference: Shoreline Oil Spill Response Knowledge Gaps and Technological Development Opportunities Workshop, May 9-11, 2023, NOAA's Western Regional Center, Seattle, WA; Coastal Response Research Center

Coastal Response Research Center

BSEE

NOAA

EXECUTIVE SUMMARY

The Bureau of Safety and Environmental Enforcement (BSEE) partnered with NOAA's Office of Response and Restoration (OR&R) and UNH's Coastal Response Research Center (CRRC) to plan and facilitate an in-person workshop on the NOAA Sand Point Campus in Seattle, WA. This event entitled "Shoreline Oil Spill Response Knowledge Gaps and Technological Development Opportunities" identified knowledge gaps and opportunities regarding technologies and scientific research associated with oil spill shoreline response. This effort included the exploration of the current state of the science of oil spill research associated with impacts of crude oil to shoreline environments and identified countermeasures and response alternatives that may become part of the oil spill response toolbox. The workshop agenda is included in Appendix A. In total, there were 49 participants, including all presenters and CRRC staff and students, that attended the three-day workshop. 19 participants attended the workshop virtually. See Appendix B for the list of workshop participants.

The specific objectives of the workshop were:

1. Develop a literature review of the state of the science regarding impacts, preparedness and responses strategies and technologies associated with oil spills on shorelines (i.e., oils from offshore facilities including crude oil and dielectric fluids).
2. Identify gaps in the current state of science regarding impacts of crude oil and dielectric fluids from offshore facilities.
3. Identify operational constraints of shoreline techniques.

The workshop included plenary presentations from federal, state, and industry representatives on: response, detection, fate and effects, policy, emerging oil/products, experimental lakes, and changing future. Presentation slides can be found in Appendix C.

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Acronyms

ARD	NOAA Assessment and Restoration Division
BSEE	Bureau of Safety and Environmental Enforcement
CEDRE	Research Institute in France
COTS	Commercial Off-the-Shelf
CRRC	Coastal Response Research Center
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Australia)
DFW	Department of Fish and Wildlife
DPP	NOAA Disaster Preparedness Program
DRC	NOAA Gulf of Mexico Disaster Response Center
ERD	NOAA OR&R Emergency Response Division
FAST	Feasibility Analysis of Shoreline Treatment
GIS	Geographic Information System
IISD	International Institute for Sustainable Development (Canada)
IR	Infrared
LiDAR	Light Detection and Ranging
MPRI	Multi-Partner Research Initiative, Fisheries and Oceans Canada
NEBA	Net Environmental Benefits Analysis
NOAA	U.S. National Oceanic and Atmospheric Administration
NJIT	New Jersey Institute of Technology
NSFCC	National Strike Force Coordination Center
OHMSETT	National Oil Spill Response Research & Renewable Energy Test Facility
OR&R	NOAA Office of Response and Restoration
OSPR	Office of Spill Prevention and Response
PAH	Polyaromatic Hydrocarbons
R&D	Research and Development
RDC	USCG Research and Development Center
ROV	Remotely Operated Vehicle
RRB	Response Research Branch
SCAT	Shoreline Cleanup and Assessment Technique
SINTEF	Research Institute in Norway
SIMA	Spill Impact Mitigation Assessment
SMART	Special Monitoring of Applied Response Technologies
SSC	Scientific Support Coordinator
UAS	Uncrewed Aerial Systems
UNH	University of New Hampshire
USCG	U.S. Coast Guard
VLSFO	Very Low Sulfur Fuel

1. Session One

The first session of the workshop was held on Tuesday May 9, 2023, and focused on the response, detection, fate and effects of shoreline oiling. A panel of experts was convened to present their views on each topic. In each of these panels, the presenters discussed knowledge gaps and opportunities for scientific research and technological improvements that related to these areas of oil spill shoreline response. A list of questions that the presenters were asked to address can be found in Appendix D. Following the panels, the in-person participants divided into breakout groups to discuss the knowledge gaps and technology needs that were noted during the plenary presentation and subsequent Q&A sessions. Other gaps and needs were added if group members identified them. Then, each group identified 2-3 knowledge gaps / needs they felt were priorities. The day concluded with all breakout groups presenting their top priorities. A vote was held among all the in person and virtual participants to select the top priorities three priorities from all the priorities identified by the breakout groups for each topic. A detailed breakdown of the prioritization can be found in Appendix E.

1.1 Plenary Panel 1: Response

Doug Helton started his presentation by discussing what the challenges are for shoreline clean-up. His list included: labor is intensive and expensive, response may further injure natural and archaeological resources, large quantities of waste are generated, it is slow, and there are health and safety concerns for the workers. Additionally, there are questions on what the efficacy is of the techniques and what is the point of diminishing return. Shoreline clean-up efforts are highly visible and may draw media and public scrutiny. Helton noted that all shoreline clean-up techniques could currently benefit from R&D to improve the efficacy as well as help understand the trade-offs.

Elliott Taylor noted that we can respond quite well for surface oiling and reasonably well for subsurface contamination, provided the response is a relatively safe working environment. The basic tools have been largely unchanged over the past 20-30 years, while there have been new developments in data management, detection, and treatment options. As for tools and technologies that could be made better, Taylor discussed opportunities to improve planning and response through adoption of shoreline segmentation efforts (i.e., Taylor described segmentation from DWH for entire GoM as part of ERMA); improved definition of expected oil behavior (i.e., field tests for potential emulsification, overwashing, and/or sinking); oil detection (mostly for subsurface oiling); and improvements in decision support tools for shoreline response. Taylor discussed the potential use of canines (detection and delineation of subsurface oil; endpoints) and knowledge exchange tools (e.g., FAST (Feasibility Analysis for Shoreline Treatment) job aid (see https://fastshores.com)). Taylor noted opportunities in knowledge sharing and decision support, such as the work initiated through the Canadian MPRI program with respect to a Shoreline Decision Support Tool that would provide users (decision makers and stakeholders) with an understanding of oil removal rates for a range of oil types, shoreline types, and treatment options (including natural attenuation). Taylor recommended creation of decision support tools to guide planners and decision makers through selecting feasible and appropriate treatment options based on the current science and in context of NEBA/SIMA considerations; the improvement of in-situ treatment options through better understanding of flushing, flooding, and in-situ treatment agents; the improvement of communications through simplified messages for stakeholders; and knowledge transfer through international exchange of research (e.g., CEDRE, CSIRO, SINTEF).

Angela Vallier started by noting that the National Strike Force's (NSF) Strike Teams capability to respond to oil spills has changed little in decades. They physically assess shorelines, which often takes a significant amount of personnel and time if the spill is large. Clean-up is done mechanically unless approval is given to use spray/flooding or surface washing agents. There is little opportunity to work with alternate means of clean-up in actual oil spill on shoreline. Currently, the OHMSETT tank is the only place they can work with oil and that is in the water. The Strike Teams use short range UAS with some IR technology, but work is being done with multiple sensor packages that would help detect oil along a shoreline. Sensors are needed to detect Class V oils that have sunk or are submerged; are under ice, or in swift water environments such as riverine areas. Additionally, sensor packages are needed that might assist in responses to oil that is burned. During an in-situ burn (ISB), the NSF deploys responders who use the SMART protocols to determine any health concerns with smoke. A UAS sensor that could find and detect concentration/ size of particulate would be helpful. The NSF would conduct some testing during dispersant use, using fluorometry equipment. This equipment is relatively old and does not interface well with new operating systems. The NSF will be getting ROVs in the 4th quarter of 2023. They will be helpful in finding submerged oil.

Knowledge gaps include response to oil in different types of ice, clean-up techniques of Class V oil, containment, booming, and skimming along shorelines with rapidly moving waters (e.g., riverine environment). Better field guidance is also needed that helps responders make decisions when there are numerous trade-offs to consider (e.g., oil into the air, surface of the water, water column; efficiencies of different alternate response techniques, herding agents, surface washing agents, dispersants, ISB).

As climate change increases risks, and more open water occurs in the Arctic allowing for more ship traffic, response options in those environments are a wise investment.

Using facilities like Poker Flat (AK) or the Experimental Lakes in Canada, will provide more opportunity to train and test tactics.

1.2 Plenary Panel 2: Detection

Tim Nedwed discussed the difficulty of detecting oil spills on shorelines. Traditional SCAT methods are slow, labor and time intensive (e.g., digging random holes in beaches searching for buried oil) with minimal accuracy. There are tools and technologies available to increase capabilities, (e.g., UASs, autonomous systems, IR/polarized IR cameras, UV cameras, dogs, smart booms). Nedwed recommended rapid and safer shoreline assessment methods e.g., autonomous SCAT) along with real-time communication of shoreline and better tools for subsurface detection. R&D spending should focus on development of autonomous systems, protocol for qualifying technologies including consistent field verification, and commercial ready prototypes that could be loaned to OSROs for real world testing and training.

Ed Owens began his discussion by highlighting the basic questions of shoreline oil detection: What are we looking for? How do we detect and delineate? What is the timing? The initial information needed is a map of how to get there, tide tables to know the water levels, and a radio for the weather. Owens noted that except for dark oil in moderate amounts on the shoreline surface, detection is very difficult. He recommended creation of training tools using existing knowledge and experience, improved detection using canines, use of robotic "K9s", and improved aerial surveys. The proven capabilities and attributes of canines for oil detection include the ability to detect all oil types, surface and subsurface oils up to 5-meters-deep, and sunken oil in shallow water. More development is needed on under -ice detection and the use of "RoboK9s". Aerial observation for oil on the shoreline is much more complex than oil on water due to the variation in colors, textures, presence of background materials, and false positives from factors such as black mineral sands, debris, and shadows. A key opportunity exists in developing job aids for training, interpretation, and communication.

Lisa DiPinto discussed factors that affect how well we can detect oil spills on shorelines, including shoreline type, nature of the oiling including extent, and the type of oil. She discussed various tools and technologies for detection that are under further development, including faster workflows for data processing and easy to read data products needed to meet rapid response timeframe information needs. She emphasized the importance of advancing our use of commercial off the shelf (COTS) tools, and how we could work to optimize the use of tools we already have available and that are likely to be used on-scene now. She highlighted some of the ongoing work with the USCG to further develop platforms such as sUAS systems and COTS remotely operated vehicles (ROVs). There are opportunities to collaborate to further develop newly emerging sensors such as multispectral/thermal IR, hyperspectral, LiDAR, polarized IR and laser fluorometry, including from various remote platforms. Research and development in areas such as use of automated or semi-automated data processing to more rapidly process large volumes of data, controlled testing to calibrate emerging sensors, testing in challenging conditions such as in ice or with newly emerging products, and detecting oil in sensitive habitats.

1.3 Plenary Panel 3: Fate and Effects

Michel Boufadel addressed beach hydrodynamics, oil persistence, and remediation. He presented data from laboratory beaches and from detailed modeling. He gave examples based on his work on Prince William Sound beaches with lingering Exxon Valdez oil on some of the beaches. He emphasized that beaches should not be treated as monolithic units, but rather multiple compartments. For oil biodegradation within the pores of beaches, the upper intertidal zone tends to be nutrient limited, and the lower intertidal zone tends to be oxygen limited. Boufadel also addressed the biodegradation of oil within the pores of the supratidal zone of beaches (landward of the high tide line). He presented data from the beaches in the Gulf of Mexico where the porewater salinity was larger than 200g/L, which is likely a main limiting factor on oil biodegradation within the supratidal zone. Oil biodegradation at 160g/L salinity was ~10% of that at 32 g/L salinity.

Prabhakar Clement discussed the fate and effects of oil spills on shorelines with a focus on tar balls. There are two types of tar balls: ones that are highly weathered and float, and relatively fresh ones that are found sunken near the shoreline. The conventional wisdom is that the weathered tar balls are formed when stranded oil floats over the ocean for many months/years. However, he noted that we do not understand how floating tar balls are formed and why they persist. Tar balls still exist along the Alabama shoreline 10 years after the Deepwater Horizon Spill (DWH). These are all sunken. The DWH oil has never formed highly weathered floating tar balls. The knowledge gap that needs to be addressed is to improve our understanding of the fate and effects of oil spills on shorelines. Specifically, he recommended: understanding how tar balls and tarmats are formed from oil spills, the background level of tar balls along the GOM coastline, development of a standard protocol for fingerprinting oil spill residues, research on the toxicological/ecological effects of heavy PAHs trapped in oil spill residues, and development of methods to destabilize and disperse floating mouse using less-toxic dispersants. He recommended R&D spending to improve the fundamental understanding of tar balls formation processes, and investment in developing eco-friendly, less toxic, dispersants that can disperse and destabilize mousse and prevent sinking near the shoreline.

Chris Hall discussed the difficulty in responding to oil spills in the Arctic, (e.g., remote locations, challenging logistical support, extreme weather, short open water season). He noted that Arctic temperatures increase the viscosity and film thicknesses on the water surface, and reduce oil weathering, spreading, evaporation, emulsification, and dispersion. Drift and pack ice reduce spreading and weathering of surface oil, and shore-fast ice and snow may act as natural barriers to limit shoreline oiling. There are tools and technologies that could improve our ability to determine the fate and effects of oil on shorelines, such as incorporation of "smarter" buoys and sensors for autonomous monitoring of oil in ice and near shorelines during breakup. He suggested that R&D spending should focus on improving trajectory modeling of oil and ice interactions, study the short- and long-term effects of oil stranded on Arctic shorelines, and improving small, easily deployable "smarter" tracking buoys, autonomous systems, and surveillance tools to rapidly identify and prioritize oiled shoreline segments.

Carl Childs believed we have fairly sophisticated understanding of the overall fate and effects of spilled oil on shorelines, but there are several ways in which we could improve that understanding. The largest knowledge gap is the inability to correlate the degree of shoreline oiling with ecological impacts. Oil spill response could particularly benefit from an improved understanding of how different levels of oiling, particularly small amounts of it, translate into ecological impact. This knowledge gap limits assessment of net environmental benefit of on-water response tactics, particularly dispersant use. There are tools and technologies that could improve understanding of oil degradation rates and biogeochemical pathways, particularly recent advances in genomics, transcriptomics, proteomics, and bioinformatics. These tools can identify changes in the microbial community composition and function throughout the process of oil degradation which correlate to overall ecosystem recovery. These tools also have the potential to improve our ability to locate buried oil. Ecosystem-level modeling could improve understanding of the fate and effects of oil on shorelines. He would focus R&D spending on remote sensing to identify and quantify shoreline oiling, ecological modeling to assess the impacts of response tactics and trade-off assessments, operationalization of molecular methods to monitor the microbial community response to oiling, and improved methods for replanting as a response strategy in oiled marshes.

2 Session Two

The second session of the workshop was held on Wednesday May 10, 2023, and focused on policy surrounding oiled shorelines, emerging oil/products and the Canadian experimental lakes, and the changing future. In each of these panels, the presenters discussed knowledge gaps and opportunities for scientific research and technological improvements related to oil spill shoreline response. A list of questions that the presenters were asked to address can be found in Appendix D. Following the panels, the in-person participants were released into the same breakout groups to discuss the knowledge gaps and technology needs. For every plenary topic, the groups prioritized up to three knowledge gaps / needs. The day concluded in the same was as Session I with all breakout groups presenting their top priorities and all participants voted on the top priorities. A detailed prioritization can be found in Appendix E.

2.1 Plenary Panel 4: Policy

Brent Koza discussed what policies exist in Texas and how well they are defined for oil spills on shorelines. There are some policies that would improve the ability to address oil spills on shorelines including expanded UAV authorization and use. Additionally, having polices that address using spills of opportunity to conduct research in a timely manner post spill would greatly help further shoreline response. Koza recommended using well informed stakeholders and continued public education along with science-based guidance for the response tactics. There should also be prioritization of data management tools that provide decision support policy that addresses the efficient use of resources.

When answering the question "How well-defined are our policies regarding oil spills on shorelines?", **Karolien Debusschere** discussed the breath of existing policies but also the need to make the available information more digestible and accessible and to ensure responders are trained on relevant policies. In addition, she discussed how policies are often driven by the large, significant incidents (e.g., Exxon Valdez, DWH) and recommended we not lose sight of the more common spills. Examples of policy improvements could be: 1) allowing oil to be spilled for the sake of research in the U.S.; 2) access to "classified"/"proprietary" information/data/technology; 3) mandatory policy training for responders and planners at all levels; 4) improving updates to guidance; and 5) establishing dedicated funding streams. When it comes to prioritizing the improvements, Debusschere recommended focusing first on what the workshop attendees agreed would give the biggest return on their investment.

Maria Hartley talked about the importance of coordination between different agencies and stakeholders during responses, along with adequate training in oil spill response science and equipment, and clear policy guidance and approval processes on use of alternative response technologies. Policies that promote collaboration and mutual aid agreements facilitate more robust and coordinated responses. In addition, policies that emphasize environmental monitoring and assessment before an oil spill can provide valuable data to evaluate potential impact and guide restoration. Policy frameworks may face challenges in keeping pace with rapidly evolving technologies, (e.g., surveillance, sampling techniques, data collection), along with alternative fuel products (e.g., biofuels, hydrogen), and new extraction methods. Being able to rapidly get

UAS emergency permits/approvals, the ability to fly beyond visual line of sight, and stay on location for 24 hours could improve situational awareness and increase response effectiveness. She recommended carefully controlled source control tests in-situ to benefit development of new response technology and improve existing ones.

2.2 Plenary Panel 5: Emerging Oil/Products and Experimental Lakes

Clifton Graham discussed M/V Wakashio accident on July 25, 2020, which involved a fuel tank breach spilling ~300,000 gal. of Very Low Sulfur Fuel Oil (VLSFO) in Mauritius. He noted that in January 2020 a Global Sulfur Cap regulation was implemented, reducing sulfur content in fuels from 3.5% to 0.5%. VLSFOs are replacing the traditional intermediate and heavy fuel oils, but little is known about the characteristics of these oils. Graham also noted that GIS has been used during response, but not always in the timeframe needed by responders. Being able to get a real-time picture of the spill would improve the response to emerging fuel spills. Additionally, the use of UAS is improving, but transmitting a large volume of data into a usable format is still difficult. Graham noted the need for better mapping and interface/product development, improved detection for the presence of oil on shorelines with UAS, and a better understanding of the behavior of new fuels and the threat they pose to the safety of responders.

Jeff Morris discussed the lack of information regarding the toxic components in many petroleum products including emerging fuels that are currently being transported via rail and pipeline indicating data on how these products weather and behave under natural conditions. He also discussed the need to collect and bank samples during and after response activities to characterize concentrations and compositions of toxic constituents and how these change with time. He recommended conducting comprehensive toxicity testing of emerging fuels for different weathering states and in the presence of other stressors (e.g., UV light) to build a catalog of toxic sublethal thresholds to relevant taxa and life stages.

Greg McGowan discussed response, detection, fate, and effects of emerging fuel spills on shorelines. For most renewable fuels, the response is well understood and is consistent with its petroleum counterpart. Ethanol is an outlier due to its solubility in water. For ethanol spills in water, response may be more focused on addressing secondary impacts such as a dissolved oxygen depletion that can lead to a sudden and significant fish kill. Visual detection of renewables on shorelines is more difficult due to their lower color contrast. Fate is broadly understood; renewables are expected to persist in the environment for a shorter time and with lower ecological consequences than their petroleum counterparts. Additional study regarding the speed of natural attenuation and the reduced ecological impacts of the fuels while in the environment is warranted to develop a defensible basis for clean-up endpoints. Renewables do not persist as long in the environment and pose reduced ecological threats, so it may be that higher residual concentrations can remain in the environment after mechanical recovery because biodegradation will occur. Effects are generally understood, and the mechanical impacts (e.g., coating of fur/feathers, smothering) would be the same as petroleum counterparts. McGowan discussed the tools and technologies that could improve response to emerging fuel spills on shorelines such as testing of various sensors for detection, mechanical equipment settings/refinements, solvent considerations for gear, and tools to predict biodegradation rates based on product and environmental conditions.

McGowan prioritized R&D spending on the following knowledge gaps in oil spill science for emerging fuels: the ability to reasonably forecast biodegradation rates, spill response benefit analysis for clean-up endpoints, wildlife response protocols for stabilization, washing, and reconditioning to ensure that renewable fuels do not pose different challenges for care. McGowan questioned whether natural attenuation in high energy wave activity should be considered a primary response technique. Additional fate and transport information for on-water spreading and shoreline substrate penetration and adhesion would be helpful for response planning and implementation.

Pauline Gerrard discussed the unique and beneficial existence of International Institute for Sustainable Development (IISD) Experimental Lakes Area, a freshwater research facility comprised of 58 small lakes in Ontario, Canada. The facility was originally established to address the challenge of large algal blooms in the Great Lakes. In use since 1968, some of the research conducted at the lakes has included microplastics, pharmaceuticals, climate change, endocrine disruption, acid rain impacts and recovery, and eutrophication. The Experimental Lakes are used for ecosystem-scale research. Provincial and federal laws contain provisions that allow pollutants to be used. The goal of the lake's research facility is to mimic real life pollution scenarios in order to help return systems to their pre-impact conditions. Gerrard discussed three recent oil studies conducted at the lakes that examined the: (1) fate, behavior, and effects of oil spills on freshwater systems, (2) effectiveness of minimally invasive shoreline clean-up methods, and (3) efficacy of engineered floating wetlands as a remediation method.

2.3 Plenary Panel 6: Changing Future

Charlie Henry discussed the problem of cleaning up oiled boulder/cobble beaches and riprap, using an example of a spill in New Orleans. He described techniques such as the omni boom, a large flushing barge like the M/V Winchester, shoreline cleaning agents, bioremediation, berm relocation, and flushing with header hoses. Most techniques did not work, so there is still need for better solutions to clean-up boulder and cobble beaches and riprap. Ultimately, the riprap along the river walk in New Orleans that was oiled was cleaned by a hurricane.

Scott Pegau focused his presentation on the needs associated with remote locations and the potential for increased vessel traffic in the Arctic. The increased traffic will lead to new routes and spills at different times throughout the year. For remote locations, the personnel and equipment necessary to respond to oil on a beach must be minimized because of the lack of logistical bases. Natural attenuation may be an important response option in many cases, but it is not well understood. Impacts on wildlife need to be considered when responding. Pegau also examined the potential of remote sensing techniques to map oil distribution.

M. J. "Lew" Lewandowski discussed prevention and response activity in terms of climate change. He noted the USCG R&D Center has started an effort to examine vessel use and transportation of alternative fuels (e.g., ammonia, hydrogen, methanol). Incident response may need a different approach, particularly for more volatile or gaseous fuels whose containment might be neither safe nor practical. In areas where subsidence is up to 2.6 cm/year, a multi-agency and industry effort could identify the most vulnerable infrastructure and develop mitigation or resilience strategies. Climate change impacts petroleum-related infrastructures (e.g., subsidence, permafrost melting). In areas prone to increasingly intense storms and associated water-level surge, regulators need to examine existing petroleum-related infrastructure and determine whether as-built piping, manifolds, control systems, and containment may be subject to inundation. There is a need to model the storm-driven extent of spill transport, including how surge-related inundation could increase the geographic extent of preventive and response activity. Lewandowski mentioned that abandoned, unplugged wells could present future problems.

Jacqui Michel discussed the expansion of mangroves in the northern Gulf of Mexico that make SCAT assessments difficult. There are limited options for effective shoreline treatment of mangroves, and they have a longer recovery time compared to marshes. Nurdles pose another problem because they can leak and sorb toxic chemicals (e.g., PAHs, mercury), complicating clean-up and waste disposal. Mapping buried oil after a spill is also an emerging field of study. UAS imagery or LiDAR can be used to assess changes in beach elevation post oil stranding. The presence of Sargassum during an oil spill greatly increases the volume of oil waste for removal and can pose a hazard to clean-up workers. Another emerging issue is the higher risk of oil transport via wash overs.

3 Session Three

The third session of the workshop was held on Thursday May 11, 2023. For this session, the breakout groups were asked to take the previously selected priorities for each of the research areas and develop a research project to address each of the knowledge gaps and technology needs. Participants were asked to: (1) decide which 2-3 research projects were the top priorities, and (2) determine its objectives and outcomes for each one. For example, under *Detection,* one of the priorities was detecting ice under challenging conditions. Participants could then design a research project to test the best methods to detect oil under ice near shore and another project on use of canines to detect oil under shoreline sands. Again, the results of each breakout group's prioritization are located in Appendix E.

3.1 Priorities, Knowledge Gaps, and Research Ideas

The workshop fostered a productive discussion about current technology needs and knowledge gaps and potential research to address them. After each individual breakout group presented their top priorities for the plenary session, all participants voted for their top three. Policy knowledge gaps were not used for the overall prioritization during Session III.

The research priorities chosen by the participants are shown in Table 1. Appendix E contains the suggested objectives/outcomes for these projects where they were delineated. The Experimental Lakes was separated from the Emerging Oil/Products topics and discussed on its own. To ensure that all topics got discussed across the breakout groups, each team started with a different topic area.

3.2 Table 1: Prioritized Research Needs for Shoreline Oil Spill Response

Response	Response technologies (crewed/uncrewed) should be developed/repurposed, specifically for clean-up	Set asides, monitoring, longitudinal studies. Assessing risk for residual oil/clean-up endpoints that may generate controversy	Research on how best to communicate shoreline response technologies to the public
Detection	Platform/sensor type evaluations for shoreline detection and rapid image processing and interpretation by SMEs	Detection of oil in challenging conditions	Development of job aids/training tools for oil detection on shorelines
Fate & Effects	Determine toxicity/risks of tar balls (e.g., how/where formed) including GIS hindcasting/fingerprinting	Develop tools so that ecosystem modeling can be used for communication with a quick turnaround time during an event, including information from specialists (e.g., biologists) and trajectory modeling	Long-term monitoring/modeling of fate and effects to help prioritize shoreline types to protect
Emerging Oils / Products	Detection, response, fate, effects, and risks of emerging products	Realistic conditions and environmentally relevant toxicity testing of emerging products	
Experimental Lakes	Oil under ice nearshore	Remote Sensing/Detection of oil on shorelines and nearshore	Shoreline Efficacy Testing of Techniques (e.g., surface washing agents, herders, set asides, in-situ burning)
Changing Future	Think Tank/incubator for new ideas on specific shoreline topics	Emerging shoreline protection technologies	Challenges with climate change and impacts to infrastructure, loss of permafrost, and changes in exposure routes and habitats

4 Workshop Findings and Recommendations

1) **Finding:** Several facilities exist in North America that could be used to conduct experimental work related to shoreline oil spill response.
    a) **Recommendation:** Develop a guide to these facilities, including locations, affiliation, capabilities, requirements, and limitations.
2) **Finding:** Data on the chemistry of emerging oils and contaminants is not located in one readily accessible location that could be used by responders.
    a) **Recommendation:** Develop a database of existing data and chemical profiles of emerging oil and contaminants.
3) **Finding:** The need to do collaborative research must be recognized and pursued.
    a) **Recommendation:** Encourage and facilitate multiple agencies working together on projects.
4) **Finding:** This workshop was successful at identifying knowledge gaps and technology development opportunities for shorelines by targeting one specific area and generating concise outcomes.
    a) **Recommendation:** Repeating this approach for other response areas (e.g., mechanical recovery, dispersants).
5) **Finding:** There is a need for field scale testing of technologies that OSROs are well positioned to achieve.
    a) **Recommendation:** Provide mechanisms to enable OSROs to use prototype technologies during actual responses.
    b) A summary of selected shoreline response literature compiled during the workshop planning process can be found here. Some of the technologies identified in the literature review and by workshop participants could support discussions with OSROs about testing prototype technologies.
6) **Finding:** Clean-up of oil in the nearshore is the best method to prevent shoreline impacts.
    a) **Recommendation:** Prioritize research that removes oil while it is in the nearshore which prevents it from reaching shorelines.
7) **Finding:** Transition of research and technology development is often not funded/pursued so that promising results are not operationalized.
    a) **Recommendation:** Facilitate regular collaboration on technology development between industry and government. This is best accomplished by in-person interactions.
8) **Finding:** For the full value of this workshop to be realized, further discussion and interaction must occur.
    a) **Recommendation:** Form and facilitate a working group on shoreline oil spill response. [N.B., The CRRC offered to facilitate this working group starting in Fall 2023 in conjunction with the Clean Gulf Conference.]

5 Appendices

Appendix A: Workshop Agenda

Appendix B: Workshop Participants

Appendix C: Workshop Presentations

Appendix D: Panelist Questions

Appendix E: Detailed Prioritization Notes

Appendix F: Literature Review

Appendix G: Post Workshop Summary Overview

Appendix H: Technical Summary

Appendix A: Workshop Agenda

SHORELINE OIL SPILL RESPONSE KNOWLEDGE GAPS & TECHNOLOGICAL DEVELOPMENT OPPORTUNITIES

MAY 9 – 11, 2023

AGENDA

NOAA Western Regional Offices – Traynor Room, Building 4 – Seattle, WA

WORKSHOP OBJECTIVES

- Identify knowledge gaps and potential specific research opportunities in the current state of the science from impacts to shorelines by crude oil and dielectric fluids from offshore facilities; and
- Identify operational constraints of shoreline techniques using data visualization platforms and case study examples.

DAY 1 – TUESDAY, MAY 9

08:00 Registration

08:30 Welcome - Nancy Kinner, Coastal Response Research Center (CRRC) (safety, etc.)

08:45 Background & workshop goals – Steven Buschang, Bureau of Safety and Environmental Enforcement (BSEE)

09:00 Participant introductions (in person and online)

09:30 **Plenary Panel 1: Response**

Doug Helton, NOAA OR&R Scientific Support Coordinator

Elliott Taylor, Polaris Applied Sciences, Inc.

Angela Vallier, National Strike Force Coordination Center (NSFCC)

Q&A / Discussion

10:30 *Break*

10:45 **Plenary Panel 2: Detection**

Tim Nedwed, ExxonMobil Upstream Research Company

Ed Owens, Owens Coastal Consultants Ltd

Lisa DiPinto, NOAA Office of Response & Restoration (OR&R)

Q&A / Discussion

11:45 **Plenary Panel 3: Fate and Effects**

Michel Boufadel, New Jersey Institute of Technology (NJIT) (virtual)

Prabakar Clement, The University of Alabama, Civil, Construction & Environmental Engineering (virtual)

Chris Hall, Alaska Clean Seas (virtual)

Carl Childs, NOAA OR&R Emergency Response Division (ERD)

Q&A / Discussion

12:45 *Lunch*

01:30 Overview of Breakout Group

Breakout Session I

03:00 *Break*

03:15 Group reports

04:15 Wrap Up

04:30 Adjourn

This event is made possible through support and partnership with NOAA's Office of Response and Restoration and Bureau of Safety and Environmental Enforcement with the Coastal Response Research Center.

For more information and resources please visit the CRRC website: https://crrc.unh.edu/resource/shoreline-response-gaps

DAY 2 – WEDNESDAY, MAY 10

08:15 Recharge & Recalibrate

08:30 **Plenary Panel 4: Policy**

Brent Koza, Texas General Land Office, Research & Development, State SSC (virtual)

Karolien Debusschere, Louisiana Oil Spill Coordinator's Office

Maria Hartley, Chevron (virtual)

Q&A / Discussion

09:30 **Plenary Panel 5: Emerging Oil/Products and Experimental Lakes**

Elizabeth Petras/Cliff Graham, U.S. Coast Guard

Jeff Morris, Abt Associates (virtual)

Greg McGowan, California DFW, Office of Spill Prevention & Response (virtual)

Pauline Gerrard, IISD Experimental Lakes Area (virtual)

Q&A / Discussion

10:30 *Break*

10:45 **Plenary Panel 6: Changing Future**

Charlie Henry, NOAA ORR Disaster Preparedness Program, Gulf of Mexico Disaster Response Center

Scott Pegau, Alaska Oil Spill Recovery Institute (virtual)

Marion Lewandowski, U.S. Coast Guard Research and Development Center

Jacqui Michel, Research Planning, Inc (virtual)

Q&A / Discussion

11:45 *Lunch*

12:45 Overview of Breakout Group Session II

01:00 Breakout Session II

02:45 *Break*

3:00 Group reports & discussion

This event is made possible through support and partnership with NOAA's Office of Response and Restoration and Bureau of Safety and Environmental Enforcement with the Coastal Response Research Center.

For more information and resources please visit the CRRC website: https://crrc.unh.edu/resource/shoreline-response-gaps

04:00 Wrap Up

4:30 Adjourn

DAY 3 – THURSDAY, MAY 11

08:30 Recharge & Recalibrate

08:45 Overview of Breakout Group Session III

09:00 Breakout Session III

10:30 *Break*

10:45 Group reports & discussion

11:30 **Plenary 7: Path Forward**

12:15 Wrap Up

12:30 *Adjourn*

This event is made possible through support and partnership with NOAA's Office of Response and Restoration and Bureau of Safety and Environmental Enforcement with the Coastal Response Research Center.

For more information and resources please visit the CRRC website: https://crrc.unh.edu/resource/shoreline-response-gaps

Appendix B: Workshop Participant List

SHORELINE OIL SPILL RESPONSE KNOWLEDGE GAPS & TECHNOLOGICAL DEVELOPMENT OPPORTUNITIES

MAY 9 – 11, 2023

PARTICIPANTS

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*Denotes Workshop Steering Committee Member

Appendix C: Workshop Presentations

Shoreline Oil Spill Response Knowledge Gaps & Technological Development Opportunities

Nancy E. Kinner, Facilitator
Coastal Response Research Center (CRRC)
University of New Hampshire

May 9, 2023

COASTAL RESPONSE RESEARCH CENTER (CRRC)

- Partnership between NOAA's Office of Response and Restoration and the University of New Hampshire
- Since 2004
  - UNH Co-Director – Nancy Kinner
  - NOAA Co-Director – Troy Baker

Coastal Response Research Center (NOAA $)

Center for Spills and Environmental Hazards (All Other $)

- Conduct and Oversee Basic and Applied Research and Outreach on Spill and Other Environmental Disaster Response and Restoration
- Transform Research Results into Practice
- Serve as Hub for Spill and Environmental Disaster R&D
- Facilitate Interaction Among Spill/Environmental Disaster Community (All Stakeholders)
- Educate/Train Students for Careers in Response and Restoration

STEERING COMMITTEE

Steve Buschang, BSEE

Troy Baker, NOAA OR&R ARD

Lisa DiPinto, NOAA OR&R

Alex Balsley, USCG RDC

Marion (Lew) Lewandowski, USCG RDC

James Hanzalik, Clean Gulf Associates

Greg McGowan, California OSPR

HOW TO PARTICIPATE

- Hybrid workshop
- ~30 attendees in Seattle at NOAA campus
- For those on Zoom:
  - **Attendees:** Muted & camera off
  - **Panelists:** Unmute & camera on ONLY when speaking
- If you have access issues, please contact:
  - Kathy at **kathy.mandsager@unh.edu**, cell 603.498.8010

AGENDA- Day 1

08:30 Welcome

08:45 Background & Workshop Goals

09:00 Participant introductions (

09:30 Plenary Panel 1: Response

10:30 *Break*

10:45 Plenary Panel 2: Detection

11:45 Plenary Panel 3: Fate and Effects

12:45 *Lunch*

01:30 Breakout Session I

003:15 Group reports

04:15 Wrap Up

04:30 Adjourn

AGENDA- Day 2

08:15 Recharge & Recalibrate

08:30 Plenary Panel 4: Policy

09:30 Plenary Panel 5: Emerging Oil/Products

10:30 *Break*

10:45 Plenary Panel 6: Changing Future

11:45 *Lunch*

12:45 Breakout Group Session II

02:45 *Break*

3:00 Group reports & discussion

04:00 Wrap Up

4:30 Adjourn

AGENDA- Day 3

08:30 Recharge & Recalibrate

08:45 Breakout Session III

10:30 *Break*

10:45 Group reports & discussion

11:30 Plenary 7: Path Forward

12:15 Wrap Up

12:30 *Adjourn*

THANK YOU FOR LISTENING

…………And Away We GO…………

https://crrc.unh.edu/resource/shoreline-response-gaps

Participant Introductions:

Name

Affiliation

Shoreline Spill Experience

Some Thoughts on Shoreline Cleanup

Doug Helton

Shoreline Cleanup Challenges

- Labor intensive and expensive
- May further injure natural and archaeological resources
- Generates large quantities of waste
- Efficacy and diminishing returns
- Slow process
- Cleanup endpoints may generate controversy
- Highly visible, media and public scrutiny
- Health and safety for workers

There may be compelling reasons

5000 pups oiled, 4000 fatally

All Shoreline Cleanup Techniques could benefit from R&D

- No Action (Natural Recovery)
- Physical/Mechanical
- Biological (Bioremediation)
- Chemical (Shoreline Cleaners)
- Burning (marshes)

R&D to improve efficacy but also to understand trade-offs

Can we improve this scenario?

Manual Recovery

T/V Prestige Spill, Spain, 2002

Better (automated?) technologies needed

Other ideas: Sand (Dry Ice) Blasting

Refugio Oil Spill, Southern California, 2015

Shoreline Response Knowledge Gaps and Technological Development Opportunities

BSEE / NOAA Workshop, Seattle

9 – 11 May 2023

Elliott Taylor, PhD.

POLARIS Applied Sciences, Inc.

Bainbridge Island, WA, USA

Questions

1. How well can we respond to oil spills on shorelines?

2. Are there tools and technologies for shoreline response that: (a) could be made better; (b) have been developed and are not being used [If yes, please explain how they might be used]; or (c) are currently under development and/or at a low technical readiness level.

3. What knowledge gaps in oil spill science or tools/technologies do you “wish” were addressed/existed that would improve shoreline response?

4. How would you prioritize R&D spending to improve shoreline spill response? (max of 3 items)

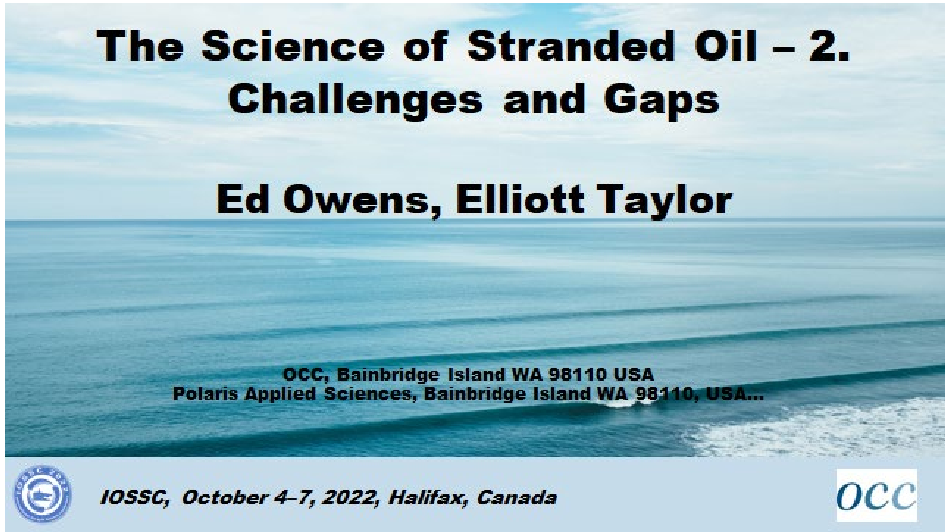
How well can we respond to oil spills on shorelines?

Quite well, provided safe to do so.

Basic tools are relatively unchanged over years

New developments in:

- Data management
- Detection
- Treatment options



Are there tools and technologies for shoreline response that: (a) could be made better?

Shoreline segmentation

- Not just ESI
- Incorporate from actual responses, exercises, and plans (lost opportunities)

Oil behavior

- What to expect, particularly as oil weathers

Oil detection

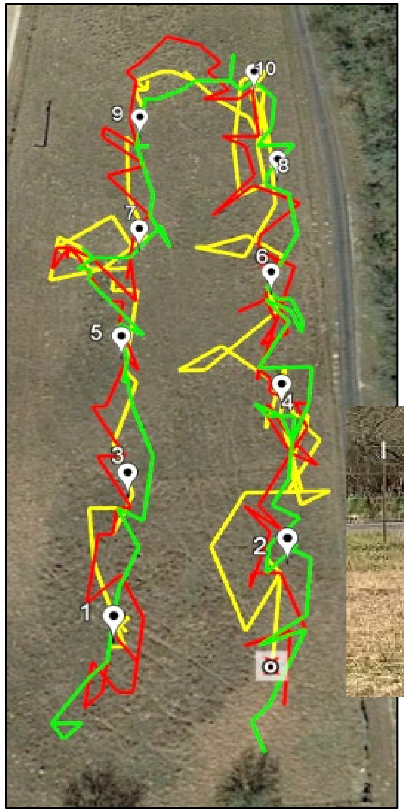
- Subsurface and relatively inaccessible oil
- K9, instrumentation

Decision support

- Treatment vs Natural Attenuation
- Targets, SIMA, and NEBA

Are there tools and technologies for shoreline response that: (b) have been developed and are not being used?

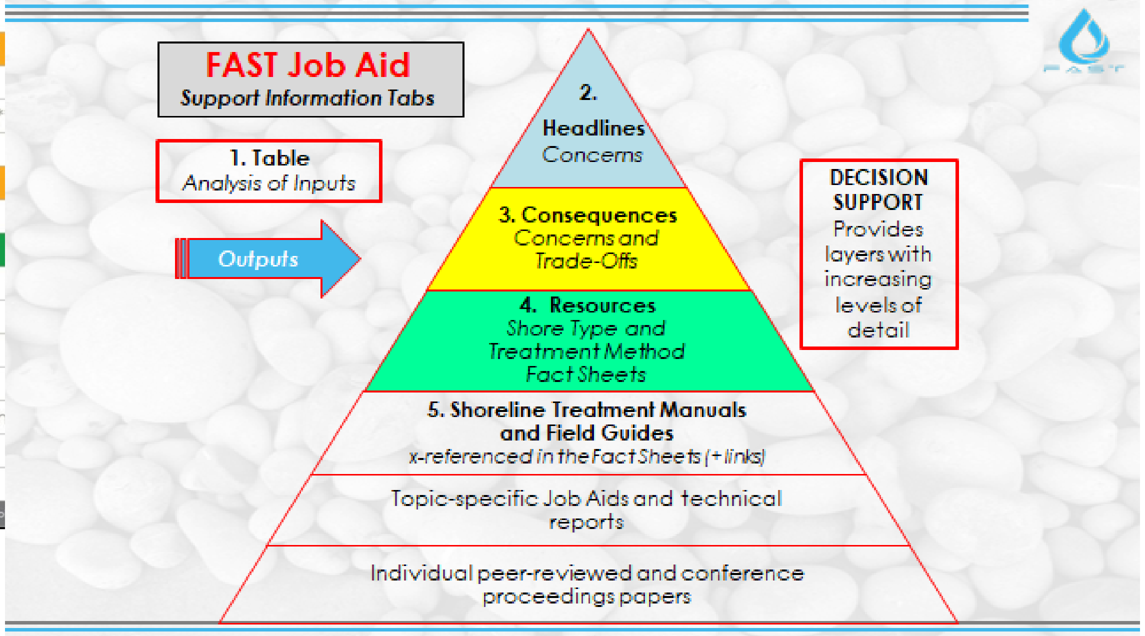
Canines



TREATMENT METHOD	FEASIBILITY ANALYSIS
Natural Attenuation	Feasible for Small Amounts
Flush/Flood***	Feasible
Low Pressure Wash***	Feasible
Low Pressure Heated Wash	Not Feasible due to Safety
High Pressure Wash	Not Feasible due to Safety
High Pressure Heated Wash	Not Feasible due to Safety
Steam Cleaning	Operationally Incompatible
Sand Blasting	
Manual Removal***	
Vacuum	
Mechanical Removal*	
Vegetation Cutting	
Passive Sorbents***	
Dry Mixing***	
Wet Mixing***	
Relocation***	
Incineration***	
Burning***	
Dispersants	
Surface Washing Ager	
Solidifiers	
Bioremediation	

***Safety is a primary concern for volatile o

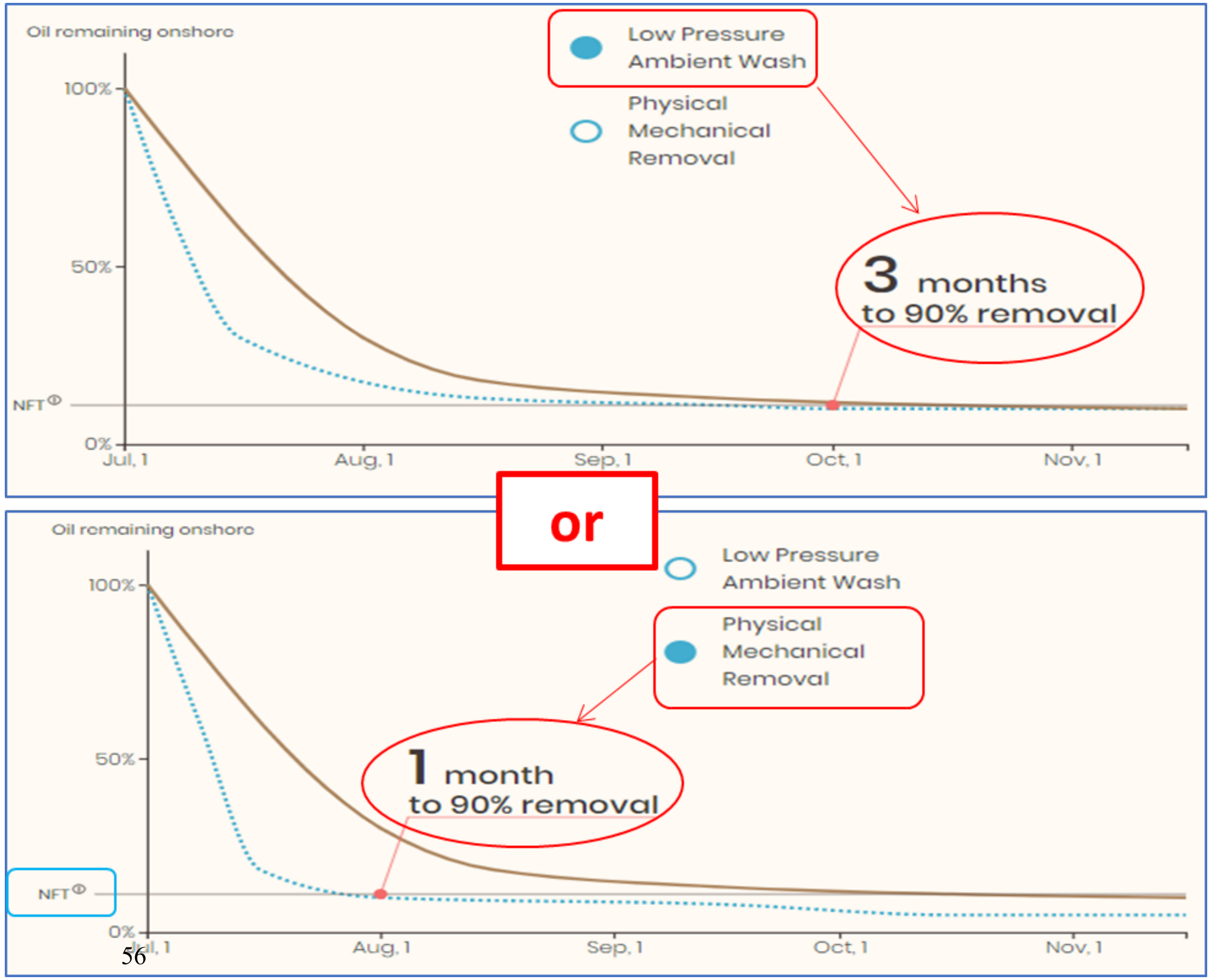
FAST



Are there tools and technologies for shoreline response that: (c) are currently under development and/or at a low technical readiness level?

MPRI and the Shoreline Decision Support Tool

- A dynamic, interactive tool for planners, decision makers and the public to help understand the tradeoffs and consequences of oiled shoreline treatment options
- A modular concept that:
    - Presents ***operationally feasible and viable response*** ….and
    - Identifies the ***consequences of each option***



What knowledge gaps in oil spill science or tools/technologies do you "wish" were addressed/existed that would improve shoreline response?

Shoreline DST

Treatment

Flood, flush, & wash

Surface washing agents

In-situ translocation

METHODS	Understanding of Operations and Implementation	Understanding of Translocation Pathway(s)	Understanding of Toxicological Effects	Supported by Peer Reviewed Scientific Literature
BIOLOGICAL				
o Bioenhancement	√√√	√√√	√√√	√√√
o Bioaugmentation	√√	√√√	√	√
o Phytoremediation	√√	√√√	√√	√
CHEMICAL				
o Surface washing agents	√√	√√√	√√	√
o Dispersant agents	√√	√√√	√√	√
PHYSICAL				
o Manual/mechanical removal	√√√	√√√	√√√	√√√
o Flood, flushing and washing	√√√	X	X	X
o Sediment dry mixing	√√√	√√√	√	√
o Sediment wet mixing	√√√	√√√	√	√
o Sediment relocation	√√√	√√√	√	√
THERMAL				
o Burning on shore	√√√	√√√	√√√	√√√
o Incineration	√√√	√√√	√√√	√√√

Opportunities:

- Documentation of the oil pathways, attenuation efficiency, and effects associated with the various in-situ removal methods
- Stranded oil behavior & buoyancy in the absence of wave energy

What knowledge gaps in oil spill science or tools/technologies do you "wish" were addressed/existed that would improve shoreline response?

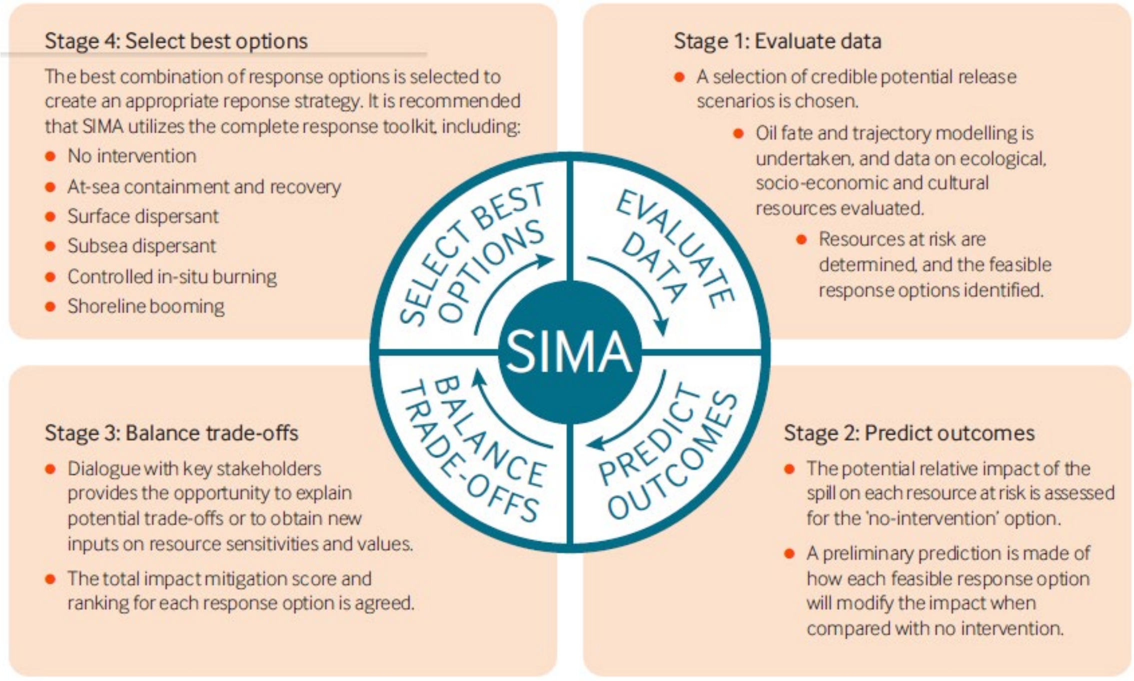
Shoreline DST

SIMA/NEBA Tools

Treatment options

Treatment targets

Carbon footprint



Opportunities:

- Phased end points and not requiring the development of "final" criteria at the outset
- Tools to quickly educate participants to understand the consequences of treatment completion criteria

How would you prioritize R&D spending to improve shoreline spill response?

Decision support tools

Guide the planners and decision makers through the steps involved in the selection of feasible and appropriate treatment options with science-based explanations to support their choices

Explain the consequences of treatment completion criteria (NEBA / SIMA)

Treatment

In-situ options and phased approaches

Efficiency, rates, & effects

Tradeoffs

Communications

Research and learnings – international exchange

Simplifying the messages for stakeholders

1. What do we wish we had known that we didn't have the tools and technology to get information about? (Top 3 things)
    - Rapid / safer shoreline assessments (rapid / autonomous SCAT)
    - Real-time communication of shoreline oiling or pre-oiling
    - A greater scientific foundation for shoreline sensitivity / recovery ranking
2. How could the existing tools be made better?
    - Utilize autonomous systems to deploy sensors
    - Maintain a kennel of oil / hydrocarbon sniffing dogs
    - Off-the shelf tools for shoreline cleanup
3. What would you prioritize for R&D spending?
    - Autonomous systems for shoreline assessments
    - Additional understanding / development of dog's noses

1. How well can we detect oil spills on shorelines?
   - Traditional SCAT methods – slow, man-power intensive
     - digging random holes in beaches looking for buried oil is very labor and time intensive with minimal accuracy

2. Are there tools and technologies for shoreline oil spill detection that: (a) could be made better; (b) have been developed and are not being used [If yes, please explain how they might be used]; or (c) are currently under development and/or at a low technical readiness level.
   - Tools are available to increase capabilities, e.g.,
     - UAVs / autonomous systems
     - IR / polarized IR cameras / UV cameras
     - Dog's noses
     - Smart booms
   - How might detection tools currently under development be used?
     - Develop consistent method to qualify commercial-ready systems using field surveys / real incidents
     - Provide commercial-ready prototypes to OSROs for field validation / proving during real incidents
     - Consistent data format / integration rules to implementing sensor data into COPs

3. What knowledge gaps in oil spill science or tools/technologies do you "wish" were addressed/existed that would improve detection of oil on shorelines?
    - Rapid / safer shoreline assessments (rapid / autonomous SCAT)
    - Real-time communication of shoreline oiling or pre-oiling including tracking offshore / nearshore oil overnight
    - Better tools for subsurface detection

4. How would you prioritize R&D spending to improve shoreline spill detection? (max of 3 items)
    - Develop / qualify autonomous systems
    - Develop a protocol for qualifying technology including consistent field verification / validation opportunities
    - Provide funding to provide commercial ready prototypes & training to OSROs for real-world testing / qualifying

Biological Recovery of Oil-Impacted Shorelines Can Take Years

Habitat	Estimated Recovery Time
Oiled Rocky Shores	0.5 - 3 Years
Oiled Salt Marshes	2 - 5 Years
Tidal Flats	5 - 10 Years
Coral Reefs	10 - 50 Years
Mangroves	25 - 80 Years

(from Aberdeen University Research and Industrial Services Ltd.)

SHORELINE HABITATS (ESI)

- 1A EXPOSED ROCKY CLIFFS
- 1B EXPOSED, SOLID MAN-MADE STRUCTURES
- 2A EXPOSED WAVE-CUT PLATFORMS IN BEDROCK
- 2B SCARPS AND STEEP SLOPES IN MUDDY SEDIMENTS
- 3A FINE- TO MEDIUM-GRAINED SAND BEACHES
- 4 COARSE-GRAINED SAND BEACHES
- 5 MIXED SAND AND GRAVEL BEACHES
- 6A GRAVEL BEACHES
- 6B RIPRAP
- 7 EXPOSED TIDAL FLATS
- 8A SHELTERED ROCKY SHORES
- 8B SHELTERED, SOLID MAN-MADE STRUCTURES
- 9A SHELTERED TIDAL FLATS
- 9B SHELTERED VEGETATED LOW BANKS
- 10A SALT- AND BRACKISH-WATER MARSHES
- 10B FRESHWATER MARSHES
- 10C SWAMPS
- 10D MANGROVES
- FRESHWATER SCRUB/SHRUB

Shoreline Response Knowledge Gaps & Technological Development Opportunities

BSEE/NOAA Workshop
Seattle, WA - May 2023

Ed Owens, PhD
OCC, Bainbridge Island, WA

Shoreline Oil Detection

What are we looking for ?

- Surface oil
- Subsurface oil in sediments

How do we look (detect and delineate)?

- from the air: *visual or sensing tools*
- on the ground: *visual or sensing tools*

What is the timing ?

- ***First response – reconnaissance - have to be quick***
- Planned phase

Shoreline Oil Detection

What would I want if had no tools and technology?

- **Topo/Road map** - to get there
- **Tide table** - to know the water levels
- **Radio** – to know the weather

Q 1 – How Well are we Doing?

	Surface	**Subsurface**
Dark oil >Moderate amounts	We're OK	**Need help**
Trace amounts	Generally OK	**Need help**
Transparent/translucent oils	**Need help**	**Need help**

API 2014 post-DWH study

*not much if anything can do from the air for **subsurface oil***

- most feasible potential tool for improvement is Oil Detection K9s

Possible R&D challenges and opportunities exist in *information management* and *communication*

POTENTIAL PRIORITIES

1 Create Training Tools using Existing Knowledge and Experience

2= Improve Detection Canine range of capabilities

2= Evaluate "RoboK9s"

2= Improve Aerial Surveys (esp. Reconnaissance) – Crewed/Uncrewed Systems

Subsurface Oil Detection and Delineation in Shoreline Sediments

Phase 2—Final Report

API TECHNICAL REPORT 1149-2A
OCTOBER 2014

energy API
AMERICAN PETROLEUM INSTITUTE

Subsurface Oil

Table 4.3—Developing Subsurface Detection/Delineation Technologies – Field Trial Candidate Selection Matrix (for planning purposes)

OIL DISTRIBUTION	TACTIC	Survey Speed	Detection		Delineation			
					Vertical		Horizontal	
			Fresh	Weathered	Fresh	Weathered	Fresh	Weathered
Scattered (Tar Balls)	Detection Dogs							
	Gas Detect – H_2S							
	Gas Detect – Sweet							
	Geophysics – GPR							
	Geophysics – EM							
	Geophysics – ER							
	Push Probes							
Continuous/Light	Detection Dogs							
	Gas Detect/H_2S							
	Gas Detect – Sweet							
	Geophysics – GPR							
	Geophysics – EM							
	Geophysics – ER							
	Push Probes							
Heavy	Detection Dogs							
	Gas Detect – H_2S							
	Gas Detect – Sweet							
	Geophysics– GPR							
	Geophysics – EM							
	Geophysics – ER							
	Push Probes							
Conventional Tactics	Pits							
	Trenches							

- Green: Reasonable potential of success
- Yellow: Possible application or application with other supporting tactic
- Red: Not applicable or efficient, low potential of success

Frankly, none of the options were particularly appealing in terms of a potential for new or to significantly advance current technologies/methodologies - <u>except K9s</u>

Table 2.1—Existing and Potential Attributes of Subsurface Oil Detection and Delineation Procedures

ATTRIBUTES	Existing Procedures			Developing Technology (Potential)			
	Excavate	Cores	Jetting	Push Probes	Detection Dogs	Geophysical	Surface Gas
Delineation (Horizontal)							
Delineation (Vertical)							
Survey Speed							
Oil Character							
Continuous cover (green) vs spot sampling (red)	S	S	S	S	C	C	C

Q 2 - Potential Opportunities

- Potential new tools and technology: **TRL-0**
- Potential new tools or technology under development: **TRL-1** – **TRL-7**
- Potential improvements to existing tools

2= Oil Detection Canines

Many proven attributes:

- any and **all oil types**: transparent & very weathered oils: **TRL-9**
- very rapid, reliable, with ~100% area coverage: **TRL-9**
- surface and **subsurface oil** (5 m-deep targets): **TRL-8**
- "**specific oil**" capability to ignore background (*doubt could ever develop a sensor that could do that*!): **TRL-8**
- **sunken oil** in shallow water (<1 meter): **TRL-3**

Capabilities still to develop/evaluate:

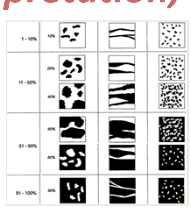
- river, lake, **nearshore sunken oil** detection (>1 m or so): **TRL-2**
- untested for marine or freshwater **under ice** detection: **TRL-1**
- "RoboK9s" - organic neuroelectronic interfaces: **TRL-4**

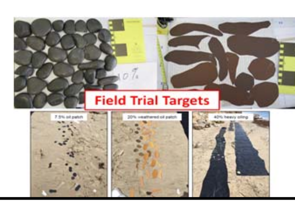
2= Crewed/Uncrewed Aerial Systems

- **UAS "mechanical eyeballs"**
  - *useful when human observations have limitations (available craft, personnel, weather, etc.)*: **TRL-6**
- Aerial is good for ***dark surface oil*** and inaccessible/difficult access areas
  - *but if access is an issue then unlikely to be low-hanging fruit for Ops when it matters most during first response phase:* **TRL-7**
- Rapid data turnaround essential during the critical first response phase - basically need ***real-time visual interpretation/analysis*** whether Mark 1 eyeball or a UAS sensor: **TRL-?**
  - *have proof of concept ("SOAR-RRTR") and have the knowledge and experience but need to take this to the next stage*: **TRL-3**
  - *Significant Research & **Development** opportunity to further develop this tool and improve DETECTION through "**SCATimage**"* **TRL-2**

GAP = Challenge = Opportunity

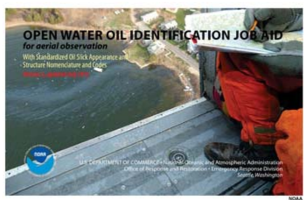
- Been trying to figure out a way to ***train how to recognize oil on shorelines*** for 45 years
- Detection surrogates (seaweed, etc.) do not work well and so far no-one has figured out the best way except for hands-on during a spill
- ***Huge gap - need a good tool for training, calibration, interpretation, analysis, and communication***

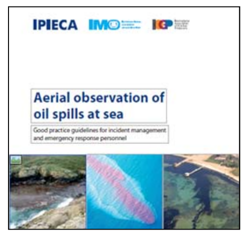




1. Knowledge Transfer - Manuals and Job Aids

- Many for **aerial on water** observations
- Many for **shoreline SCAT**
- A large gap for **aerial shoreline** observations: *current aerial observer Job Aids have few, if any, visual aids for shoreline oiling or shoreline false positives*





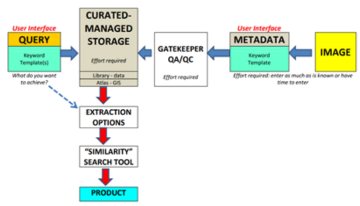
Aerial Observations of Oil on Shorelines

- Much more complex than oil on water as many more variables:
  - Oil **colors** and textures
  - **Background materials** (shore types, colors, and textures; such as yellow quartz sands, black volcanic sands, gray or multicolored pebbles/cobbles, textures)
  - **Physical and biological false positives** (wrack lines, black minerals sands, debris, shadows, etc.)
- *Unlikely to be a good candidate for AI/ML – insufficient input data ?*

The challenge could be met with existing knowledge and experience – if it can be better accessed

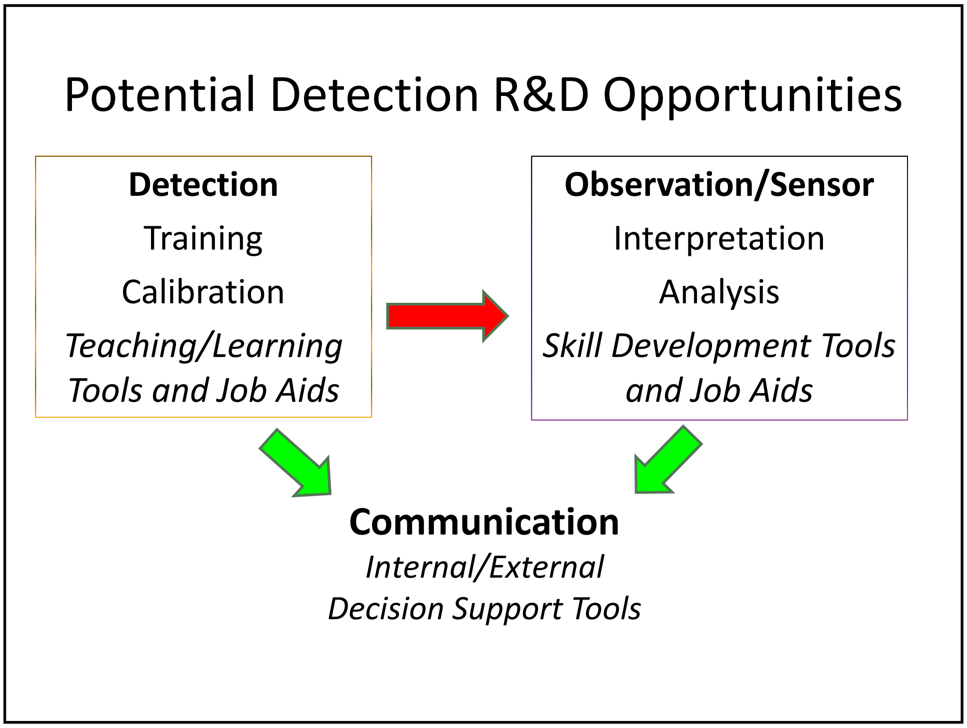
SCATimage (Clean Gulf 2021)

- A Job Aid to Support Aerial Shoreline Oiling Assessment Programs: **TRL-2**
- Searchable key word driven database (library and atlas) of oiled shoreline aerial images *including false positives*
- A tool for training, calibration, interpretation, analysis, and communication



An Opinion (or two …)

1. A key gap/opportunity is a Shoreline Tool/Job Aid for ***training***, ***interpretation,*** and ***communication***
2. ***Airborne gas sniffers*** used back in 1980s – *is that technology better/applicable today?* ***RoboK9****s?*
3. Is there a sensor or sensor array for an UAS that can ***reliably detect and delineate a range of surface and subsurface oil types over large/long shoreline areas*** - *NETL spent $2.15M on an airborne gas leak detection project ("ANGEL") in 2003/2004*
4. **AI/ML** probably not an avenue worth pursuing as not enough data to train a neural network


Potential Detection R&D Opportunities
Detection
Training
Calibration
Teaching/Learning Tools and Job Aids
Observation/Sensor
Interpretation
Analysis
Skill Development Tools and Job Aids
Communication
Internal/External
Decision Support Tools

Beach Hydrodynamics

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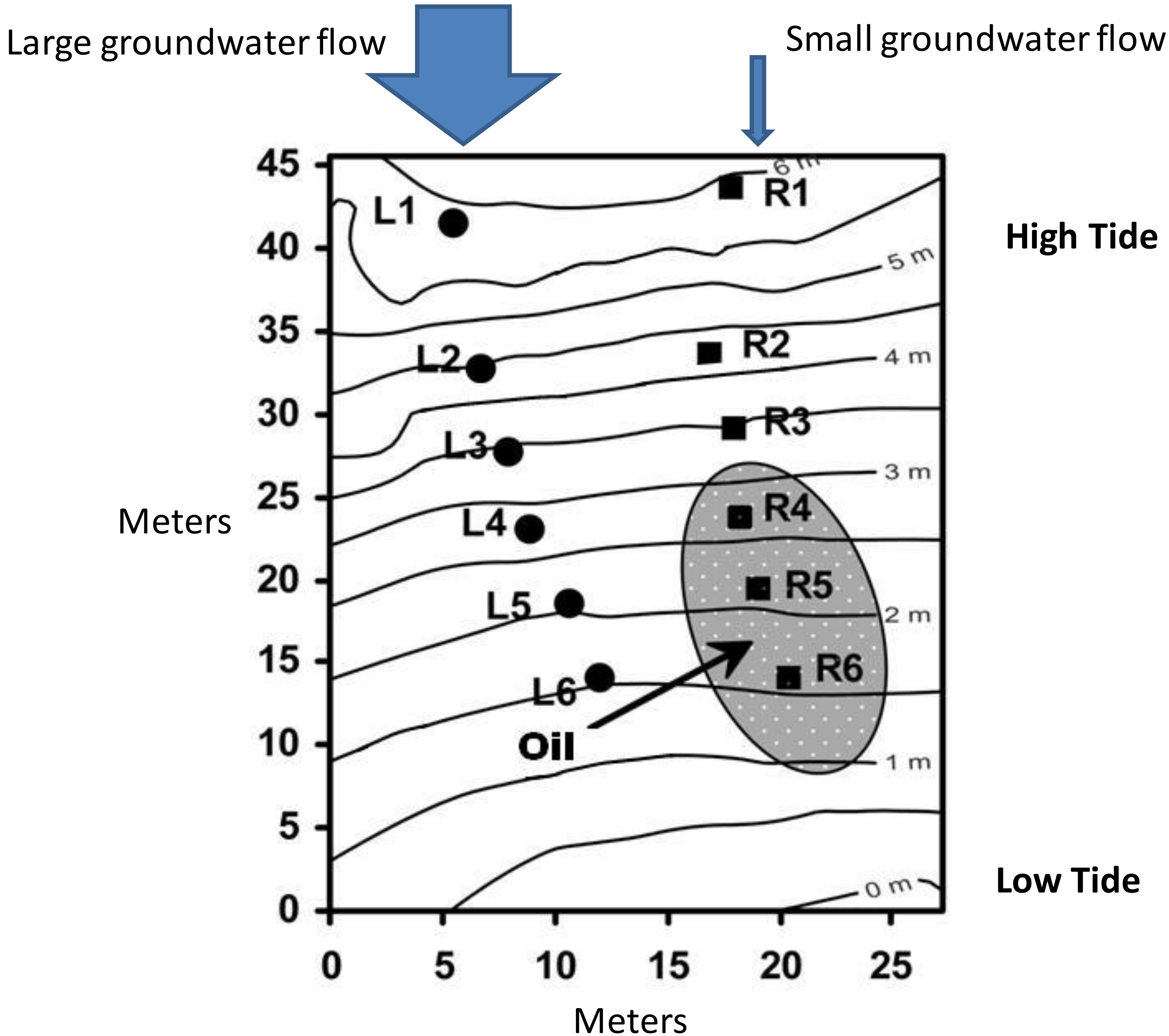
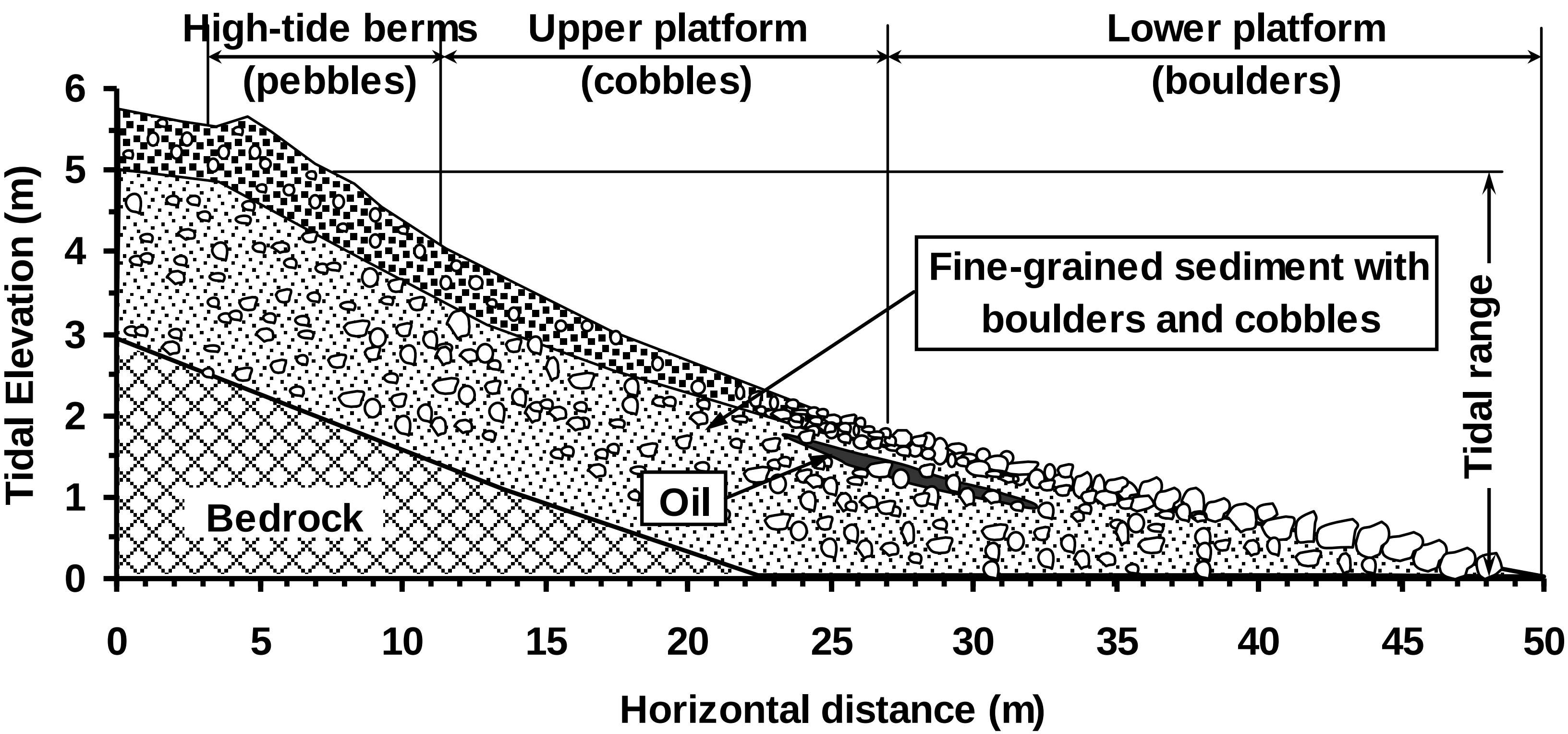
Anchorage
Valdez
GROUNDING SITE ON BLIGH REEF
Whittier
Cordova
Seward
KENAI PENINSULA
COOK INLET
DAY 4
March 27
37 miles
Homer
DAY 7
March 30
9 miles
ALASKA PENINSULA
GULF OF ALASKA
DAY 11
April 3
140 miles
AFOGNAK ISLAND
SHELIKOF STRAIT
DAY 14
April 7
180 miles
DAY 19
April 11
250 miles
KODIAK ISLAND
N
0 50 100
miles
DAY 38
April 30
280 miles
DAY 56, May 18
470 miles
(farthest southwest observation)
0 50 100
kilometers

Prince William Sound Alaska, 2008.



Large groundwater flow
Small groundwater flow
High Tide
Low Tide
Meters
Meters
45
40
35
30
25
20
15
10
5
0
0
5
10
15
20
25
L1
L2
L3
L4
L5
L6
R1
R2
R3
R4
R5
R6
Oil
6 m
5 m
4 m
3 m
2 m
1 m
0 m

- High K layer underlain by a low K layer.
- During low tides, WT in the oiled transect drops into the lower layer due to small R
- Oil gets trapped in the lower layer.

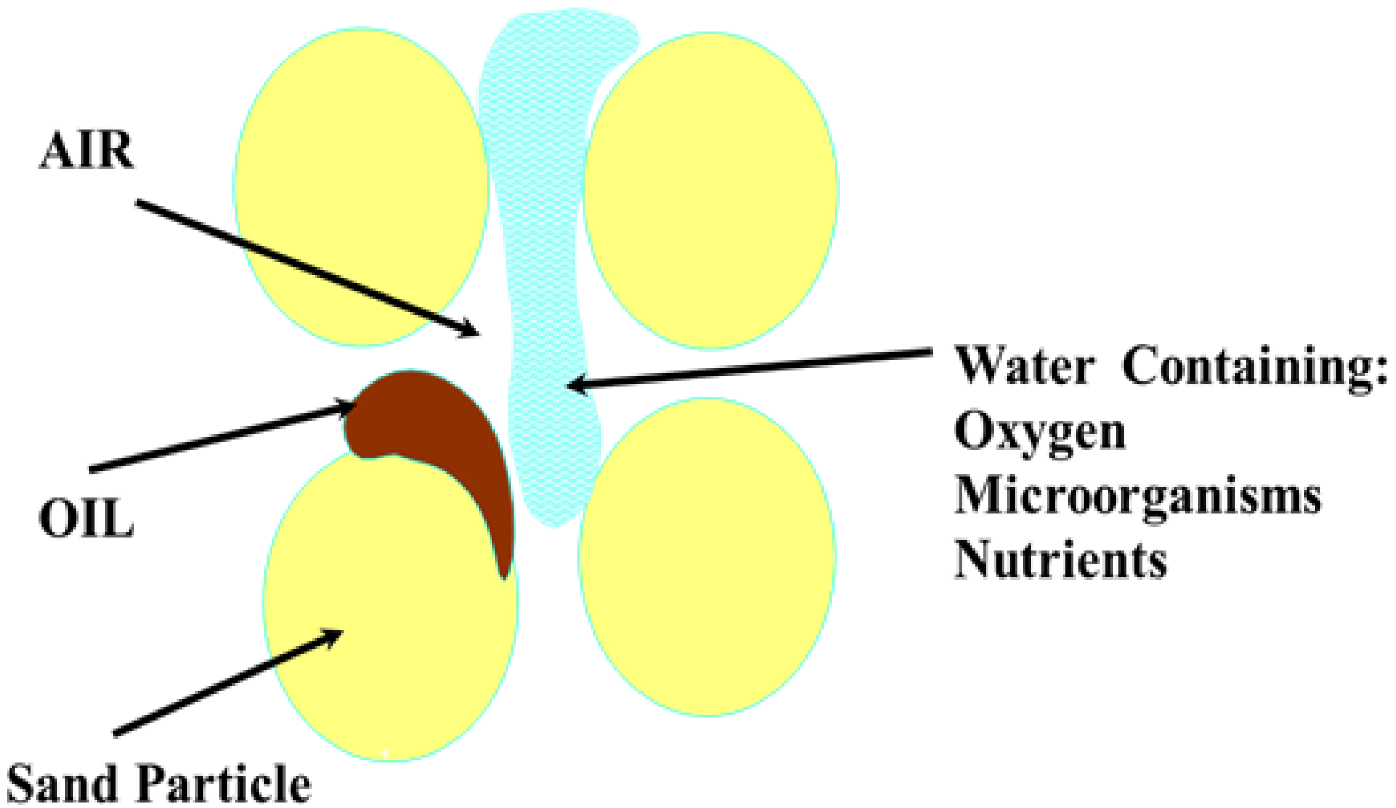


Li and Boufadel, ***Nature*** *geoscience*, *3,* 96-99, 2010.

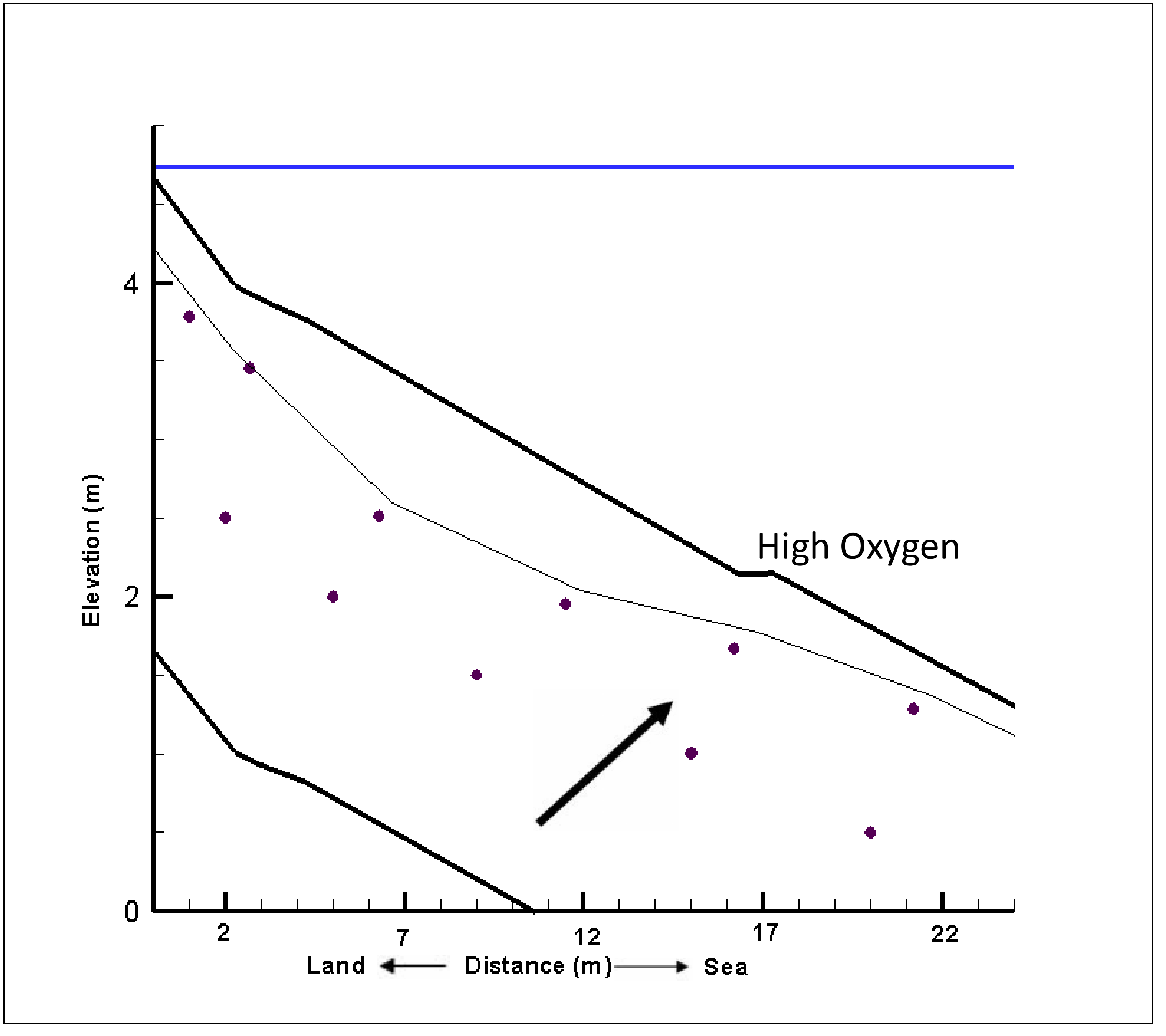
Guo, Boufadel, et al., ***J. Geophysical Research*****,** 115, C12077, 2010.

Xia, Li, and Boufadel, ***Water Resources Research***, 46, W10528, 2010.

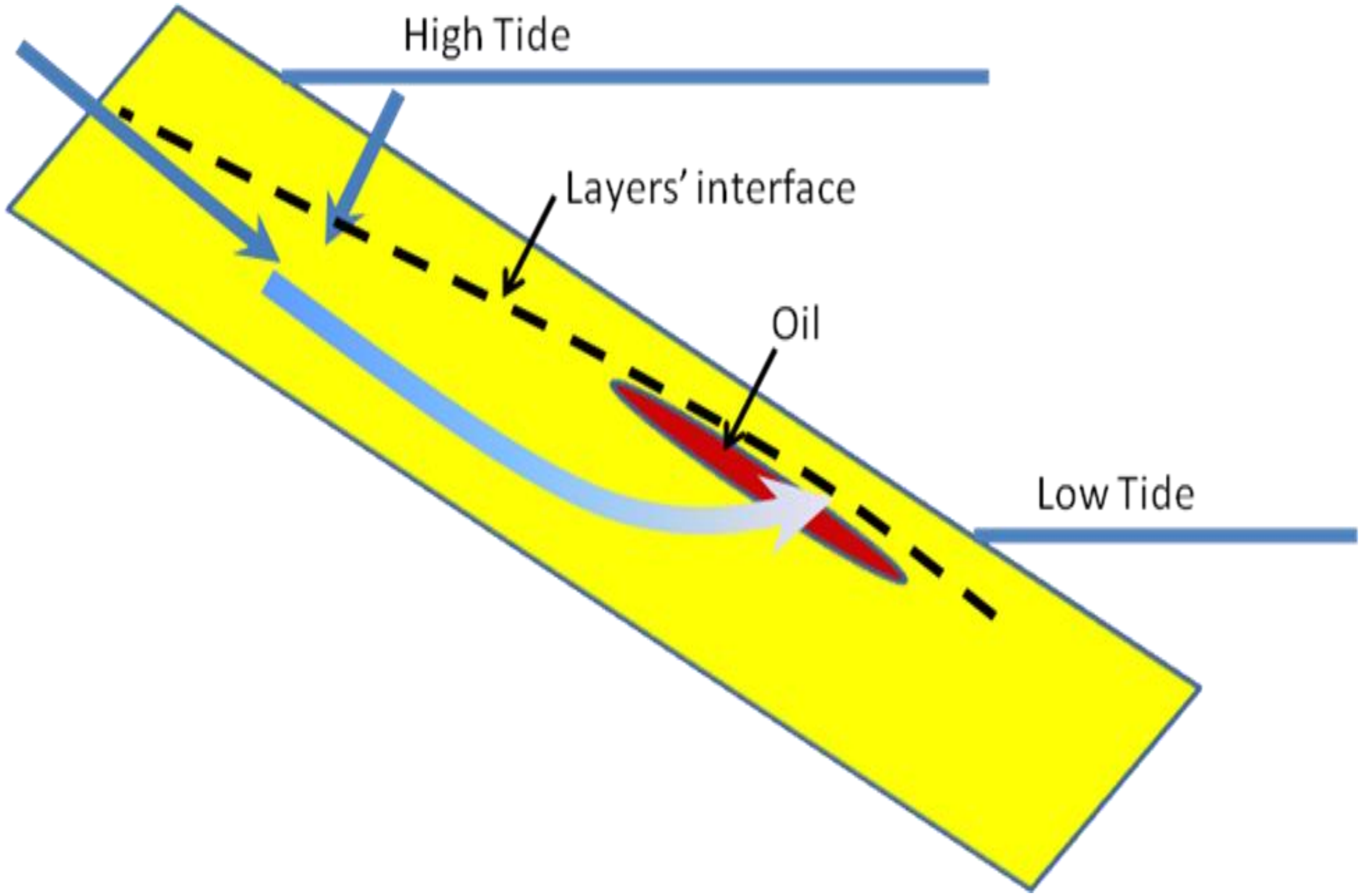
Oil biodegradation in beaches



Tidal hydraulics opposes oxygen diffusion from sea into the Lower Intertidal Zone



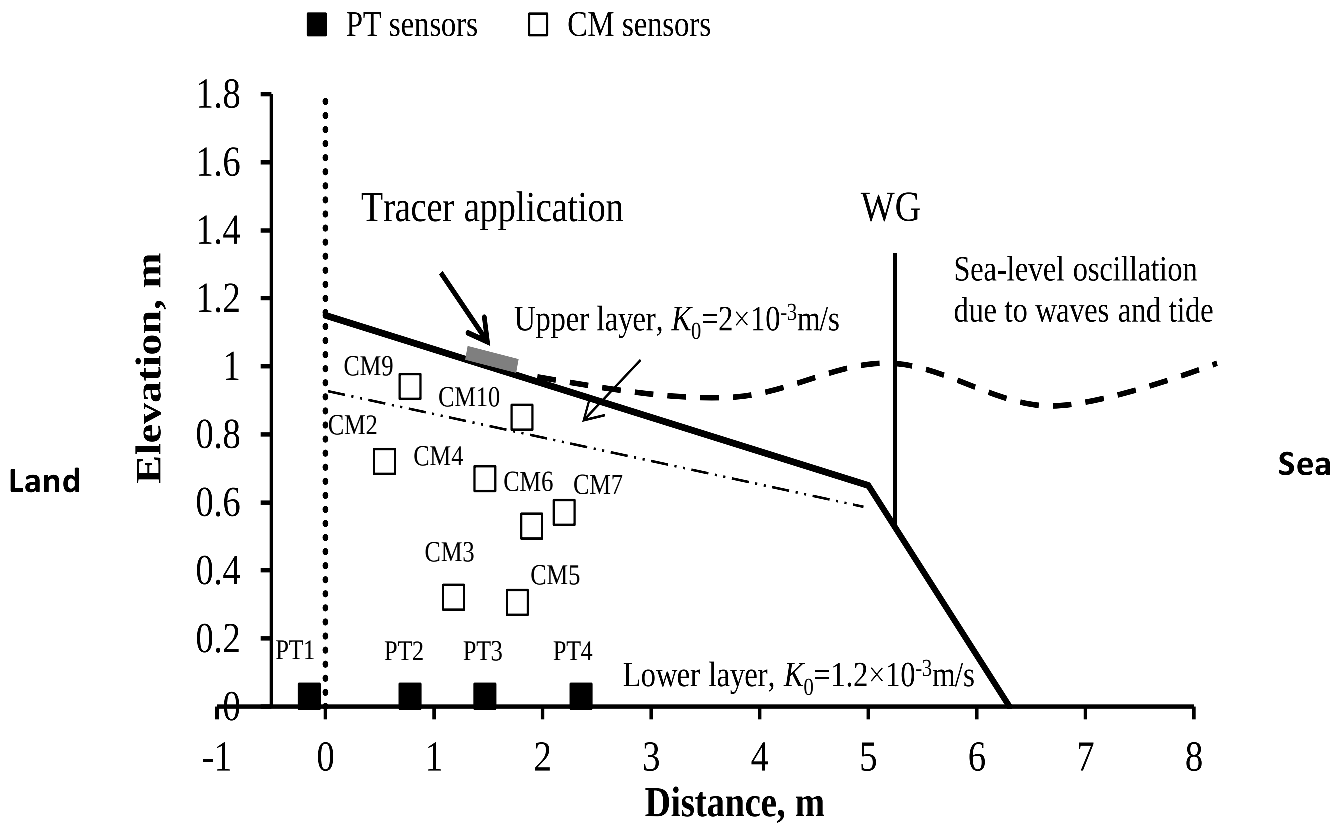
Li and Boufadel,
NATURE geoscience, 2010



Boufadel et al., ***Environmental Science and Technology***, *44* (19), p 7418–7424, 2010
Sharifi, V A, and Boufadel, ***J. Water Quality Exposure and Health***, 2 (3), 157-168, 2011

Heterogeneity

Tracer studies were conducted in a laboratory beach to investigate the effect of wave on groundwater flow and solute transport

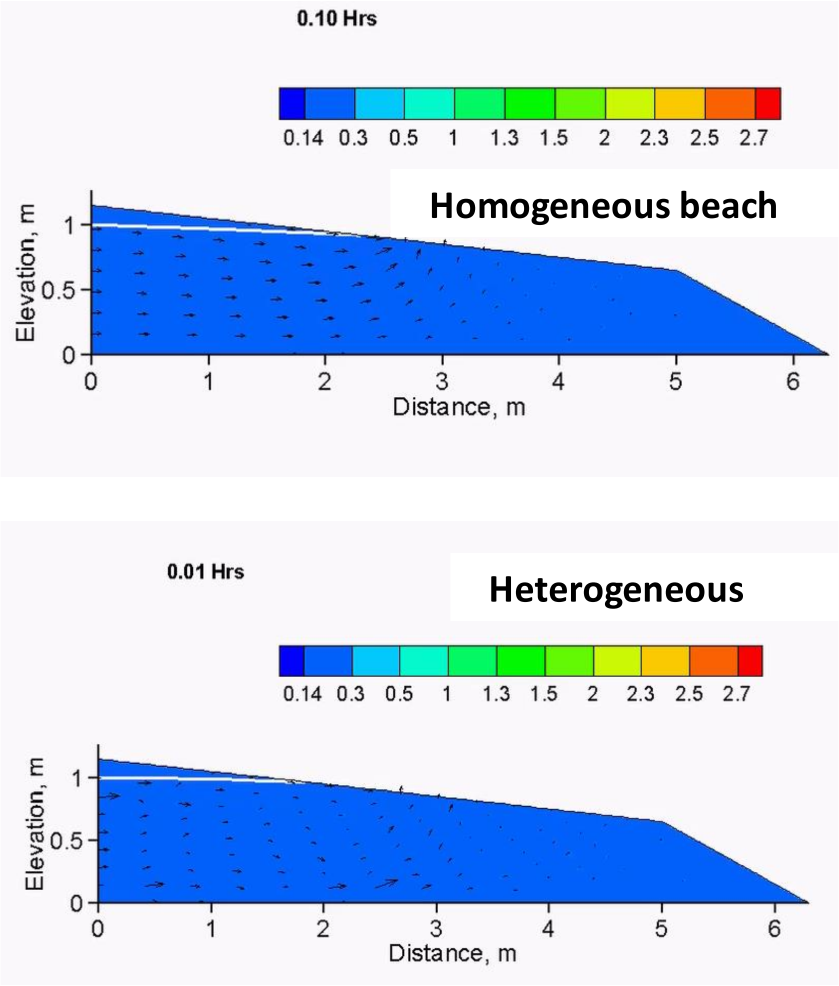


Boufadel et al., J. Env. Enggr. ASCE, 133:722-732, 2007

Geng, Boufadel, et al, Journal of Contaminant Hydrology, 165, 37-52, 2014.

Heterogeneity

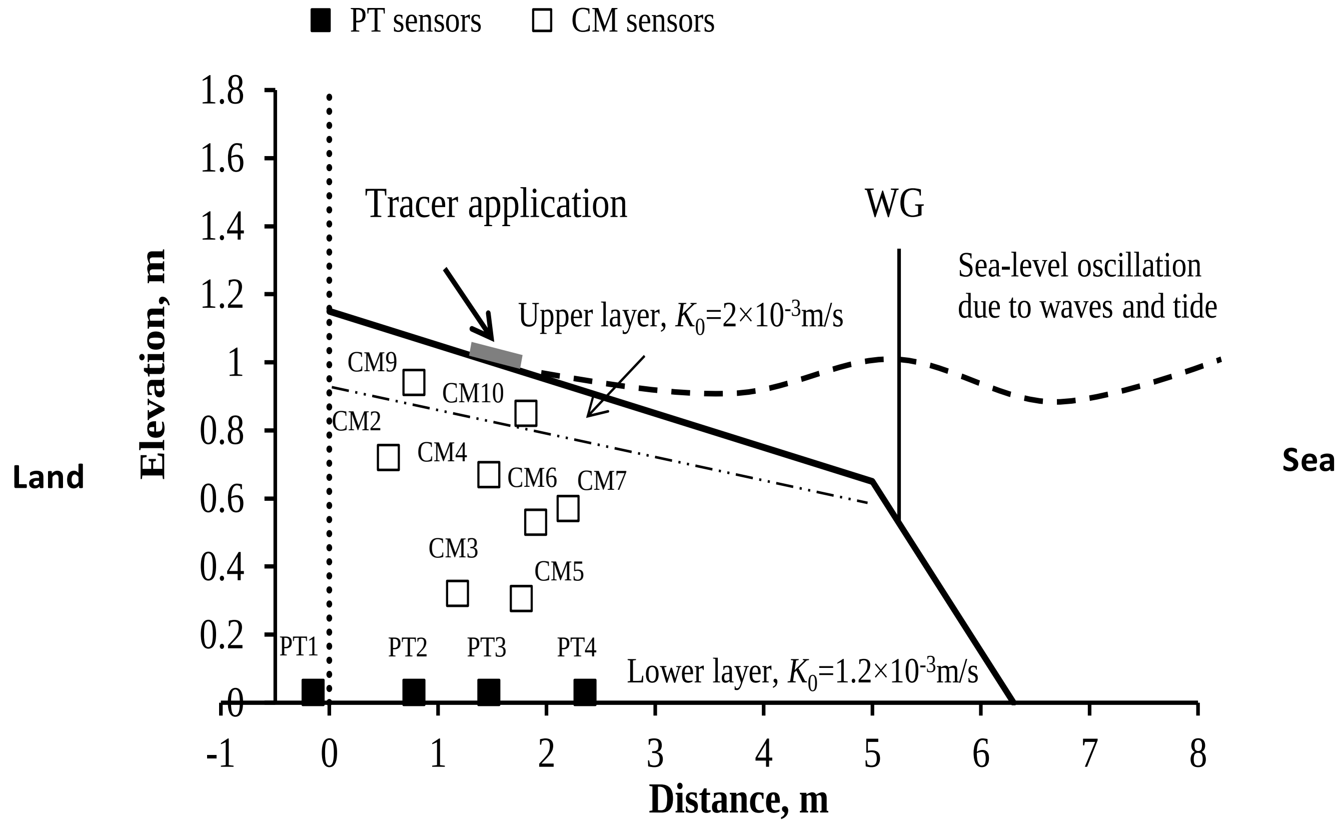
- Migration of tracer plume



Geng, X. Boufadel, Rajaram, et al., 2020. ***Water Resour. Res.*** 56(3), e2019WR026430

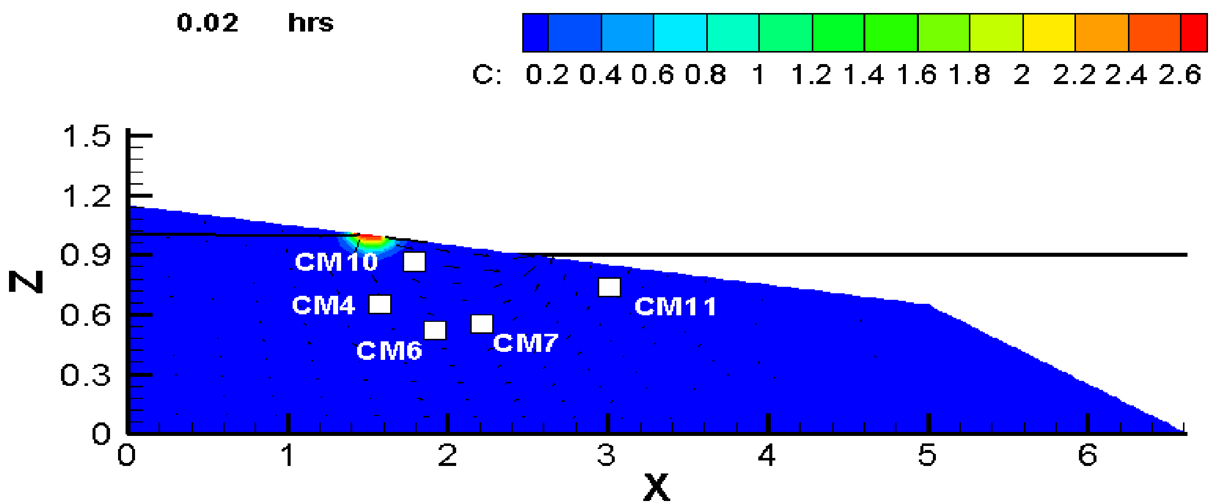
Waves

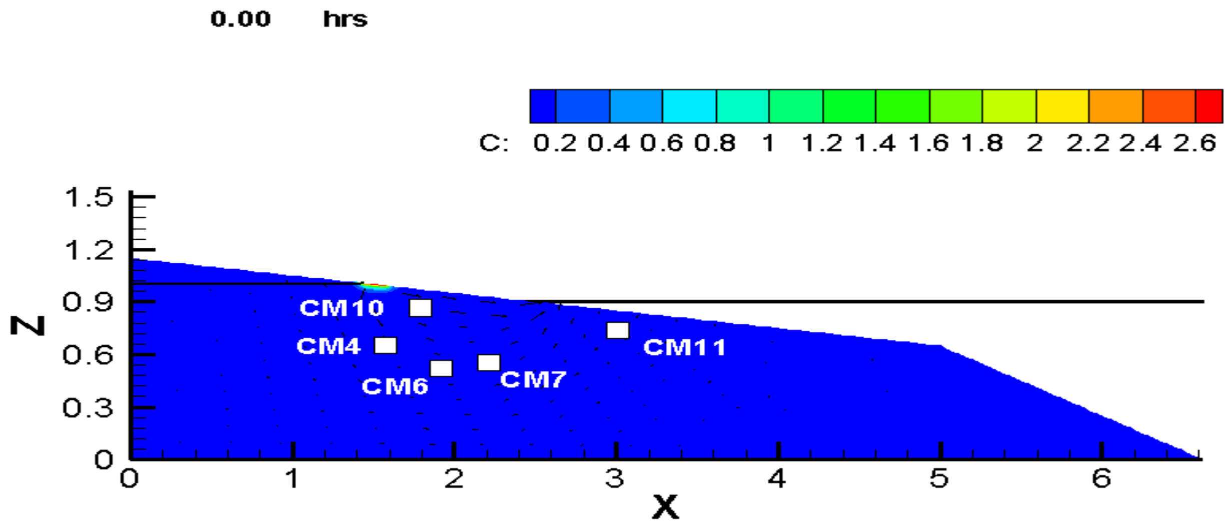
Tracer studies were conducted in a laboratory beach to investigate the effect of wave on groundwater flow and solute transport



Boufadel et al., J. Env. Enggr. ASCE, 133:722-732, 2007

Geng, Boufadel, et al, Journal of Contaminant Hydrology, 165, 37-52, 2014.


0.02 hrs
C: 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2 2.2 2.4 2.6
CM10
CM4
CM6
CM7
CM11
Z
X
1.5
1.2
0.9
0.6
0.3
0
0 1 2 3 4 5 6


0.00 hrs
C: 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2 2.2 2.4 2.6
CM10
CM4
CM6
CM7
CM11
Z
X
1.5
1.2
0.9
0.6
0.3
0
0 1 2 3 4 5 6

Findings on waves

For a given tide level:

Waves slow down the seaward transport of plumes applied landward of the beach.

Waves drive the solutes deeper into the beach.

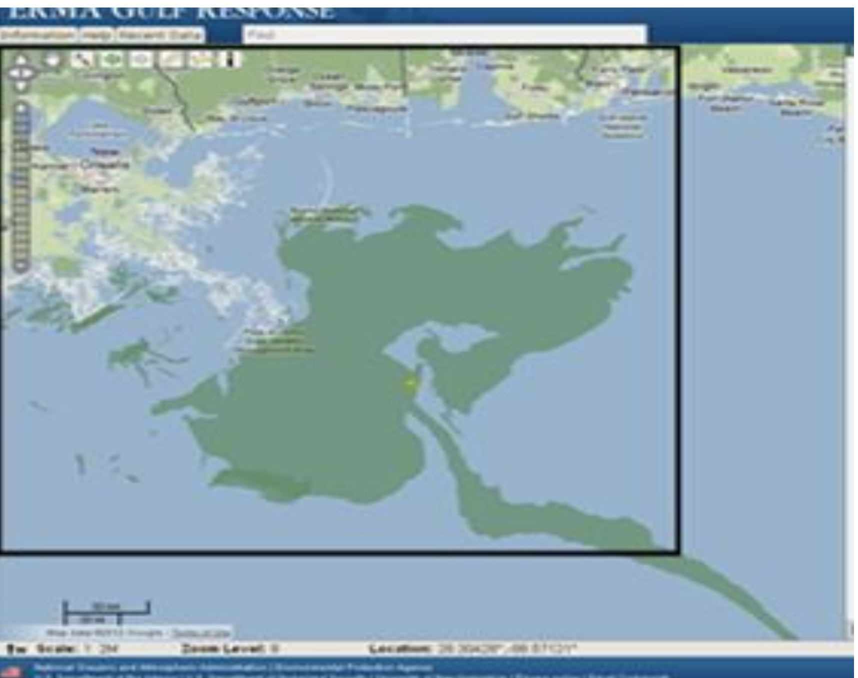
Waves "pull" the water from the beach horizontally (rundown).

Geng, X., MC Boufadel, et al., **J. Contaminant Hydrology**, 165: 37-52, 2014
Geng, X., MC Boufadel, **J. Geo. Res., Oceans**. 120(2), 1409-1428, 2015.

The Deepwater Horizon Blowout (2010)

- Around 200,000 tons of oil released at 1.0 mile depth
- Eleven people killed
- Fisheries were closed.
- A thousand kilometer of shorelines polluted.

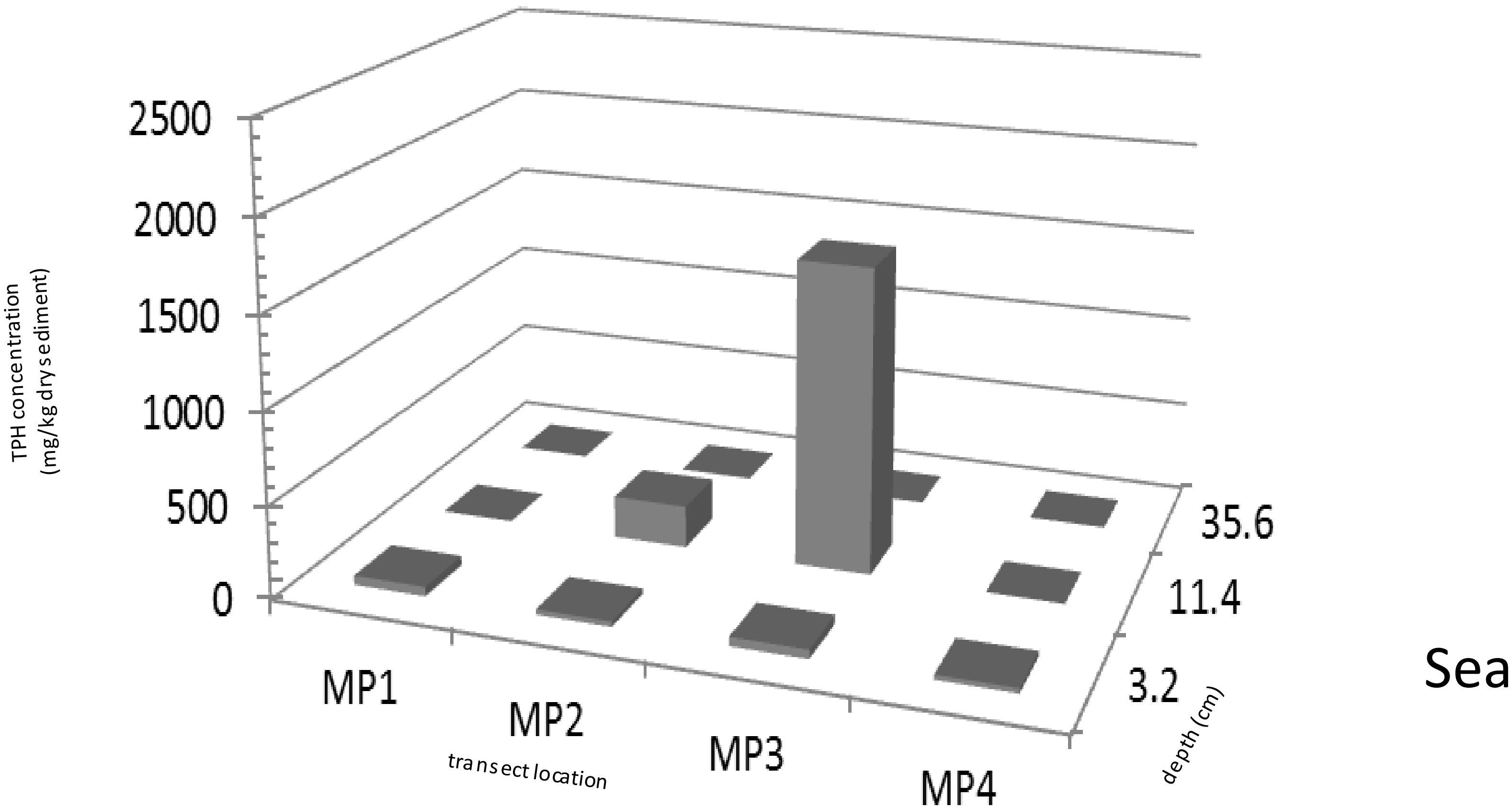
May 25th



Sept. 1st.

Oil entrapped in the supratidal zone

The oil was brought to the supratidal zone of beaches by waves action during storm events.


2500
2000
1500
1000
500
0
TPH concentration
(mg/kg dry sediment)
MP1
MP2
MP3
MP4
transect location
35.6
11.4
3.2
depth (cm)
Sea

Salinity at the solubility limit in the supratidal zone in GOMEX

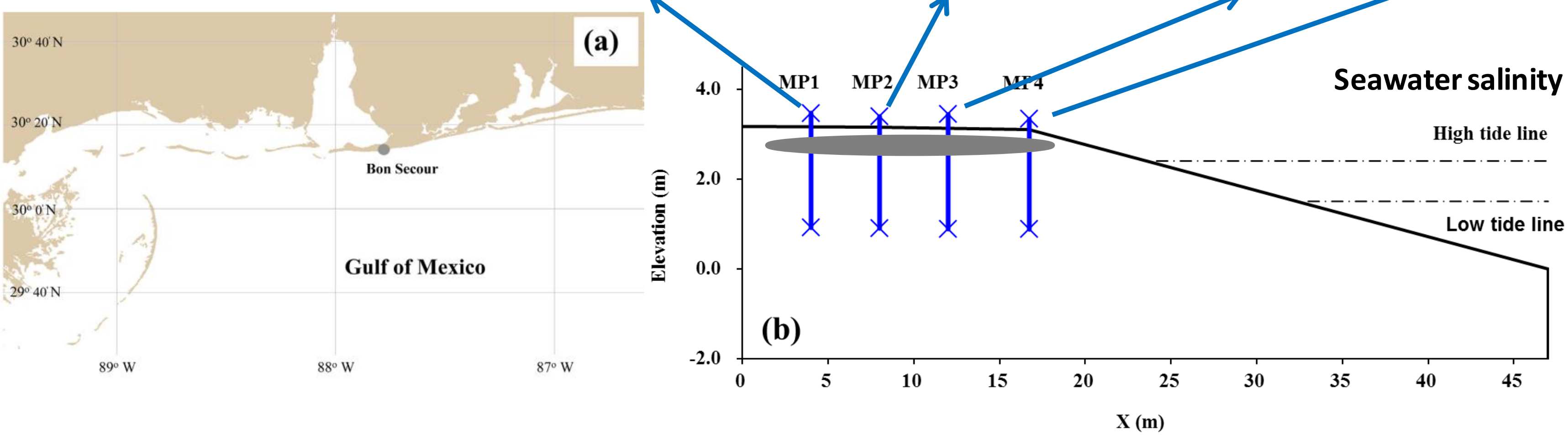
Depth (m)	Moisture	**Salinity** (g/L)
0.05	20%	**191**
0.15	60%	165
0.35	80%	143
0.5	80%	19

D	M	**S**
0.05	40%	**SL**
0.15	80%	94
0.35	70%	**187**
0.5	70%	162

D	M	**S**
0.05	50%	SL
0.15	60%	125
0.35	80%	**212**
0.5	100%	173

D	M	S
0.05	20%	**351**
0.15	90%	134
0.35	90%	215
0.5	100%	77

Seawater salinity = 27 g/L

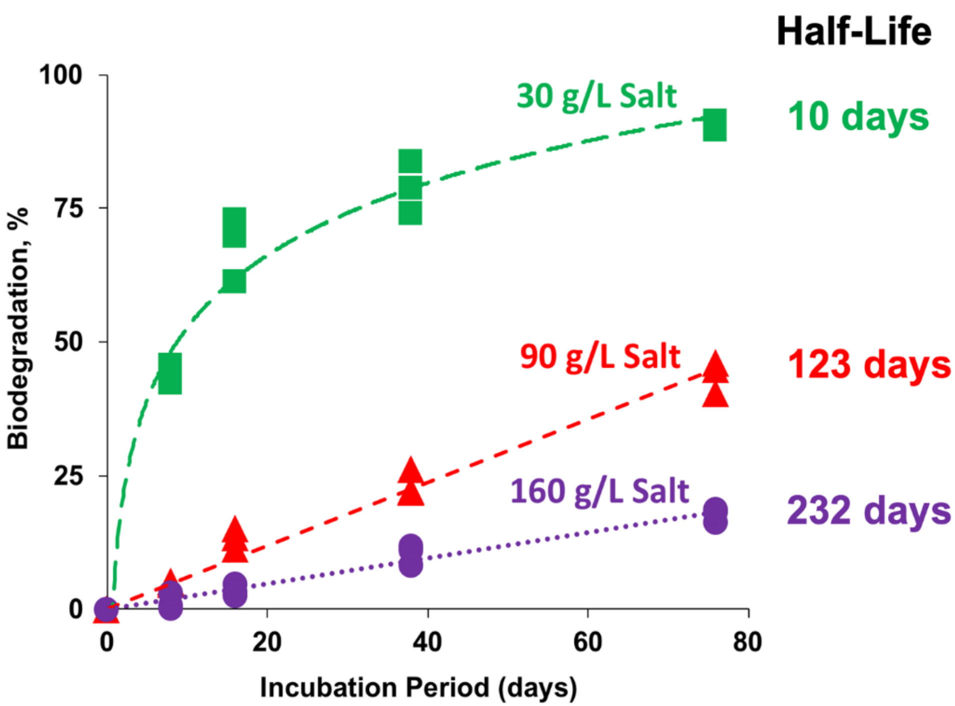


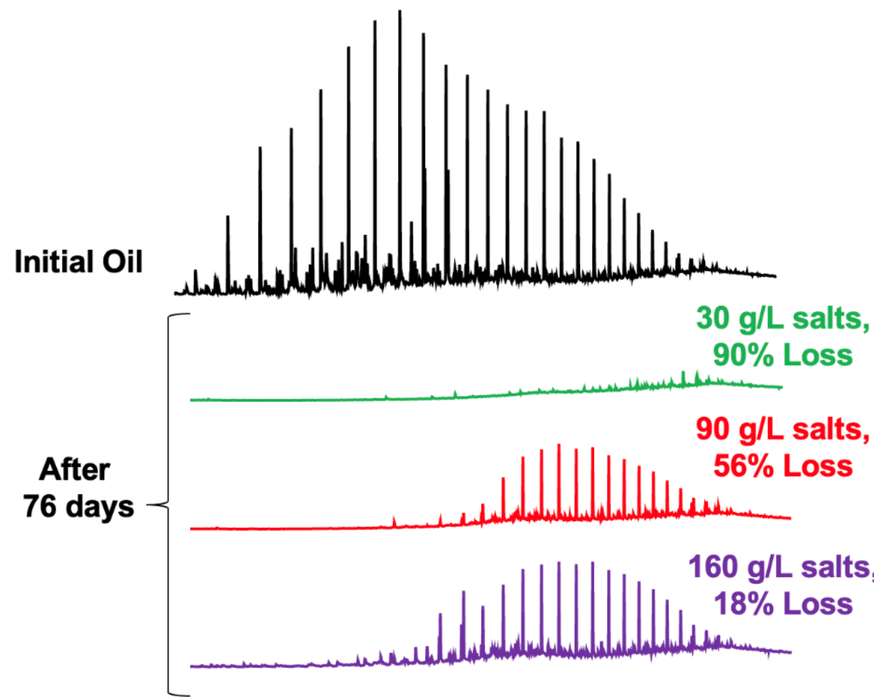
Geng, Boufadel, et al., Environmental Science and Technology, 2021.

Oil Biodegradation Results

Experiment #1

First-order rate constants (k) for the biodegradation of hydrocarbons decreased by ~75% at 90 g/L salts and ~90% at 160 g/L salts





Abou Khalil, C., Fortin, N., Prince, R. C., Greer, C. W., Lee, K., & Boufadel, M. C. (2021*). Crude oil biodegradation in upper and supratidal seashores*. Journal of Hazardous Materials, 416, 125919.

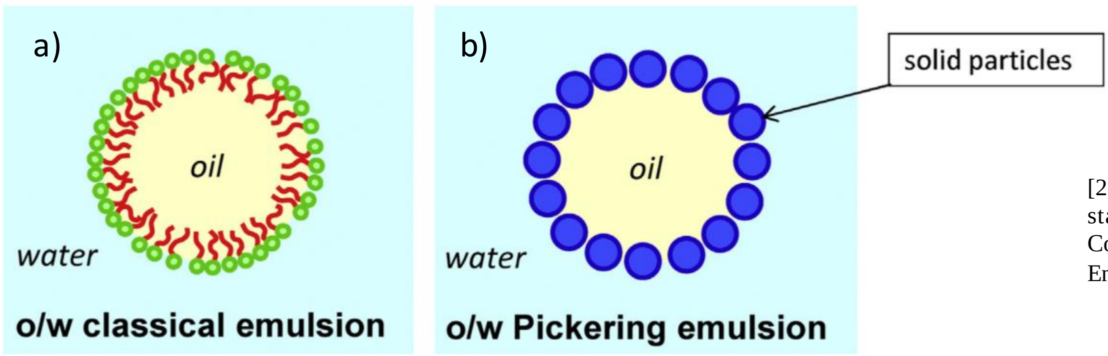
Abou Khalil, C., Prince, V. L., Prince, R. C., Greer, C. W., Lee, K., Zhang, B., & Boufadel, M. C. (2021). *Occurrence and biodegradation of hydrocarbons at high salinities*. Science of the Total Environment, *762*, 143165.

CONCLUSION on Salinity

Salinity (due to evaporation) slows down oil biodegradation.

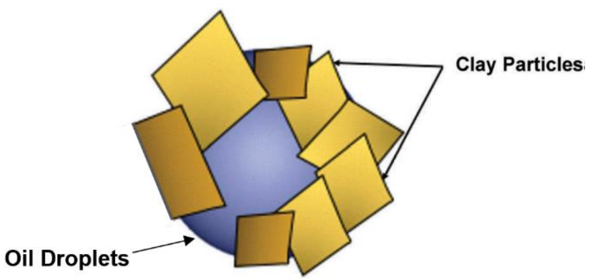
Oil Particle Aggregates (OPA)

- Pickering Emulsion



[2] Chevalier, Y., & Bolzinger, M.-A. (2013). Emulsions stabilized with solid nanoparticles: Pickering emulsions. Colloids and Surfaces A: Physicochemical and Engineering Aspects, 439, 23–34.

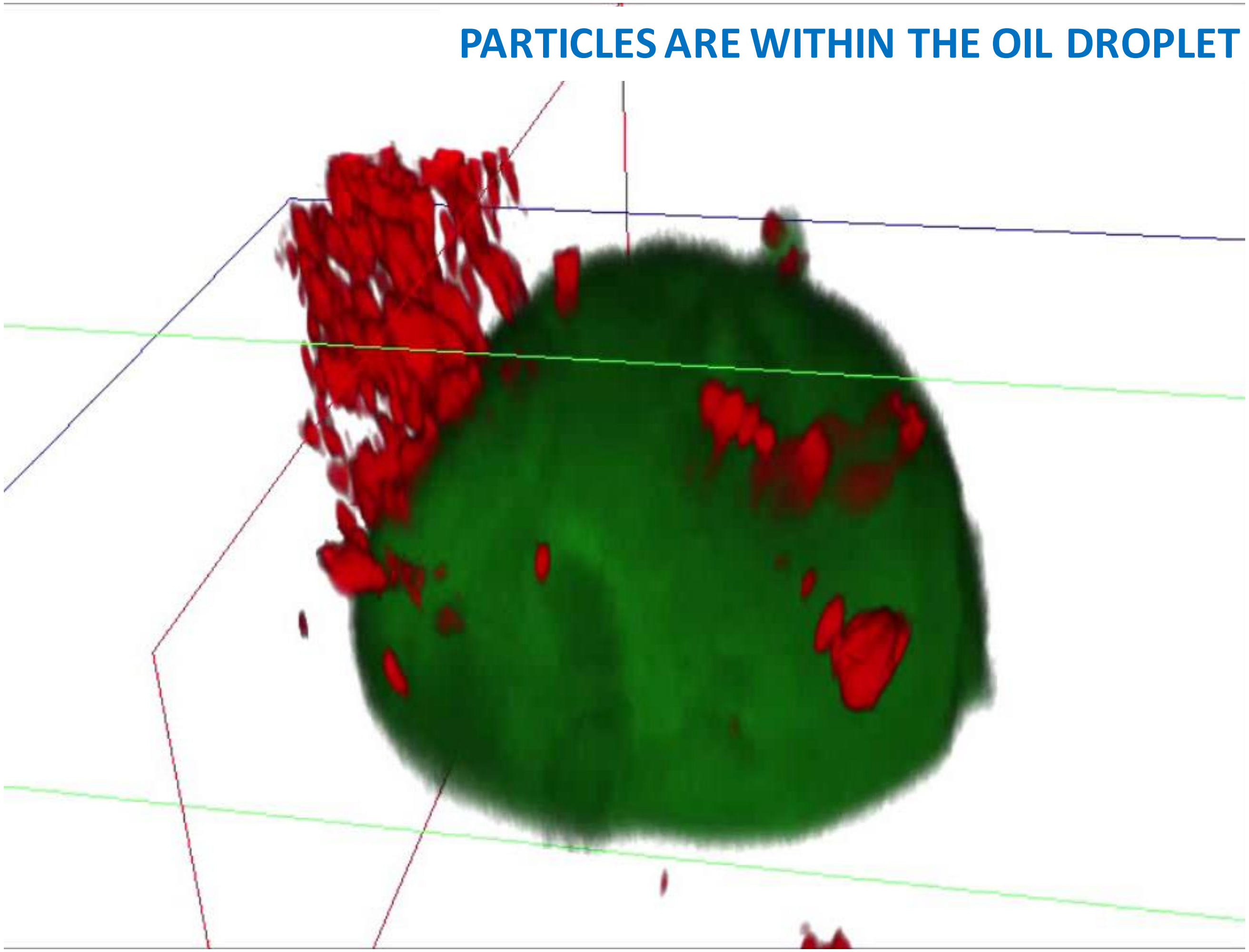
c)



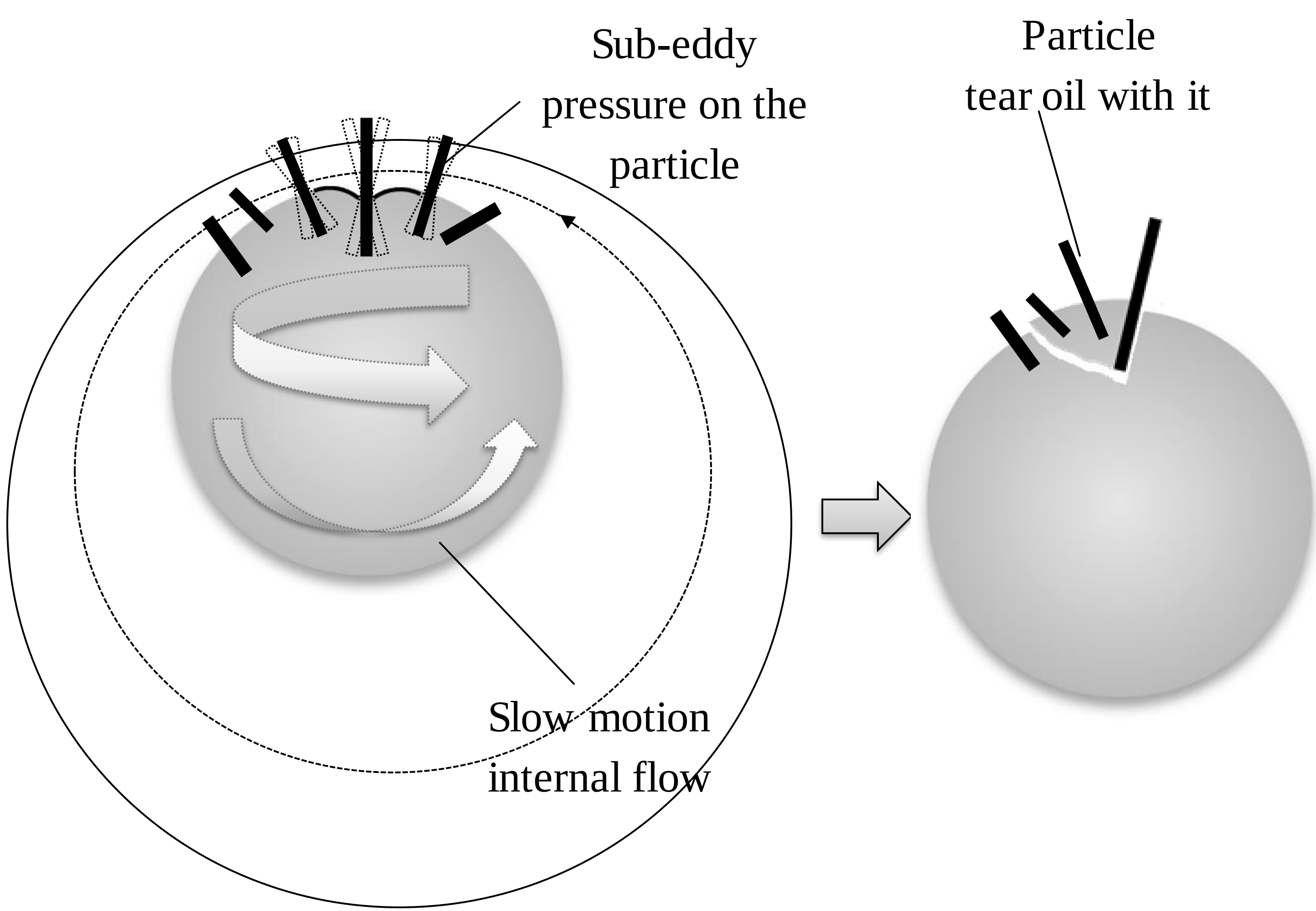
Clay particles are assumed **covering** oil droplets

[3] Johnson, Jeffrey A., Deborah A. Edwards, Douglas Blue, and Sara J. Morey. 2018. 'Physical properties of oil-particle aggregate (OPA)-containing sediments', Soil and Sediment Contamination: An International Journal, 27: 706-22.

OPA-3D structures: confocal imaging



Zhao, Boufadel, Lee et al. Env. Sci. and Technology 51(19), 11020-11028, 2017



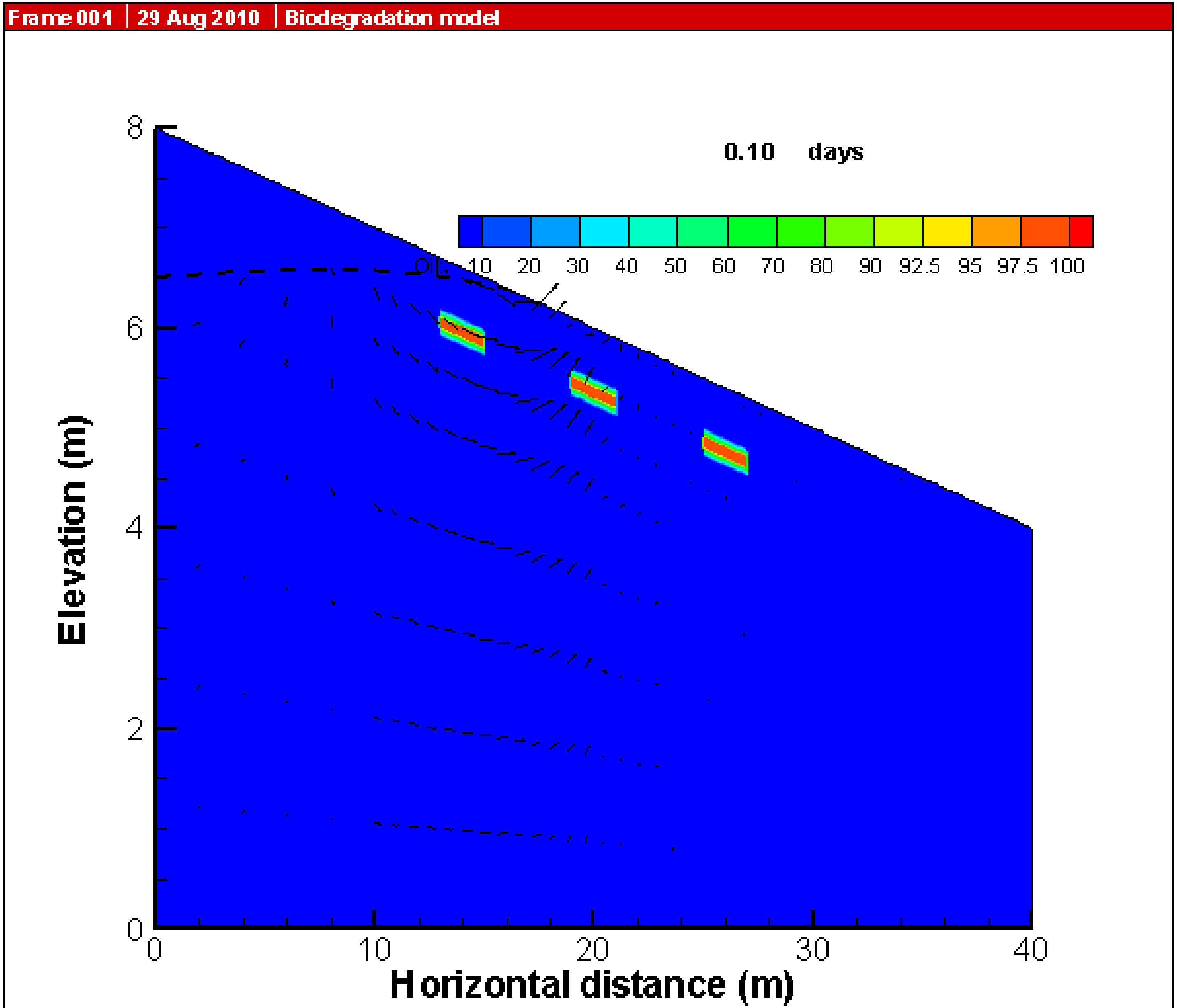
- OPA formation is likely to break the oil into small droplets.

CONCLUSIONS

- One needs to understand beach hydrogeology to effectively address oil response on it.

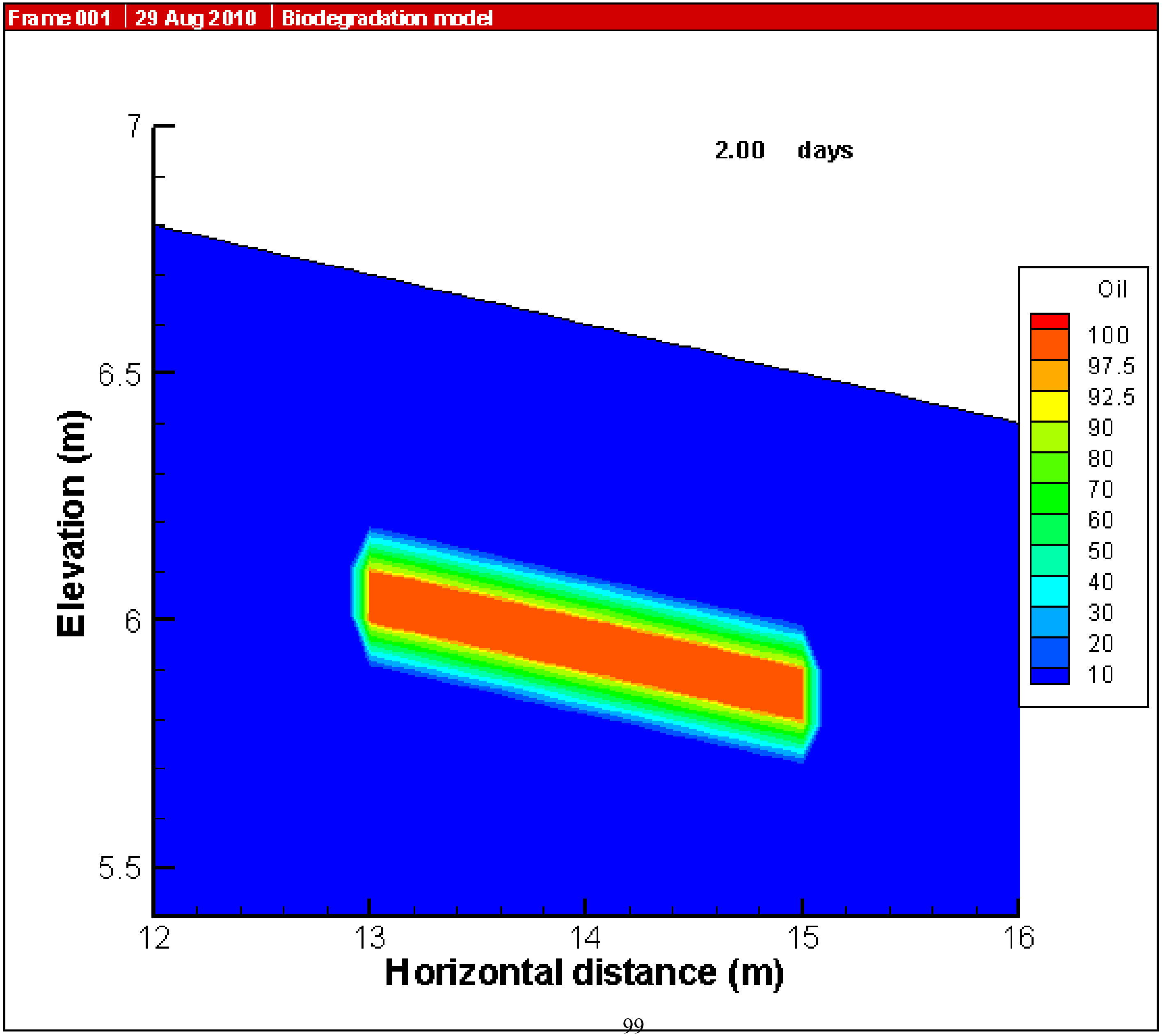
- A beach has very different environmental compartments, and thus should not be treated as uniform. Oil biodegradation is likely to be nutrient-limited in the upper intertidal zone and oxygen-limited seaward of it.

BIOMARUN

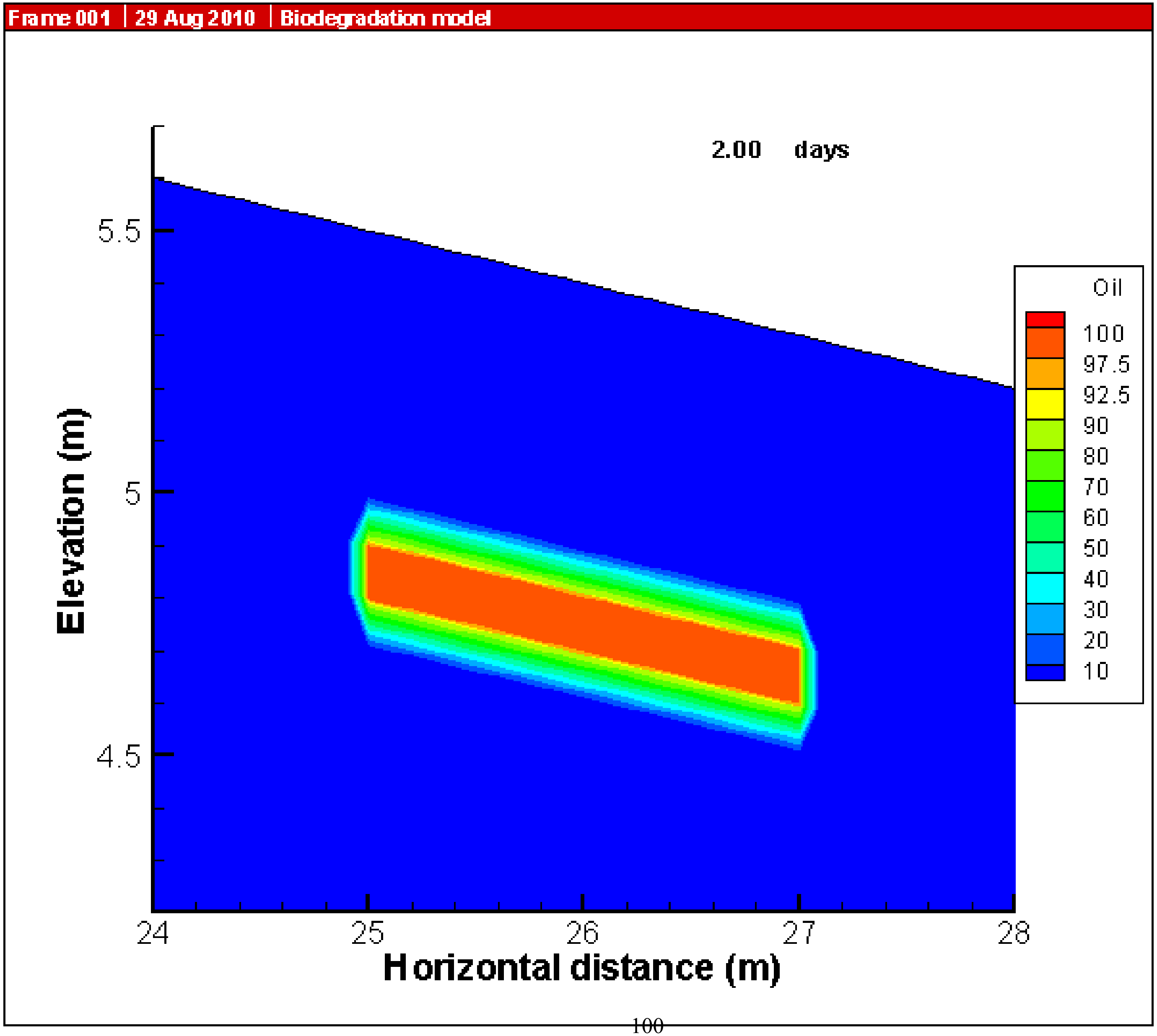


Frame 001 | 29 Aug 2010 | Biodegradation model
0.10 days
OIL: 10 20 30 40 50 60 70 80 90 92.5 95 97.5 100
Elevation (m)
Horizontal distance (m)
0 2 4 6 8
0 10 20 30 40

Landward blob



Seaward blob



SHORELINE OIL SPILL RESPONSE KNOWLEDGE GAPS & TECHNOLOGICAL DEVELOPMENT OPPORTUNITIES

(NOAA Seattle Meeting May 9th 2023)

Presented by

Prabhakar Clement, The University of Alabama
(Email: pclement@ua.edu)

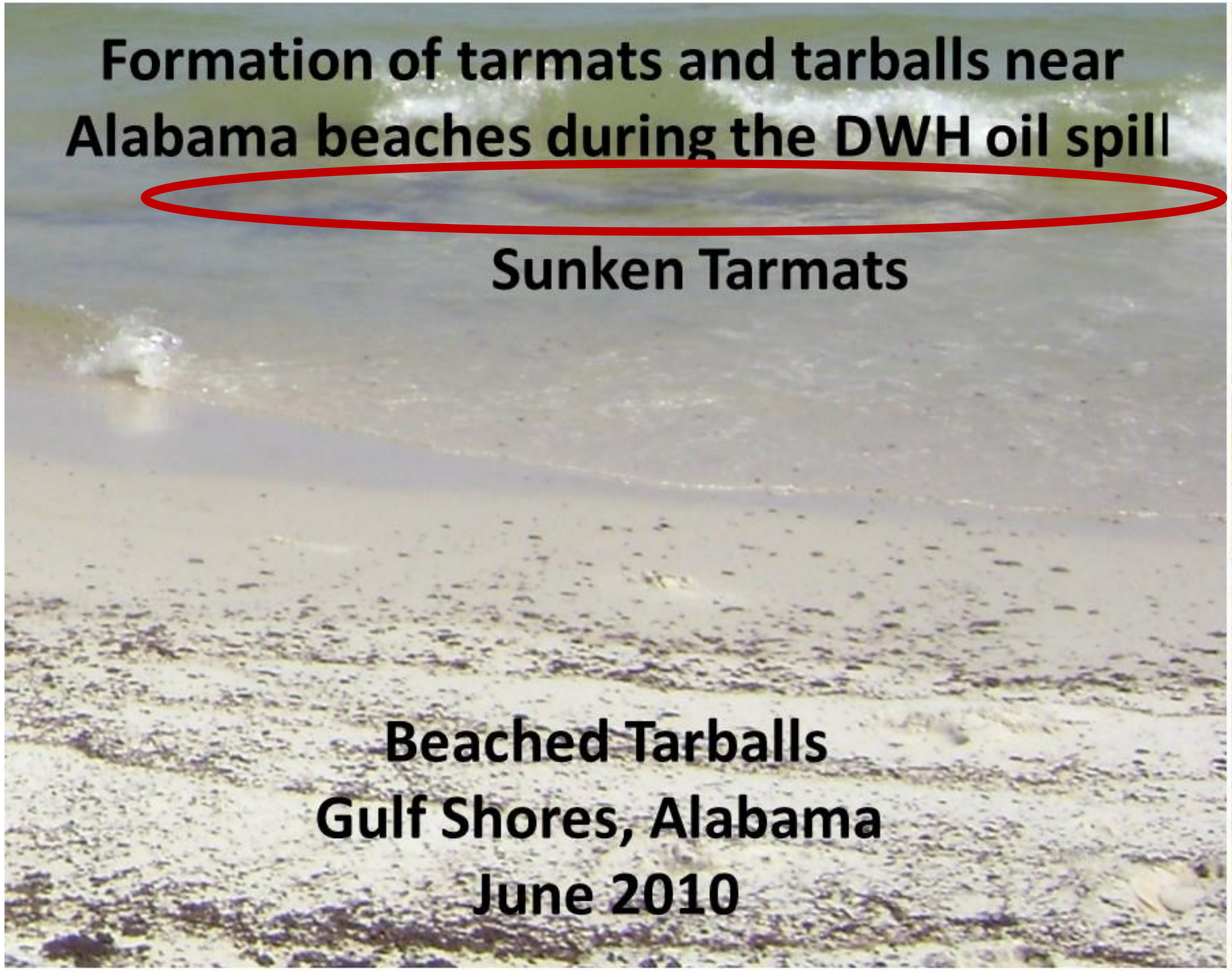
Question 1: How well do we understand the fate and effects of oil spills on shorelines?

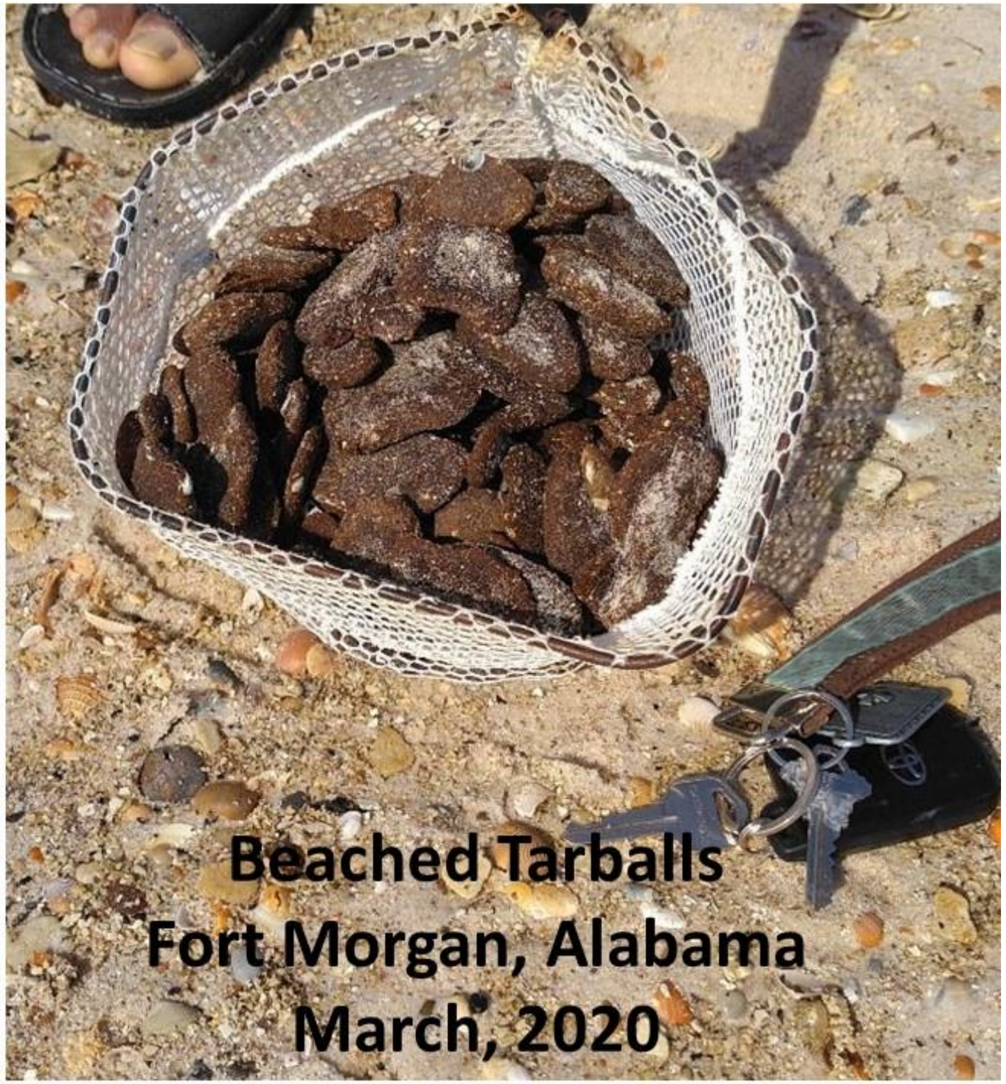
- Short answer– very little! Here are some issues:

How tarballs and tarmats are formed?

(Specifically, I have seen two types of tarballs—highly weathered, floating, black, rubbery tarballs that have very little or no sand (traditional tarballs), and 2) relatively fresh, sunken, brownish, fragile tarballs that have lots of sand (e.g., DWH tarballs). The conventional wisdom is that the weathered tarballs are formed when stranded oil floats over the ocean for many months/years. However, even after 10+ years, we have not seen a weathered, floating, black tarballs of DWH origin along Alabama coastline, why?

We do see plenty of the second type of tarballs even after 10+ years! We simply do not fully understand how these two distinctly different types of tarballs are formed, and how and why they persist in the environment for decades?)


Formation of tarmats and tarballs near
Alabama beaches during the DWH oil spill
Sunken Tarmats
Beached Tarballs
Gulf Shores, Alabama
June 2010


Beached Tarballs
Fort Morgan, Alabama
March, 2020

Question 1…

- We do not fully understand the role biodegradation. Are these published ideas facts or fallacy?

1) "Everywhere we look, oil is degrading extremely rapidly" [Kerr, 2010].
2) "Despite the varying field and microcosm conditions, the ***oil half-lives are 1.2 to 6.1 days***" [Hazen et al. 2010].
3) Edwards et al. (2011) concluded that the indigenous microbial community in the GOM has the potential to rapidly degrade the oil.

References:

- Kerr RA: A lot of oil on the loose, not so much to be found, Science 2010, 329:734-735.
- Hazen TC et al.: Deep-sea oil plume enriches indigenous oil degrading bacteria. Science 2010, 330:204-208.
- Edwards BR et al. Rapid microbial respiration of oil from the Deepwater Horizon spill in offshore surface waters of the Gulf of Mexico. Environ Res Lett 2011, 6:035301.

Question 2: Are there tools and technologies that could improve our ability to determine the fate and effects of oil on shorelines

- We need standardized fingerprinting methods to identify oil spill residues.

- We need methods to quantify contaminant mass removal due to biodegradation and differentiate it from other sinks.

(We need better methods to compare contaminant mass removal due to biochemical processes (microbial biodegradation) vs. removal due to physicochemical processes such as photo-oxidation, dilution/dispersion, and evaporation. I believe microbial processes get too much credit!)

Question 3: What knowledge gaps do you "wish" were addressed to improve our understanding of the fate and effects of oil spills on shorelines?

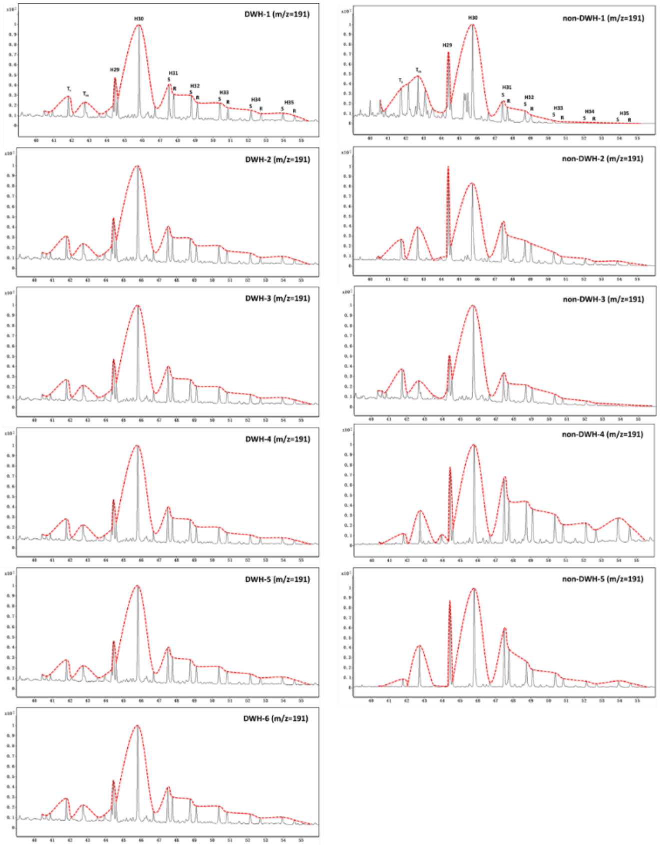
- How are tarballs formed?
- What is the background level of tarballs along the GOM coastline?
- Can we develop a standard protocol for fingerprinting/identifying oil residues?
- What are the toxicological/ecological effects of heavy PAHs (such as chrysene) trapped in oil spill residues?
- How can we destabilize and disperse mouse using less-toxic dispersants?

Question 4: How would you prioritize R&D spending to improve our understanding of the fate and effects of oil spills on shorelines? (max of 3?)

1) Understand how different types of tarballs are formed?

Question 4: Second suggestion…

2) Develop a standard protocol for fingerprinting oil spill residues. Develop an oil fingerprint database, which can be harnessed by web-based, machine learning models to rapidly fingerprint future spills.



Question 4: Third suggestion

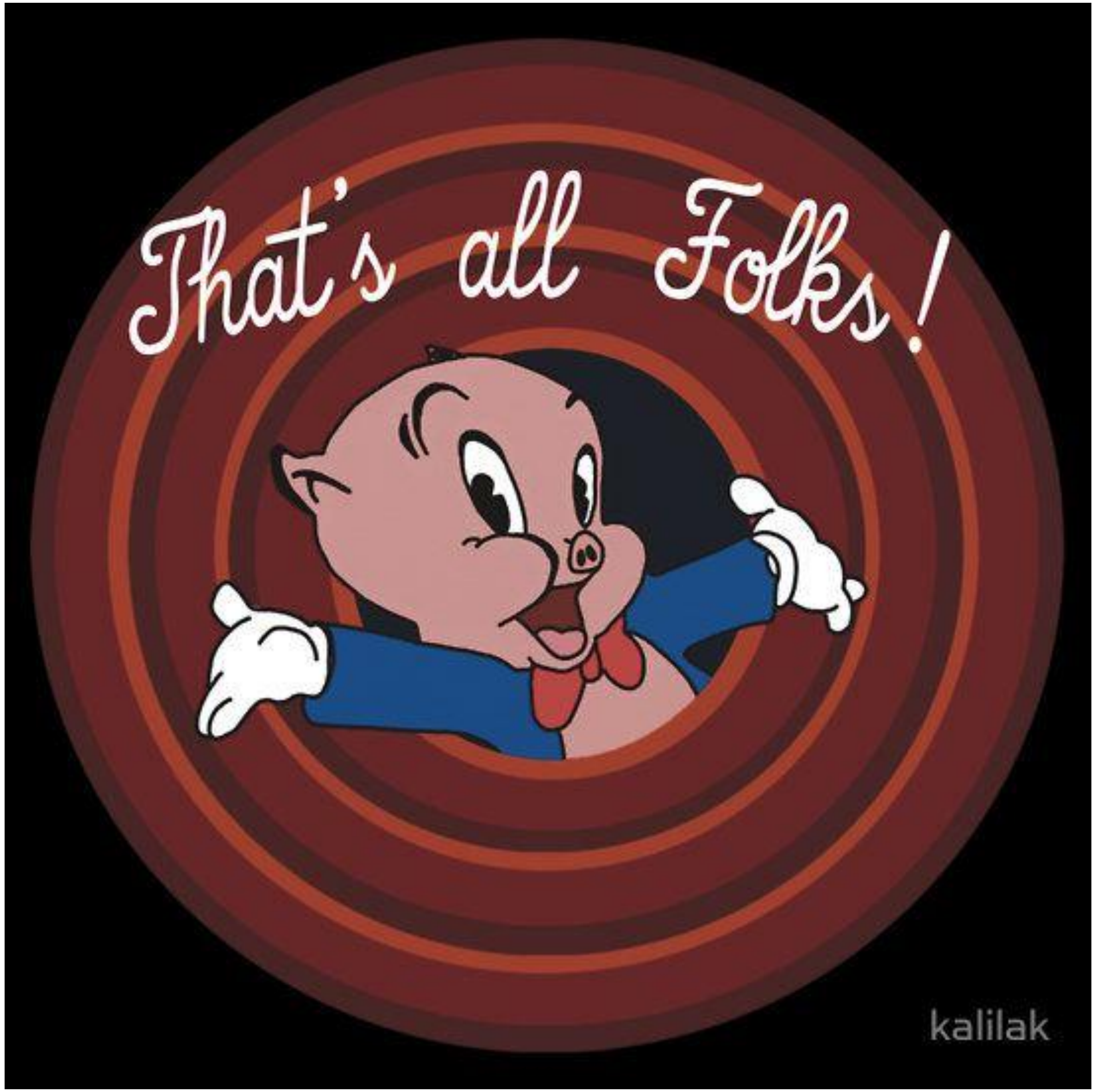
3) Fund projects that can help understand the role of biodegradation and photooxidation in reducing the toxicity of oil spills?

(For example, are transformed photodegradation byproducts as toxic as the original chemicals? How can we monitor the byproducts such as oxygenated compounds, are they easily biodegradable?)

Bonus idea (if NOAA has lots of extra dollars ☺).

Dilution appears to be the primary solution to oil pollution. We should invest more in developing eco-friendly, less toxic, dispersants that can destabilize mouse and disperse.

Questions?



Five key journal publications from my group

1) **Clement, T.P.** and G.F. John, A perspective on the state of Deepwater Horizon oil spill related tarball contamination and its impacts on Alabama beaches, Current Opinion in Chemical Engineering, https://www.sciencedirect.com/science/article/abs/pii/S2211339822000090.
2) Arekhi, M., L. G. Terry, G. F. John, J. A. Al-Khayat, A. B. Castillo, P. Vethamony,**T.P. Clement**, Field and Laboratory Investigation of Tarmat Deposits found on Ras Rakan Island and Northern Beaches of Qatar, Science of the Total Environment, 735 (2020) 139516, 2020.
3) **Clement, T.P.**, G.F. John and F. Yin, Assessing the increase in background oil contamination levels in Alabama's nearshore beach environment resulting from the Deepwater Horizon oil spill, published in Oil Spill Science and Technology (Second Edition), Edited by Merv Fingas, Elsevier Publishers, Chapter 16, P. 851–888, 2017.
4) Gustitus, S.A., and **T.P. Clement**, Formation, fate and impacts of microscopic and macroscopic oil-sediment residues in nearshore marine environments, Reviews of Geophysics, 55 (4), 1130-1157, https://doi.org/10.1002/2017RG000572, 2017.
5) Yin, F., G. F. John, J.S. Hayworth, J.S. and **T.P. Clement,** Long-Term Monitoring Data to Describe the Fate of Polycyclic Aromatic Hydrocarbons in Deepwater Horizon Oil Submerged Off Alabama's Beaches, Science for Total Environment Journal, v.508, p. 46–56, 2015.

Plenary Panel 3:

Fate & Effects

SHORELINE OIL SPILL RESPONSE KNOWLEDGE GAPS & TECHNOLOGICAL DEVELOPMENT OPPORTUNITIES

Christopher Hall
Planning & Development Manager
Alaska Clean Seas
planning@alaskacleanseas.org

Green, B., 2019.

Fate & Effects Questions

- How well do we understand the fate and effects of oil spills on shorelines?
- Are there tools and technologies that could improve our ability to determine the fate and effects of oil on shorelines?
- What knowledge gaps in oil spill science or tools/technologies do you "wish" were addressed/existed that would improve our understanding of the fate and effects of oil spills on shorelines?
- How would you prioritize R&D spending to improve our understanding of the fate and effects of oil spills on shorelines? (max of 3 items)

Limitations in the Arctic

Remote locations

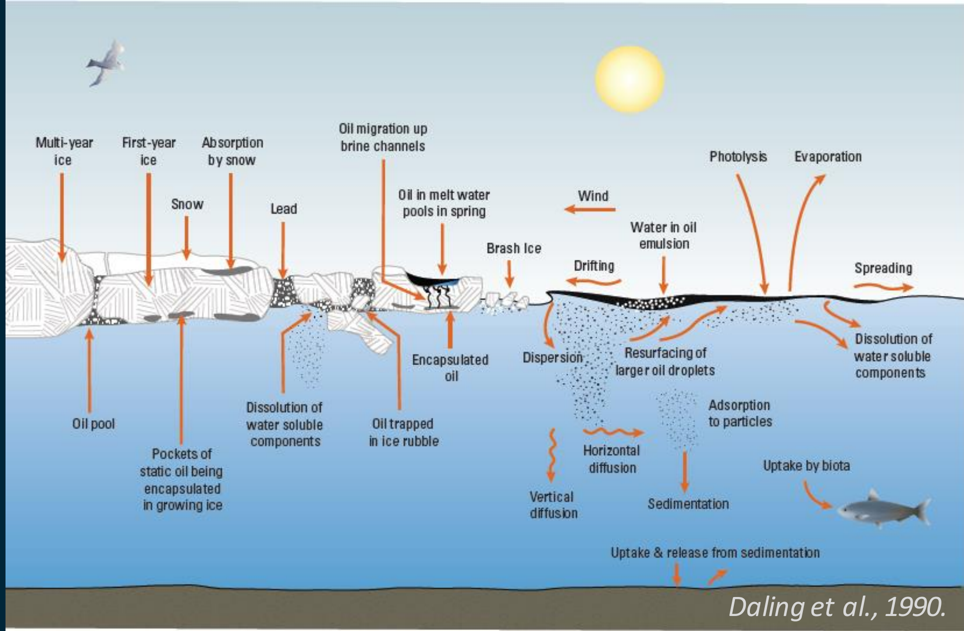
Challenging logistical support

Extreme weather and short open-water season

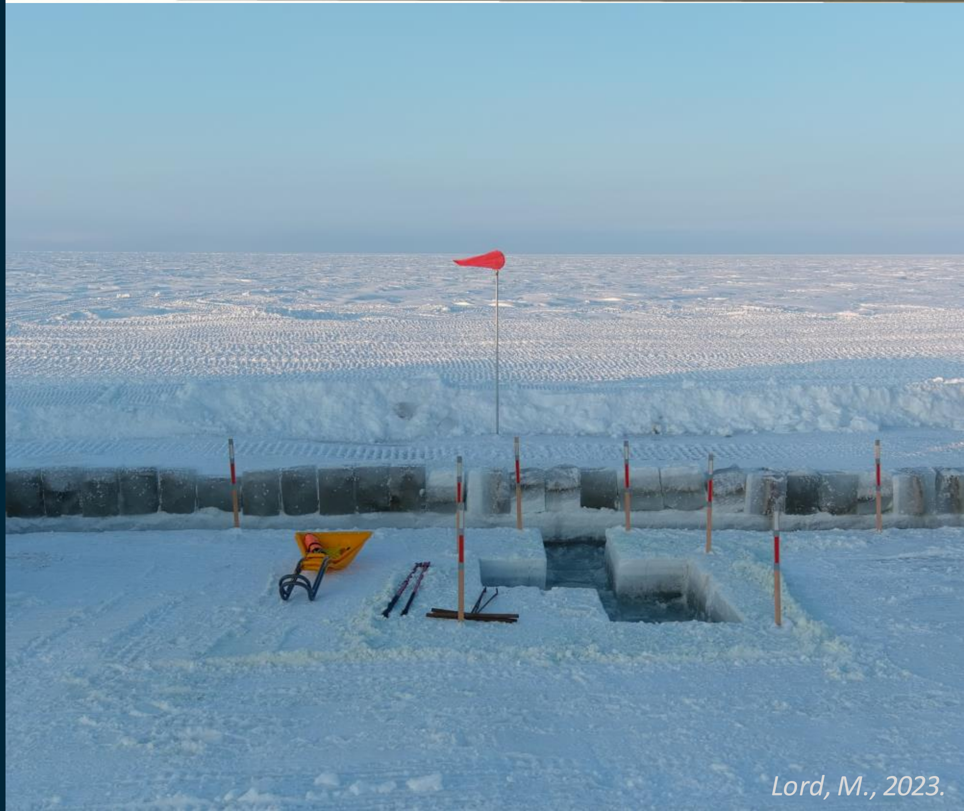
Hall, C., 2019.

How well do we understand the fate and effects of oil spills on shorelines?

- Cold Arctic temperatures increase the viscosity and film thicknesses on the water surface, and reduce oil weathering, spreading, evaporation, emulsification and dispersion, which extends the window for effective mechanical recovery and in situ burning
- The presence of drift and pack ice further reduces spreading and weathering of surface oil
- Shore-fast ice and snow may act as natural barriers to limit shoreline oiling
- Mechanical equipment has been developed and modified to maintain encounter and recovery rates



Daling et al., 1990.



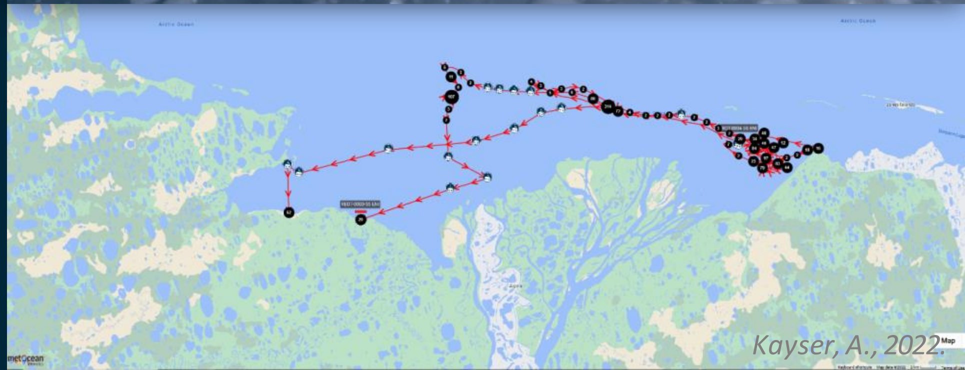
Lord, M., 2023.

Are there tools and technologies that could improve our ability to determine the fate and effects of oil on shorelines that: (a) could be made better; (b) have been developed and are not being used; or (c) are currently under development and/or at a low level of readiness?

- Incorporation of “smarter” buoys and sensors for autonomous monitoring of oil in ice and near shorelines during breakup
- Oil spill trajectory modeling is limited in
  - Drift and pack ice
  - Ice-overflood
  - Areas of oil under ice
  - Wind conditions which locally raise water level


Hall, C., 2019.


Lord, M., 2022.


Kayser, A., 2022.

What knowledge gaps in oil spill science or tools / technologies do you "wish" were addressed/existed that would improve our understanding of the fate and effects of oil spills on shorelines?

- Greater understanding of the effects of short- and long-term stranding of oil on Arctic shorelines could enable in situ treatment methods that generate less waste requiring removal
- Better trajectory modeling with ability to model oil and ice interactions, ice overflood, and wind-driven changes to water depths stranding oil inland


Lord, M., 2023.

How would you prioritize R&D spending to improve our understanding of the fate and effects of oil spills on shorelines? (max of 3 items)

- Improving trajectory modeling for oil and ice interactions, reduced oil weathering, oil under ice, ice overflood conditions, and storm events stranding oil far inland
- Continue study of short- and long-term effects of oil stranded on Arctic shorelines
- Continued improvement of small, easily deployable “smarter” tracking buoys, autonomous systems, and surveillance tools to rapidly identify and prioritize oiled shoreline segments

Kayser, A., 2022.

Thank you

Christopher Hall
Planning & Development Manager
Alaska Clean Seas
planning@alaskacleanseas.org

Shoreline Response Knowledge Gaps and Technological Development Opportunities
Panel 3: Fate and Effects

Carl Childs, PhD.

NOAA Emergency Response

How well do we understand the fate and effects of oil spills on shorelines?

- We have a sophisticated understanding of the differences that make a difference but there's always more to learn.
- Microbial community composition and function
- How much do different levels of oiling, particularly on the lower end, translate into differences in ecological impact?

Are there tools and technologies that could improve our ability to determine the fate and effects of oil on shorelines that: (a) could be made better; (b) have been developed and are not being used [If yes, please explain how they might be used]; or (c) are currently under development and/or at a low level of readiness?

- Microbial community composition & function.
  - Can we correlate eDNA profiles with recovery?
- Improved detection of buried oil

What knowledge gaps in oil spill science or tools/technologies do you “wish” were addressed/existed that would improve our understanding of the fate and effects of oil spills on shorelines?

- eDNA
- Anaerobic biodegradation / Aeration of anoxic sediments
- Ecosystem-level modeling

How would you prioritize R&D spending to improve our understanding of the fate and effects of oil spills on shorelines?

- Remote sensing that can provide operationally relevant identification & quantification of shoreline oiling.
- Ecological modeling to assess impact of response actions & inform trade-off assessments
- Correlate oil fate with microbial community profiles.
- Refined protocols for replanting as a response tactic in oiled marshes.

Texas General Land Office

Texas General Land Office • Commissioner Dawn Buckingham, M.D.

How well defined are our policies regarding oil spills on shorelines?

- Wildlife Refuges
- Private Property
- Counties
- Remote Locations
- Surface Washing Agent Preapproval Areas
- Geographic Response Plans, Site Specific Response Plans, Tidal Inlet Protection Strategies

Are there policies regarding tools and technologies that could improve our ability to address oil spills on shorelines?

- Drone/ UAV authorization & use
- Science to inform policy: NEBA and dispersant use, SSDI, and in-situ burning of marshes
- Tools that integrate data across platforms and facilitate common operational pictures
- Spills of Opportunity

Texas General Land Office
Commissioner Dawn Buckingham, MD

What policies regarding oil spill science or tools/ technologies do you wish existed that would improve our ability to address oil spills on shorelines?

- Drone systems for field data collection across all aspects of response and preparedness
- Readily deployable technologies for decision-making during spill response
- Remote sensing/ detection
- Technologies to improve the understanding of behavior, transport, fate, and recovery of unconventional oils

Texas General Land Office
Commissioner Dawn Buckingham, MD

How would you prioritize policy development to improve our ability to address oil spills on shorelines?

- Well informed stakeholders and continued public education
- Science-based guidance for response tactics
- Data management tools for decision support (Stafford Act events)
- Efficient use of resources

Texas General Land Office
Commissioner Dawn Buckingham, MD

Brent Koza
Texas General Land Office
Scientific Support Coordinator
Research & Development Program Manager
https://www.glo.texas.gov/ost/

U.S. Coast Guard

Panel 5
Emerging Oil/Products and Experimental Lakes

LCDR Clifton Graham
Office of Marine Environmental Response Policy

Shoreline Oil Spill Response Knowledge Gaps and Technological Development Opportunities
workshop
May 10, 2023

Emerging Issues Case Study: M/V Wakashio

- 25 July 2020, Bulk Carrier M/V Wakashio grounds on reef off the coast of Mauritius.
- Fuel tanks breach spilling up to 300,000 gal. of Very Low Sulfur Fuel Oil (VSLFO, <0.5%).
- First documented spill involving VLSFO.
- Global Sulfur Cap regulation was implemented (IMO/MARPOL convention, Annex VI) from January 2020. Previously 3.5% reduced to 0.5%.
- The compliant residual fuels, termed "Very Low Sulfur Fuel Oil" (VLSFO), are replacing the traditional intermediate fuel oils or heavy fuel oils e.g. IFO 180 and IFO 380 but little is known about the characteristics of VLSFOs

(Graphic 1: https://gcaptain.com/wakashio-breached-oil-leaks-from-grounded-bulk-carrier-in-mauritius-police-investigation-launched/
Graphic 2: https://www.flickr.com/photos/62937028@N02/50237761237/))

1. How well do we understand response, detection, fate, and effect for emerging fuel spills on the shorelines?

Generally, shoreline response preparation is good, but there's a need to keep testing GRPs and ensure that they are updated.

CG must consult with tribes and natural resources trustee agencies during response and there's a need for adequate information to conduct these.

Ability to message effectively to the general public needs to be improved.

2. Are there tools and technologies that could improve to response to emerging fuel spills on shorelines that: (a) could be made better; (b) have been developed and are not being used [If yes, please explain how they might be used]; or (c) are currently under development and/or at a low level of readiness?

- GIS is a tool that has been used during response, but not always on the timeframe needed by responders. Being able to get a real time picture of the response, beyond the Situation Unit.
- The use of UAS is improving, but transmitting a large volume of data (e.g., video) into a usable format (e.g., briefing materials and ops planning) is still difficult.

3. What knowledge gaps in oil spill science or tools/technologies do you "wish" were addressed/existed that would improve our understanding of emerging fuel spills on shorelines?

Better mapping abilities and interface/product development.

Improved ability of UAS that could detect the presence of oil scattered over a shoreline and characterize it.

The behavior of new fuels and safety risk to responders, e.g., low sulfur and biofuels.

Risks of fire associated with use of lithium batteries on vessels.

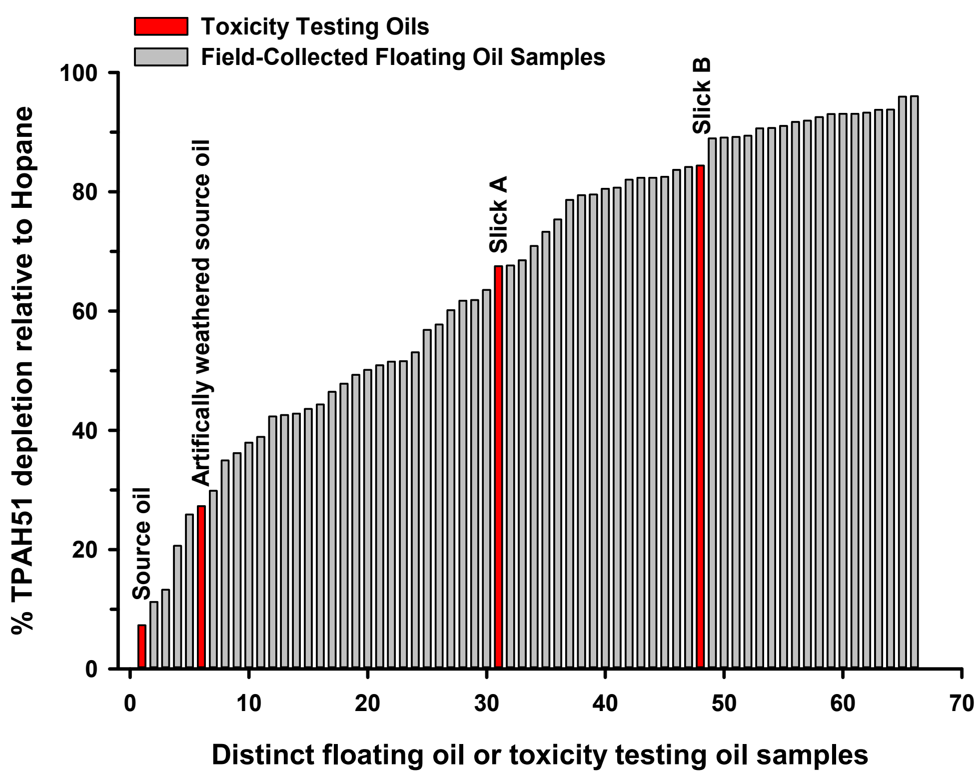
Shoreline Oil Spill Response Knowledge Gaps & Technological Development Opportunities

Jeff Morris

May 10, 2023

Level of Understanding

- Effects of emerging fuel spills on shorelines?
  - Composition of toxic components in spilled fuel?



Slick A Oil

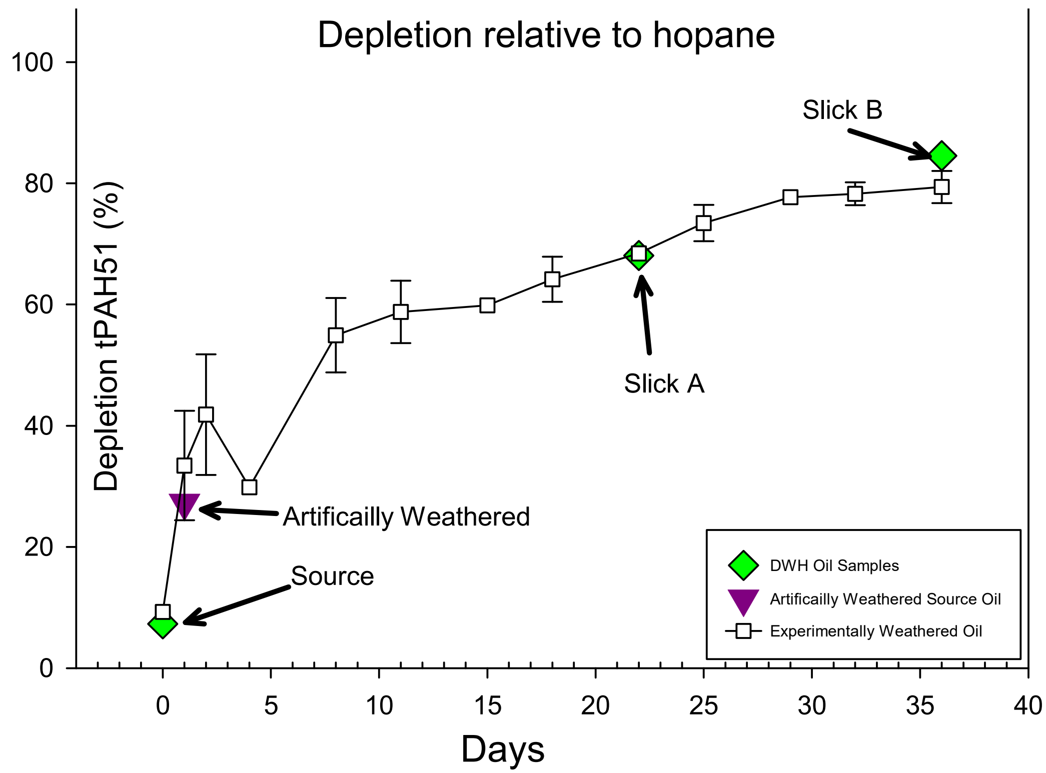
68% depletion

Slick B Oil

85% depletion

Level of Understanding

- Effects of emerging fuel spills on shorelines?
  - Changes in composition over time?



Slick A Oil

68% depletion

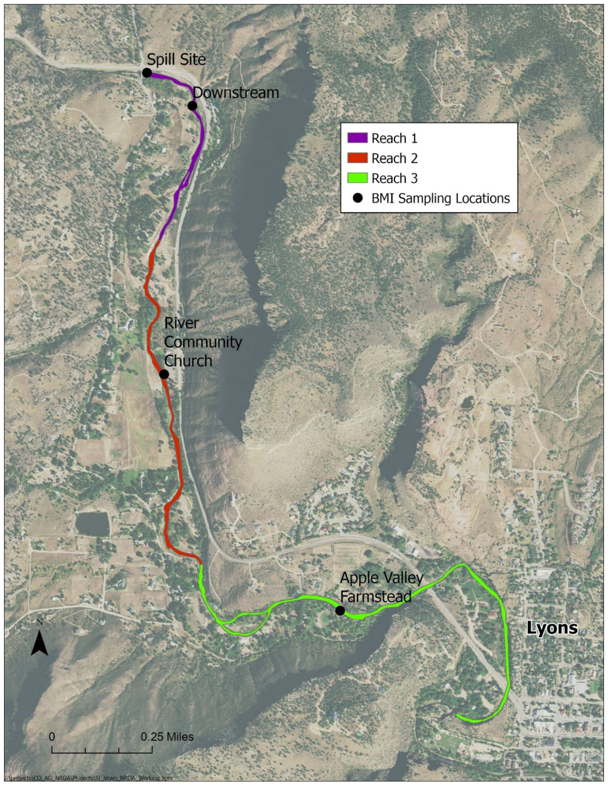
Slick B Oil

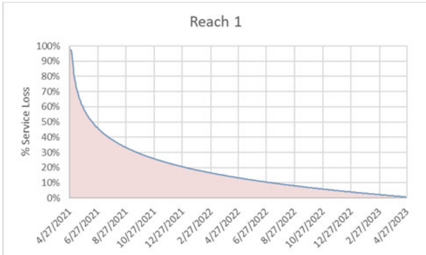
85% depletion

Johnson, J., B. Bailey, H. Forth, J. Morris, and R. Griffitt. 2016. Design and Testing of a Novel System for Producing Weathered Oil. Gulf of Mexico Oil Spill and Ecosystem Science Conference, Tampa, FL. February 1–4.

Knowledge Gaps

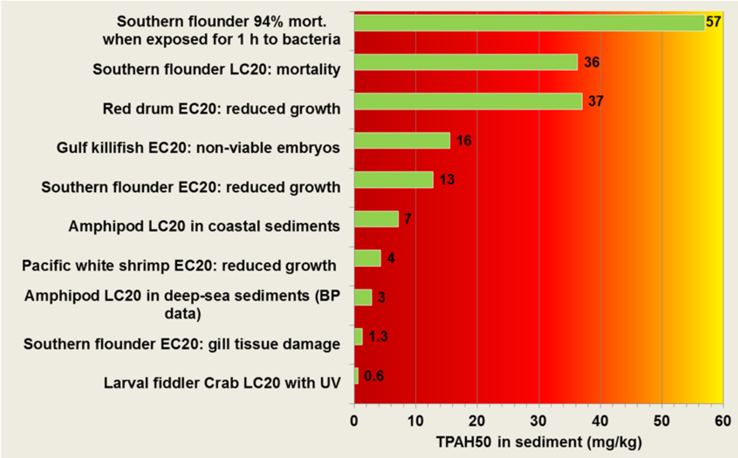
- Recovery time of impacted resources
  - Important for NRDA injury and damages estimates

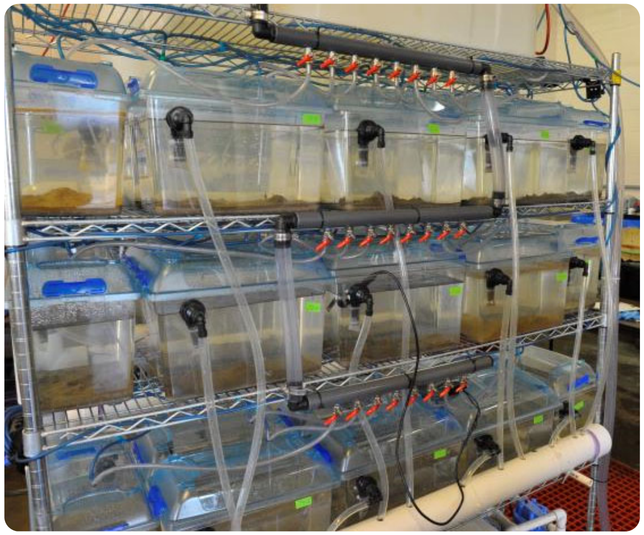




R&D Spending?

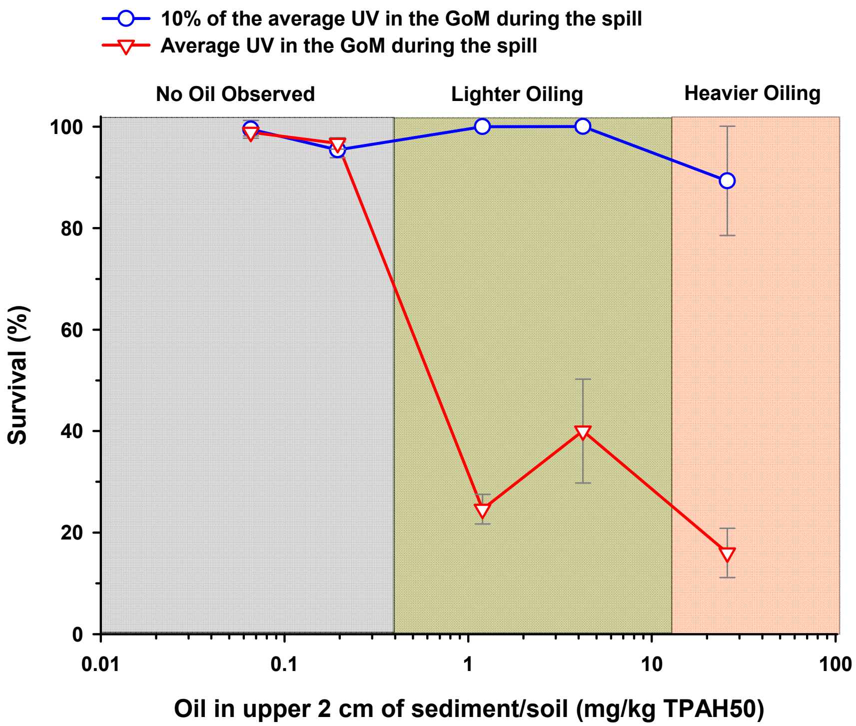
- Comprehensive toxicity testing of emerging fuels at different weathering states.
  - Build a catalog of toxic thresholds
  - Test relevant taxa and life stages
  - Include sublethal adverse impacts
  - Include multiple stressors (e.g., UV light)

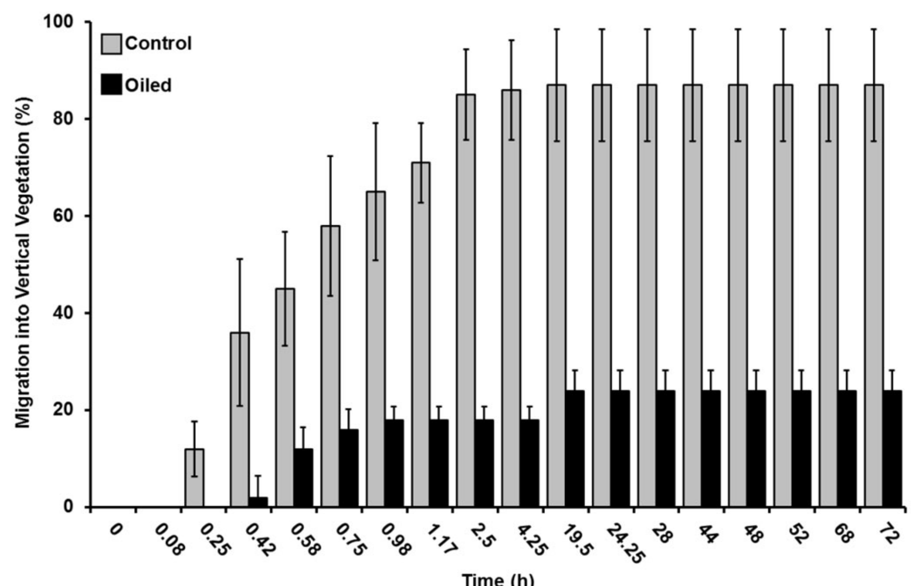




R&D Spending?

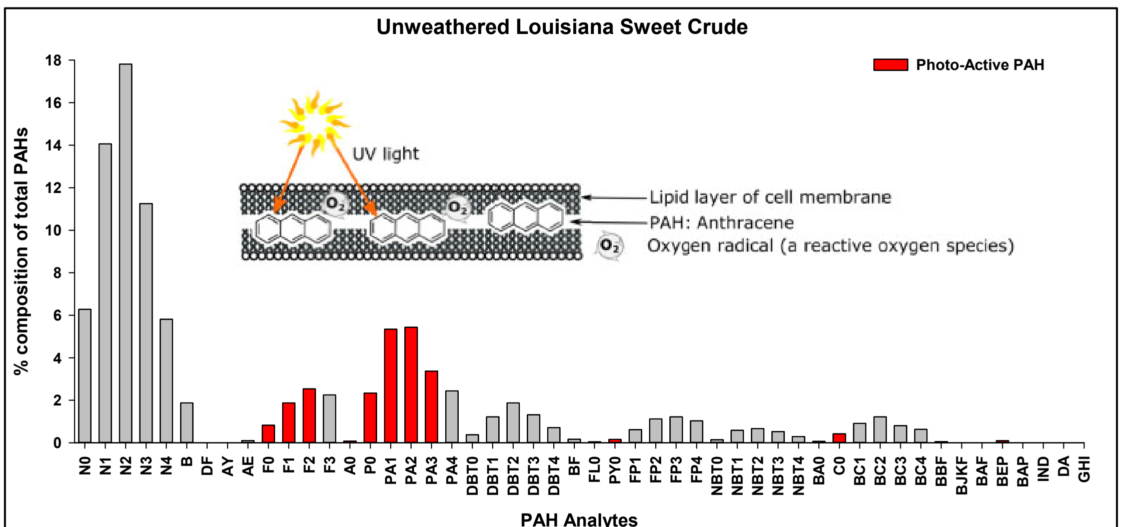
- Build on what we've learned

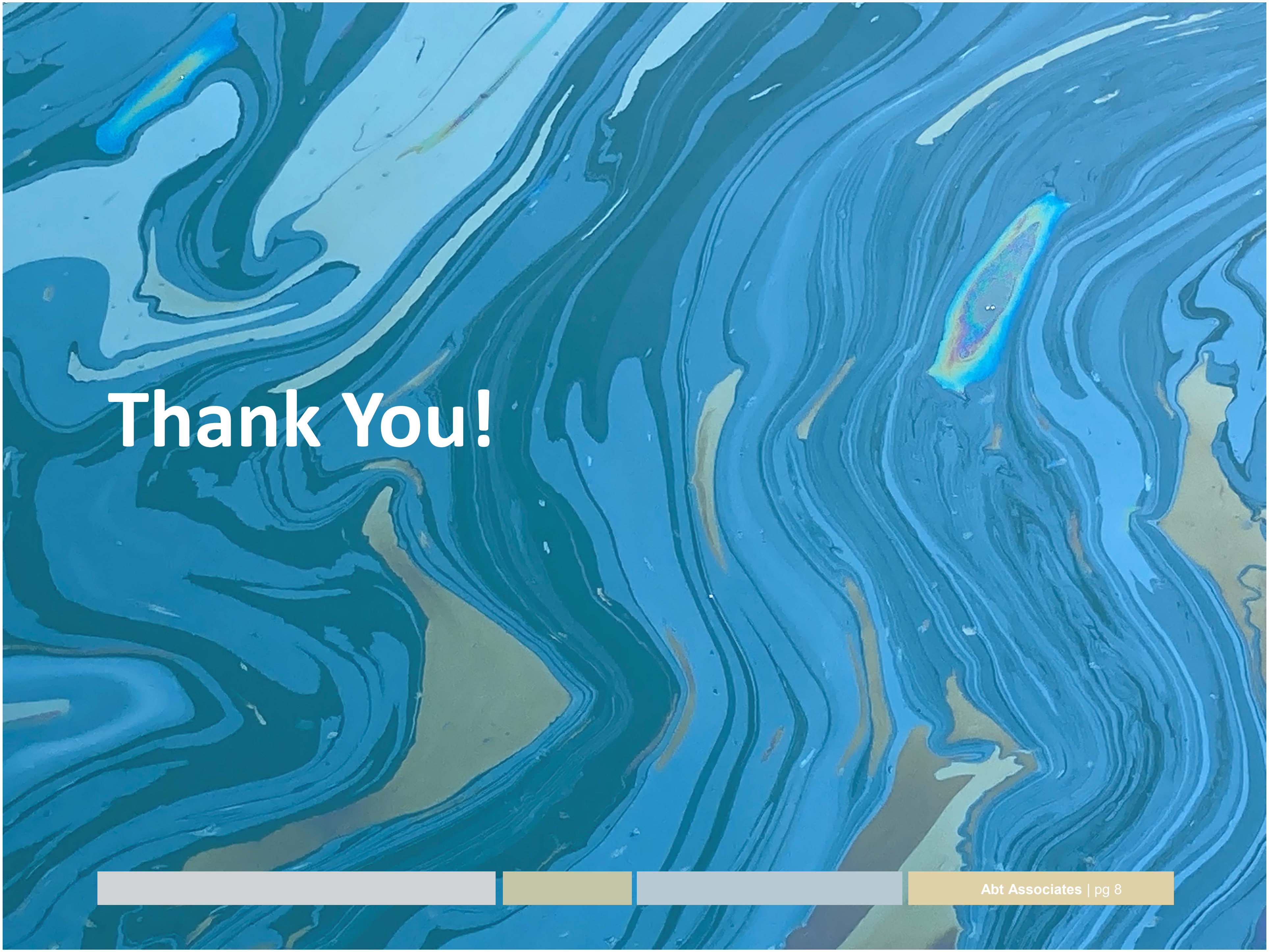




R&D Spending?

- Chemistry is important for injury assessment
  - Need to collect and bank samples during the response to characterize concentrations and compositions of toxic constituents
  - Changes in concentration and composition over time as oil/fuel weathers will also inform injury and damages calculations




Thank You!
Abt Associates | pg 8

BSEE/NOAA Shoreline Oil Spill Response Workshop

Greg McGowan
Biologist
Chief – Spill Response Technology & Support Branch
Office of Spill Prevention and Response
California Department of Fish and Wildlife

How well do we understand response, detection, fate, and effects for emerging fuel spills on shorelines?

- Response – Understood well as most renewable products are very similar to their petroleum counterpart. Ethanol is an outlier, but is quite volatile, and response is focused on secondary impacts (e.g., dissolved oxygen crash).

- Detection – More difficult due to lower color contrast (clear or translucent gold) and less known about use of remote sensing tools such as IR, polarized light, or even standard RGB (color camera) in different lighting Research Opportunity?

- Fate – Broadly understood well, but not with the granularity to be able to direct cleanup endpoints. We know that we can leave more in the environment and let it biodegrade, and that will occur more rapidly than for its petroleum counterpart, but *we don't know how much more we can leave or how much faster it will degrade*. Research Opportunity?

- Effects – Generally understood, generally lower toxicity issues. Some mechanical impacts would be the same as petrol counterparts (e.g., smothering).

CALIFORNIA DEPARTMENT OF FISH & WILDLIFE

Are there tools and technologies that could improve response to emerging fuel spills on shorelines that: (a) could be made better; (b) have been developed and are not being used; or (c) are currently under development and/or at a low level of readiness?

- (a) Testing sensors for detection, particularly remote sensing
- (a) Mechanical equipment settings/refinements (e.g., skimmers, sorbents, etc.) – Solvent considerations for gear (e.g., degradation of natural rubber)
- (b) Tool to predict biodegradation rates based on product and environmental conditions (e.g., temperature, shoreline substrate, etc.)

CALIFORNIA DEPARTMENT OF FISH & WILDLIFE

What knowledge gaps in oil spill science or tools/technologies do you "wish" were addressed/existed that would improve our understanding of emerging fuel spills on shorelines?

- Cleanup endpoints – Ability to reasonably accurately forecast biodegradation rate and Spill Response Benefits Analysis
- Wildlife response protocols – Should stabilization, wash and reconditioning protocols be different from petroleum contamination protocols. Are impacts (e.g., skin burns, ingestion issues, fur/feather impacts) different? Research Opportunity?
- On-water spreading and shoreline substrate penetration and coating (adhesion). Are they the same as for petroleum counterparts? Research Opportunity?
- Wave impact results – Should natural attenuation in a high energy (wave action, significant tides) be considered more of a primary response technique?

CALIFORNIA DEPARTMENT OF FISH & WILDLIFE

How would you prioritize R&D spending to improve our understanding of the emerging fuel spills on shorelines?

- Cleanup Endpoint Justifications – Documentation of key parameters associated with natural attenuation relative to cleanup endpoint targets (e.g., no longer a threat to fur or feathers, no visible product, no release of product during tides).
- Wildlife Response – Should response be different than for petroleum incident (field stabilization, care, rehabilitation, release)?
- Shoreline penetration/adhesion (and fate/transport)

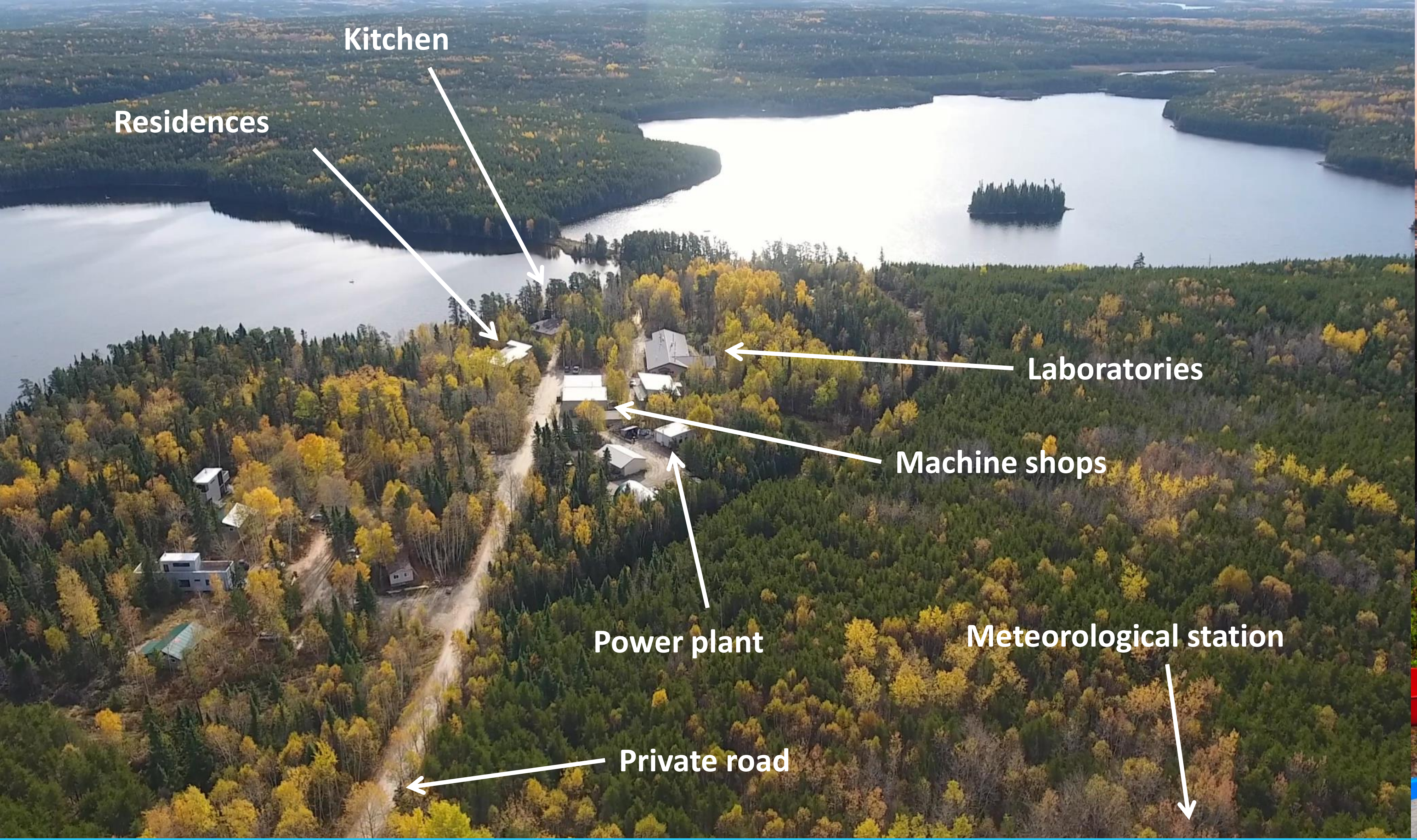
CALIFORNIA DEPARTMENT OF FISH & WILDLIFE

IISD EXPERIMENTAL LAKES AREA

THE WORLD’S FRESHWATER LABORATORY

IISD Experimental Lakes Area

What are we?

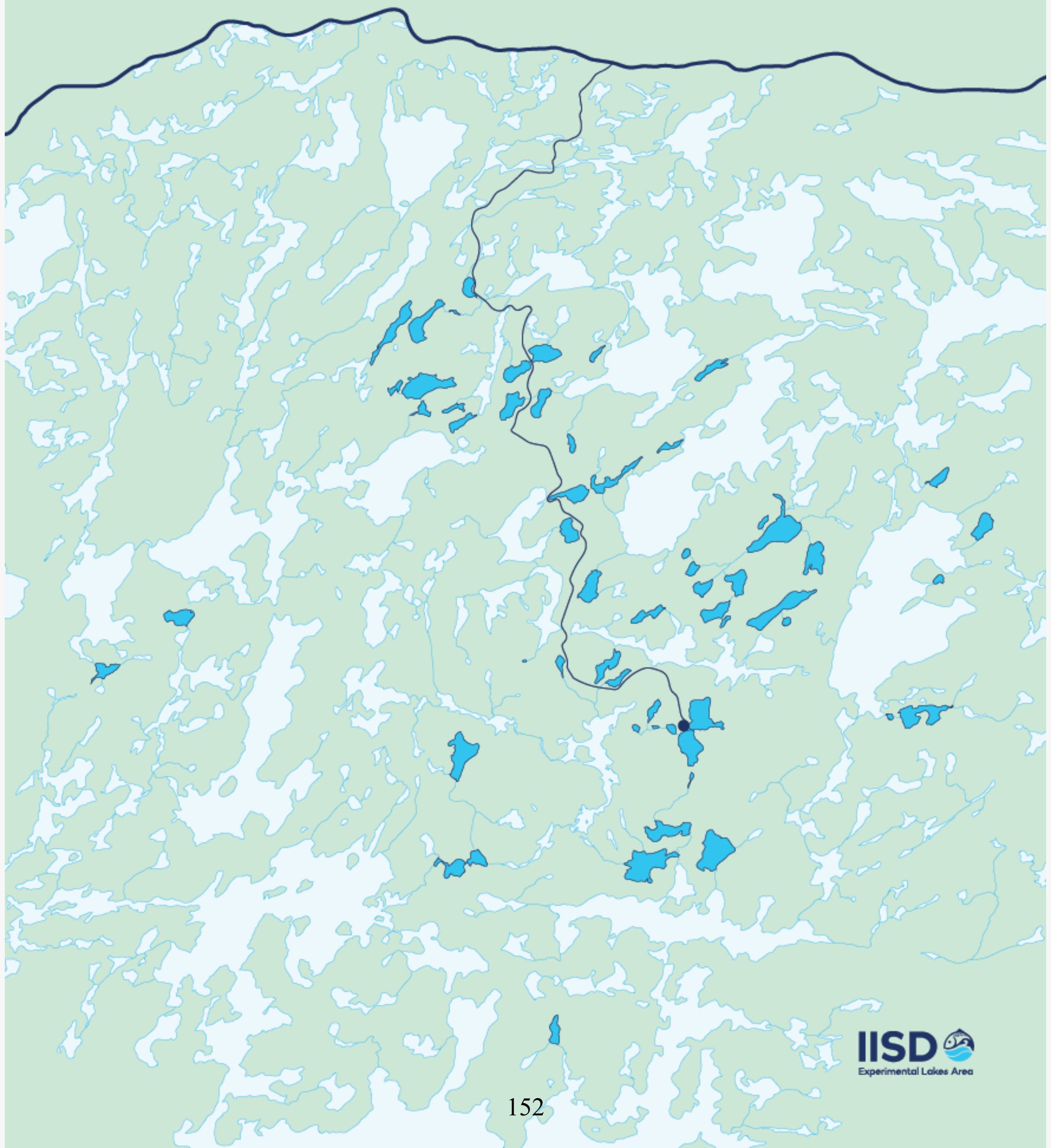




Science working to improve our understanding of human impacts on freshwater systems

IISD EXPERIMENTAL LAKES AREA

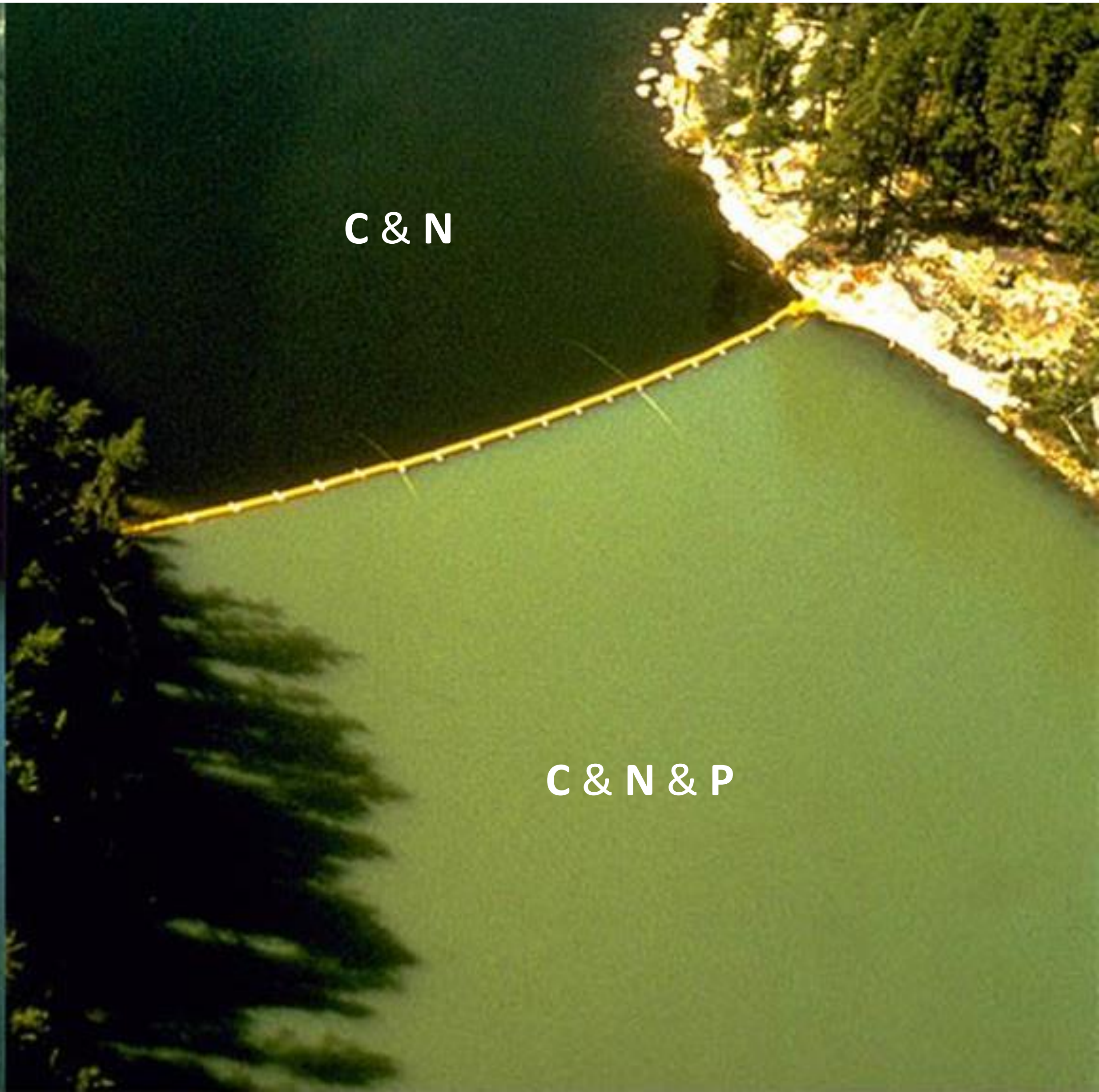
49.6597, -93.7278



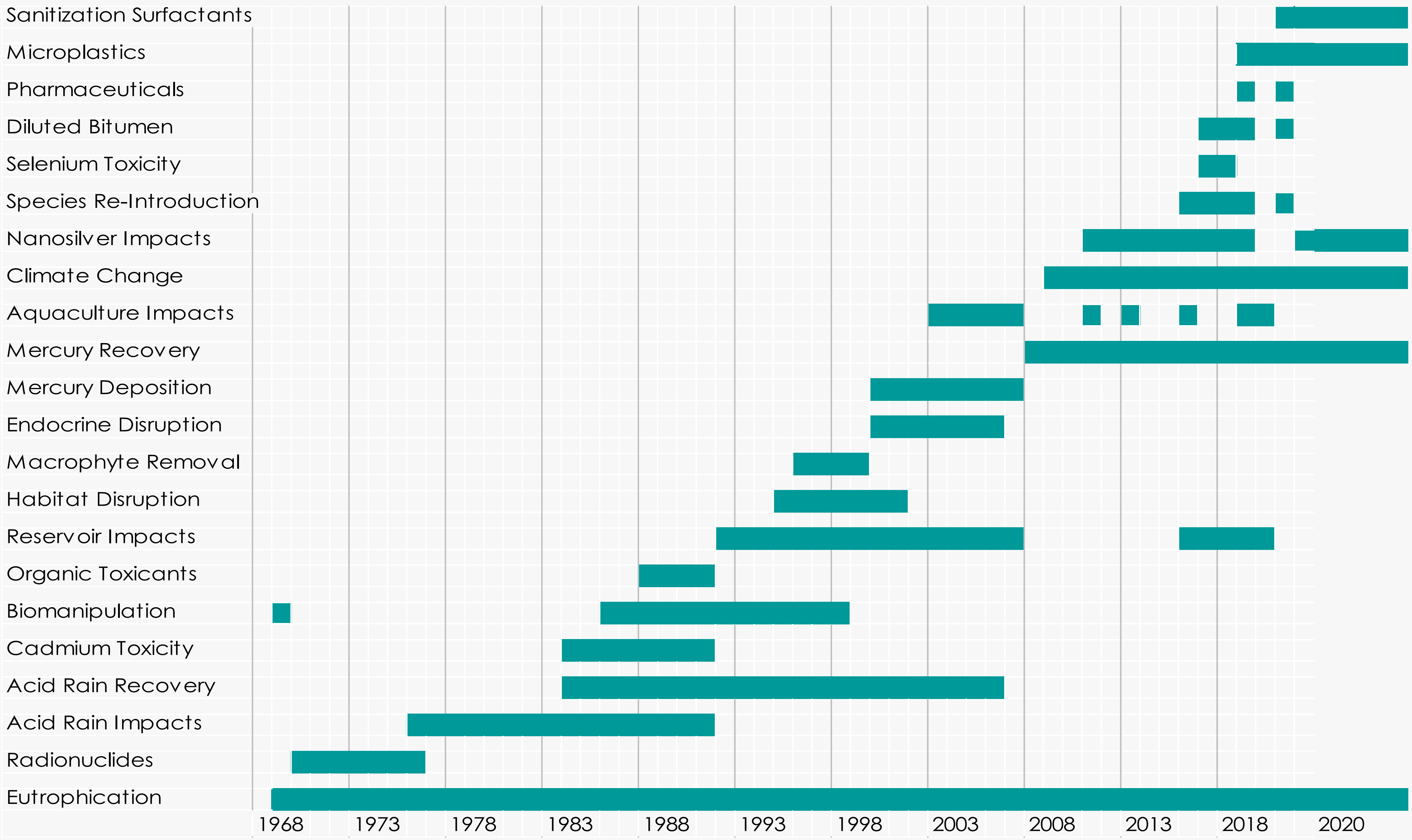
History

Originally established to address the challenge of large **Algal Blooms** in the the **Great Lakes**

Early experiments: Eutrophication



55 Years of Ecosystem Research (1968 – 2023)



Basic principles of our work

- **Ecosystem scale** research
- **Legal right** to do whole ecosystem research – both provincial and federal laws in place
- **Strong governance** system in place
- **Mimic real life** pollution scenarios
- **Return** all systems to **pre-impact status**
- Seek to **involve partners** with different points of view and with different stakes in the outcome

Recent work with oil

Three studies, three levels

1. Basic **fate, behavior, and effects** of oil spills in **freshwater** systems (BOREAL study)

2. Effectiveness of **minimally invasive shoreline cleanup** methods (FOReSt Project)

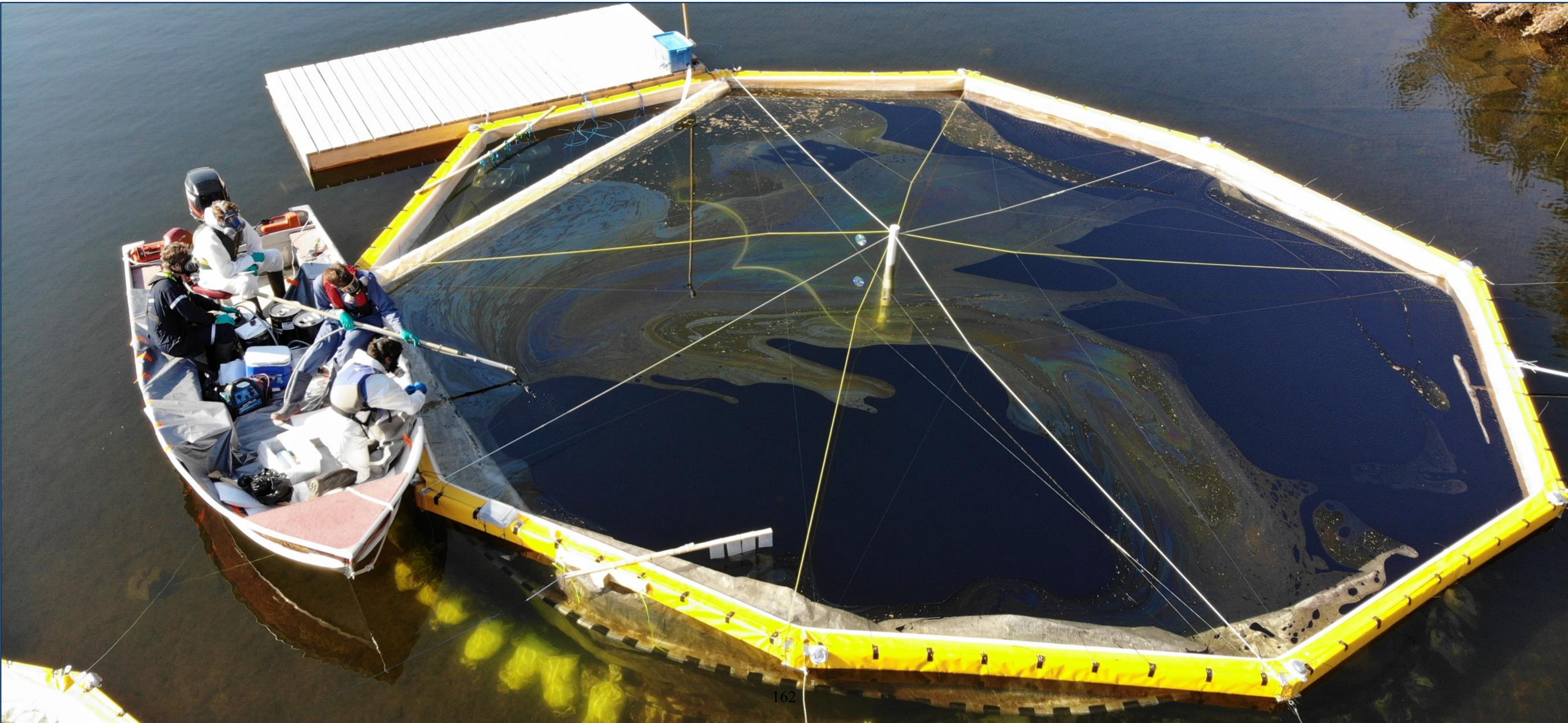
3. Efficacy of **engineered floating wetlands** as a remediation method (FLOWTER Project)

BOREAL

Understanding Oil Spills in Freshwater

BOREAL project (2017 – 2018)

Simulated diluted bitumen spills



7 levels of oil exposure

FOReSt

Freshwater Oil Spill Remediation Study

Minimally invasive shoreline cleanup

FOReSt Project (2019 – Present)



Engineered floating wetlands and remediation

FLOWTER Project (2021 – 2022)

Thank You

Any questions?

Shoreline Response Knowledge Gaps and Technological Development Opportunities

Changing Future

1.

What new or developing threats do you see on the horizon that will challenge our ability to prepare or respond to spills affecting shorelines?

"The more I tried to think about future problems, the more I thought about an old problem – the shoreline type that has probably frustrated more than any other during my thirty plus year career because it is still a problem."

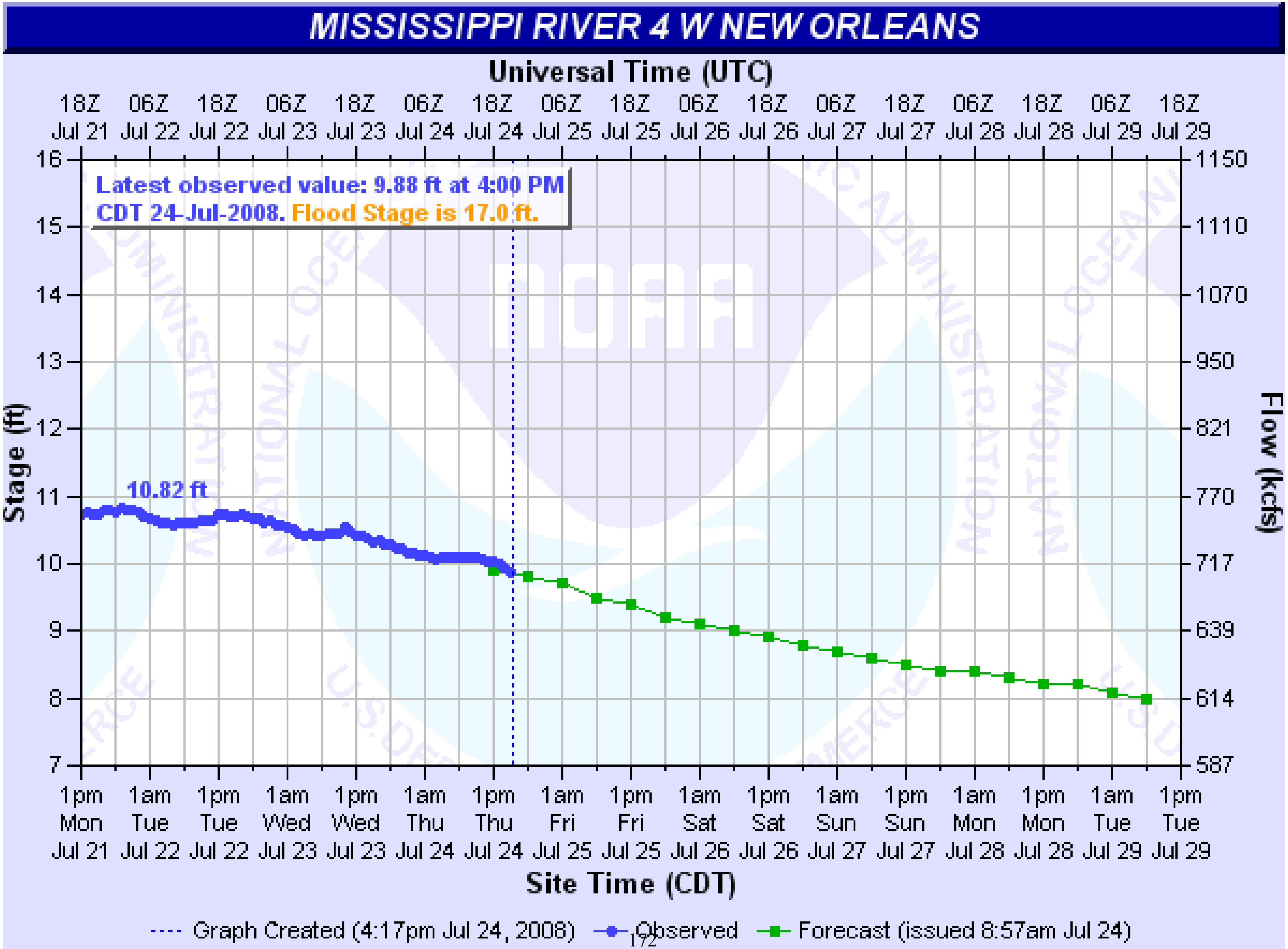
Charlie Henry

Director, NOAA's Disaster Response Center

Mobile, Alabama

Shoreline Response Knowledge Gaps and Technological Development Opportunities


"OK, think. Work with nature and not against it, but…"


MISSISSIPPI RIVER 4 W NEW ORLEANS
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Latest observed value: 9.88 ft at 4:00 PM CDT 24-Jul-2008. Flood Stage is 17.0 ft.
10.82 ft
Stage (ft)
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15
14
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12
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Site Time (CDT)
Graph Created (4:17pm Jul 24, 2008)
Observed
Forecast (issued 8:57am Jul 24)

Shoreline Response Knowledge Gaps and Technological Development Opportunities

2. What 'out of the box' approaches might you envision that could be developed for future shoreline preparedness and response?

Omni Boom

Monster Flush Barge (M/V Winchester)

Flushing with Flood/Header Hoses

Hot Water, No - Not So Hot Water Best

Shoreline Cleaning Agents

Bioremediation

Manual w/ Hand Scrappers and Rags

Berm Relocation / Rip-Rap Replacement

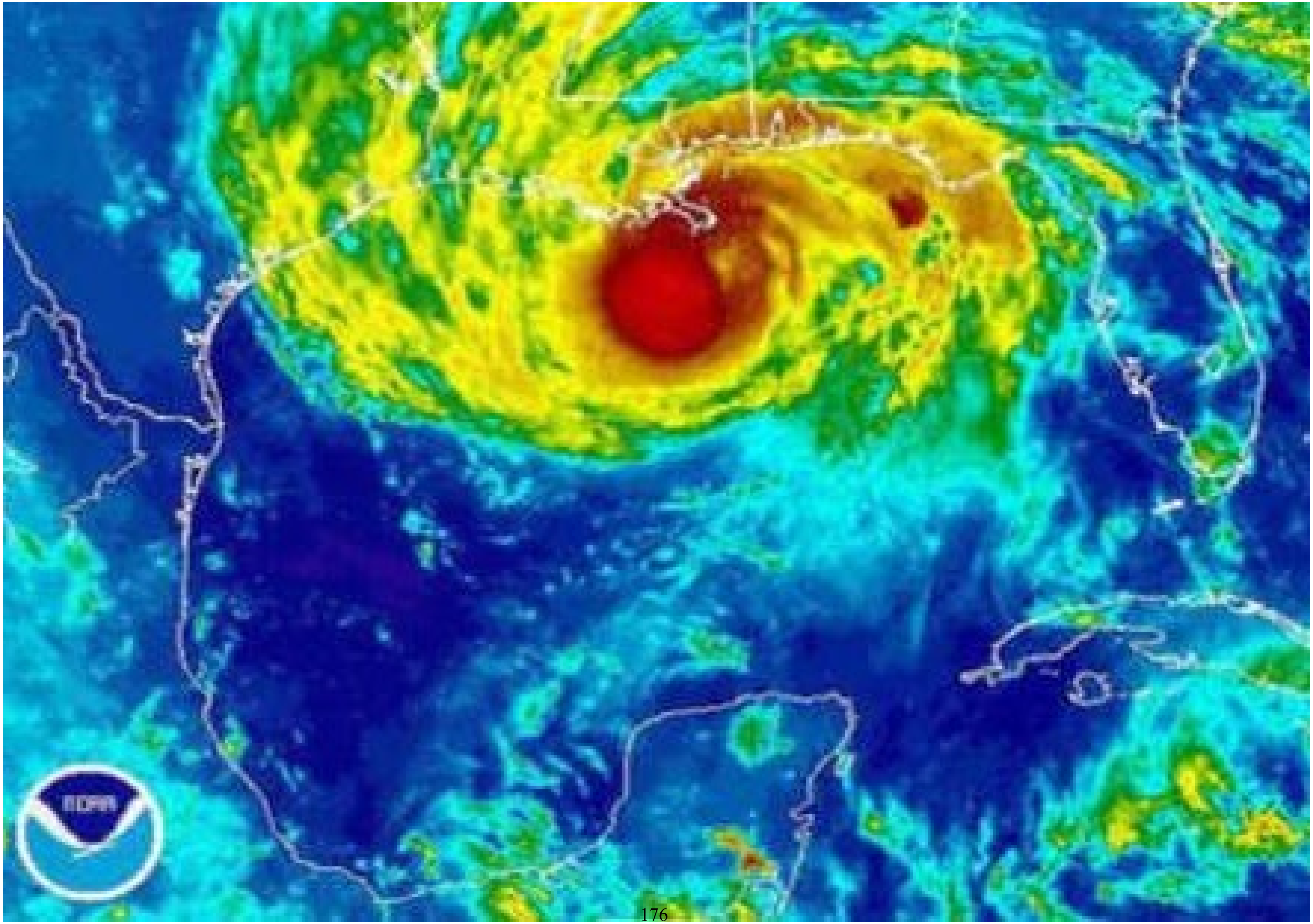
What we have sometimes works, but more often than not we eventually just walk way…

Sisyphus teaches us to never give in to circumstantial disappointments or run away from failures, rather accept failures the same way we accept our achievements.

I'm guessing this means…

…we still need better solutions to clean boulder/cobble beaches and rip-rap and we should continue to have workshops like this.

How did we eventually clean the rip-rap along the River Walk in New Orleans?



Shoreline Oil Spill Response Knowledge Gaps workshop: Changing Future Panel

Jacqueline Michel, Ph.D., President, Research Planning, Inc.

1. Expansion of mangroves in the northern Gulf of Mexico
2. Co-contaminants: Nurdles and other marine debris
3. Imagery for mapping buried oil after a spill
4. Increased *Sargassum* stranding on shorelines
5. Higher risks of oil transport during storms via washovers

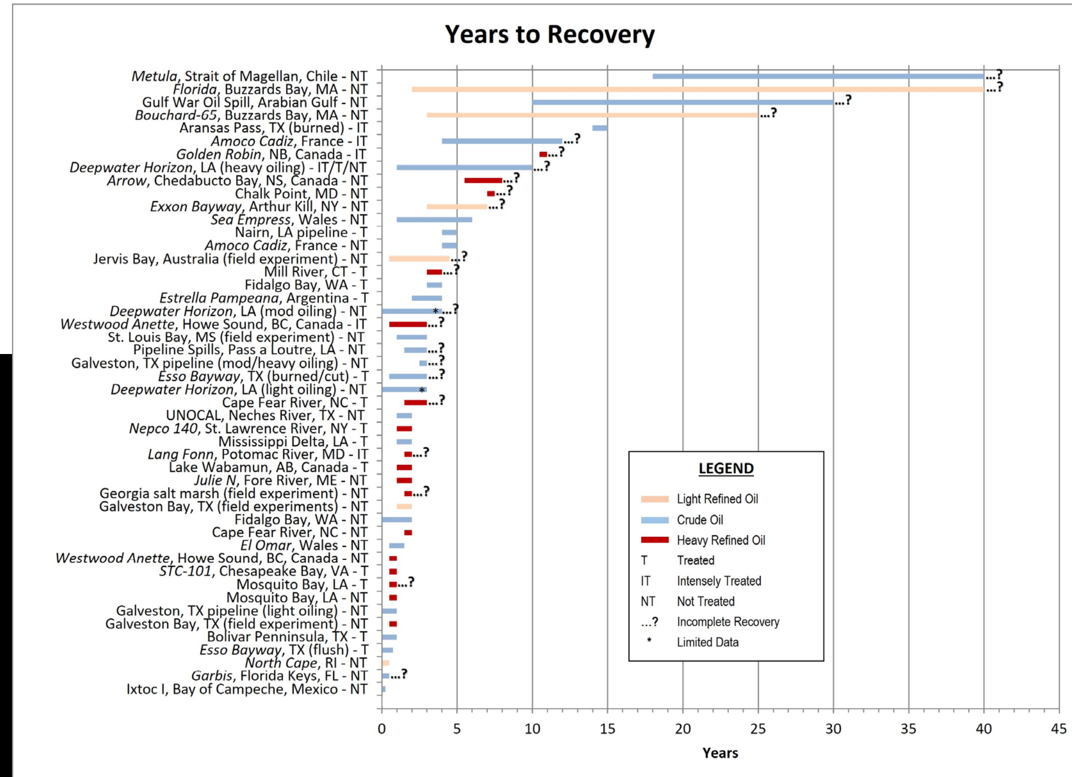
RPI

Expansion of Mangroves

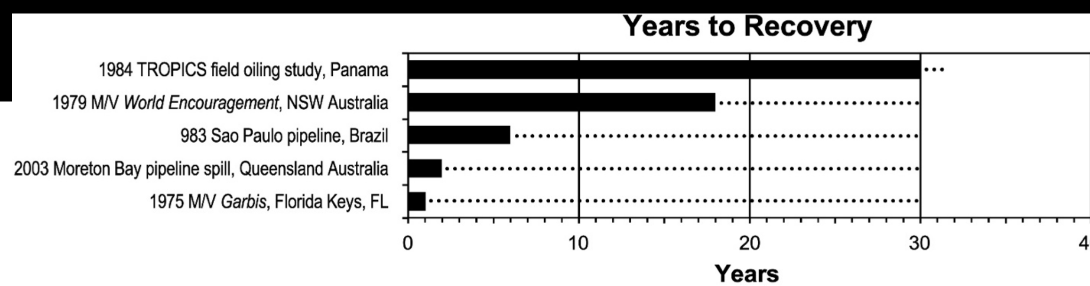
can lead to:

- More difficult SCAT assessments
- Fewer options for effective shoreline

[redacted]



Osland et al. 2022. *Global Change Biology* 28:3163-3187.

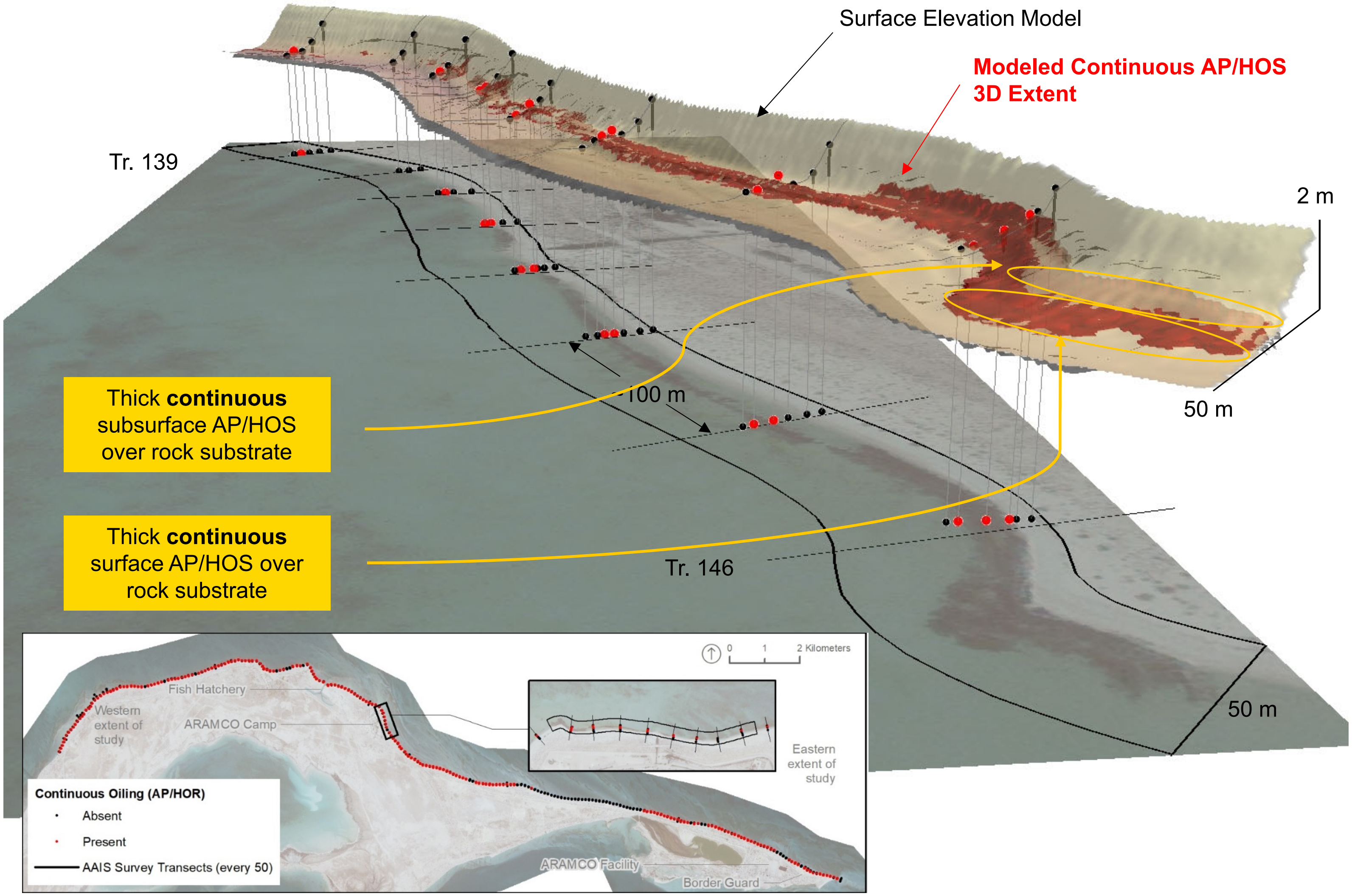


Co-Contaminants: 1) Nurdle Spills; 2) Other Types of Marine Debris

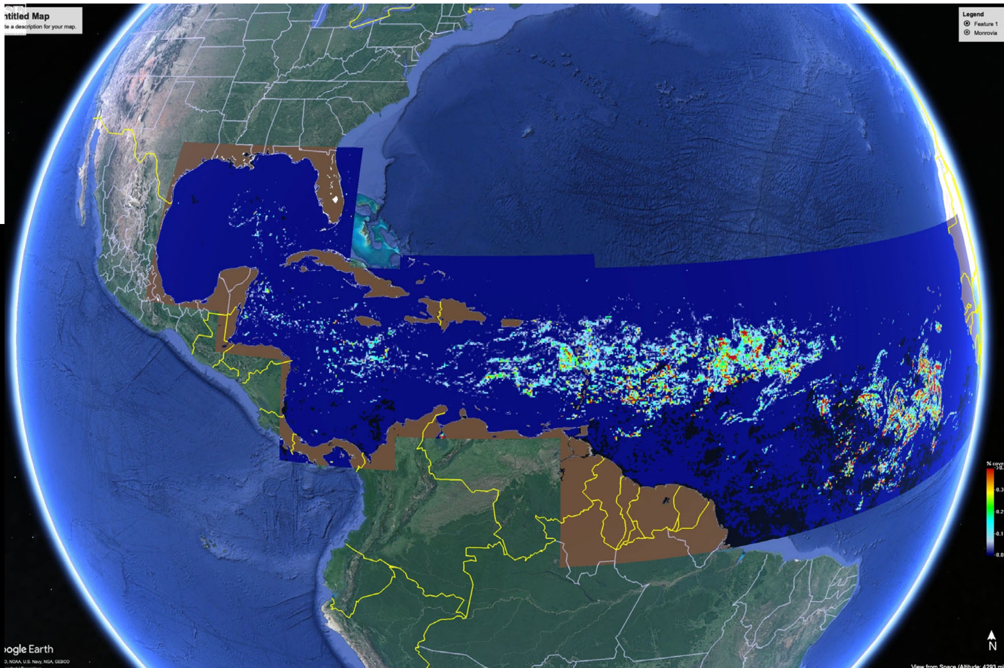
Nurdles can both leach and sorb toxic chemicals, complicating cleanup and waste disposal. Contaminants include [redacted]

[redacted] spherical nurdles in addition to fuel (de Vos et al., 2022).

Use of UAS imagery or LiDAR for Changes in Beach Elevation Post Oil Stranding to Map Buried Oil: SfM time series



Oil Spills + *Sargassum* Events



Galveston

Sargassum on the shoreline can greatly increase the volume of oil wastes for removal, AND pose hazards to cleanup workers.

Higher Risks of Oil Transport during Storms to Back Barrier Habitats via Washovers

Assateague Island

South Padre Island, TX

Appendix D: Panelist Questions

Response Questions:

1) How well can we respond to oil spills on shorelines?
2) Are there tools and technologies for shoreline response that: (a) could be made better; (b) have been developed and are not being used [If yes, please explain how they might be used]; or (c) are currently under development and/or at a low technical readiness level.
3) What knowledge gaps in oil spill science or tools/technologies do you "wish" were addressed/existed that would improve shoreline response?
4) How would you prioritize R&D spending to improve shoreline spill response?

Detection Questions:

1) How well can we detect oil spills on shorelines?
2) Are there tools and technologies for shoreline oil spill detection that: (a) could be made better; (b) have been developed and are not being used [If yes, please explain how they might be used]; or (c) are currently under development and/or at a low technical readiness level.
3) What knowledge gaps in oil spill science or tools/technologies do you "wish" were addressed/existed that would improve detection of oil on shorelines?
4) How would you prioritize R&D spending to improve shoreline spill detection?

Fate and Effects Questions:

1) How well do we understand the fate and effects of oil spills on shorelines?
2) Are there tools and technologies that could improve our ability to determine the fate and effects of oil on shorelines that: (a) could be made better; (b) have been developed and are not being used [If yes, please explain how they might be used]; or (c) are currently under development and/or at a low level of readiness?
3) What knowledge gaps in oil spill science or tools/technologies do you "wish" were addressed/existed that would improve our understanding of the fate and effects of oil spills on shorelines?
4) How would you prioritize R&D spending to improve our understanding of the fate and effects of oil spills on shorelines?

Policy Questions:

1) How well defined are our policies regarding oil spills on shorelines?
2) Are there policies regarding tools and technologies that could improve our ability to address oil spills on shorelines?
3) What policies regarding oil spill science or tools/technologies do you "wish" existed that would improve our ability to address oil spills on shorelines?
4) How would you prioritize policy development to improve our ability to address oil spills on shorelines?

Emerging Fuels Questions:

1) How well do we understand response, detection, fate, and effects for emerging fuel spills on shorelines?
2) Are there tools and technologies that could improve to response to emerging fuel spills on shorelines that: (a) could be made better; (b) have been developed and are not being used [If yes, please explain how they might be used]; or (c) are currently under development and/or at a low level of readiness?
3) What knowledge gaps in oil spill science or tools/technologies do you "wish" were addressed/existed that would improve our understanding of emerging fuel spills on shorelines?
4) How would you prioritize R&D spending to improve our understanding of the emerging fuel spills on shorelines?

Changing Future Questions:

1) What new or developing threats do you see on the horizon that will challenge our ability to prepare or respond to spills affecting shorelines:
    a. New transportation routes/hubs/vessels/offshore development technologies that may need consideration.
    b. Climate change effects on infrastructure, loss of permafrost, changes in exposure routes
2) What 'out of the box' approaches might you envision that could be developed for future shoreline preparedness and response?

Appendix E: Detailed Prioritization Notes

Shoreline Oil Spill Response Knowledge Gaps & Technological Development Opportunities

RESPONSE THEME

Group A		Group B		Group C	
Topic	**Notes**	**Topic**	**Notes**	**Topic**	**Notes**
Set asides, monitoring, and longitdinal studies. Assessing risk for residual oil/clean up endpoints that may generation controvercy. Documentation in literature that trade off are needed (public appeal)	**It has been done in the past but is often not accepted unless there is a big event such as DWH. What can we do on spills of opportunity to execute when you have a spill? Environmental unit would probably be the main motor behind it. NOAA has the experience. More of a methodology and best practice to keep in mind. It can apply to many tools/technologies. Funding a science group to have a plan of action and undertake these studies. Have something designed/fully conceptualized. A plan and series of protocols to use on a spill of opportunity. You need command approval, so all sectors need to have their priorities set. Funding could be a challenge, but you can phrase it to showcase the benefits.**	**In-situ treatment and related technologies**		Response technologies, (e.g., drones, AI used for remote sensing) Calibration of these technologies for false positives. Decision matrix for responders to assist in trade off, best practice, guidance for use of uncrewed response technologies. (McGyver)	**Response technologies (crewed/uncrewed) to be developed/repurposed specifically for cleanups, the tools that are available are what get used and need to be adapted for spill cleanup, we need to emphasize communicating what we know (how do we commnuicate that across the response effort). This includes Mr. Batski, the smart boom, rock roomba, sandshark, etc. These technologies need to be obtainable by the end-user and retrofitted as needed**
Decision matrix for responders to assist in trade off, best practice, guidance	This has been discussed for many years. The USCG just finished a biological assessment. This is different, it looks at how many species are present, etc. Decision support tool that gives responders the information they need to make decisions and communicate it to the outside world. You want to be able to quickly communicate the prefered options, trade-offs, and how it will save time and money. There are pieces of it out there. It is in progress. We are really doing this to recover the resource though. Trade-offs of intrusion and lack of intrusion.	Phone enabled/presentation of decision support. Repackaging the information for use	**DST for communications to decision makers (internal)**	Shoreline Segmentation and options set NEBA/SIMA including Oil detection: subsurface and relatively inaccessible oil (instrumentation options).	What are the changes from segment to segment and what needs to be addressed? What is the data that preceded the segment assessment? You can't use the same segementation for every spill even though you might have baselines from previous years.

Communication with the public to justify response locally, internationally, and within the oil community	This is important. SeaGrant has put a lot of effort into publications. That needs to be put out there for the public to see. What we are doing for shoreline cleanup should be done in the same type of format to be posted. The public affairs people in Huntington brought social media people into the command post to give them information. One challenge is that we do not have people trained in doing this for oil spills. We are not nimble. Need someone with social media expertise. The USCG could identify companies with expertise and hire them with a contract. Need to do this now, not waiting for a spill to happen. We should be tweeting now about who to call when a spill happens, etc.	**Transfer of information on response technologies to people and the public. Communicate trade offs (external)**		**Survey long and short term biological resources, habitats, and baselines. Needed before spill occurs to determine completion degree of response. End point targets are based in baseline information which is needed prior to the spill. Need for biological characterization of shorelines (for multiple purposes) for a shoreline prior to having oil hit. Develop new tools to expedite shoreline characterization.**	Many resources available to NEBA analyses through consultations that have already been done and this data is accessible. Baselines change seasonally, the gap here is to update the GRP and/or sensativity maps
				Set asides, monitoring, and longitdinal studies. Assessing risk for residual oil/clean up endpoints that may generate controversy. Documentation in literature that trade off are needed (public appeal)	After the data is gathered, what happens to it? How is it put into an accessible format? What data provides a valuable contribution? What is the funding source? Applies ot existing consultations
				Communication with the public to justify response locally, internationally, and within the oil community	Communicating and understanding group psychology, how do you do effective risk communication (communicating information during crisis and how to get them to believe and trust you)

Shoreline Oil Spill Response Knowledge Gaps & Technological Development Opportunities					
DETECTION THEME					
Group A		Group B		Group C	
Topic	**Notes**	**Topic**	**Notes**	**Topic**	**Notes**
Platform and Sensor Types: Canines, hyperspectral, multispectral, fluorosensor, smart boom, Mr. Batski, Polarographic senors, satellites, range of products available for sensitivity validation, **Rapid Image Processing, Have true shoreline subject matter expert team for detection**	**Addressing surface oil detection**. High priority. Universal system for downloading. Data management. Needs to go with rapid image processing category. These experts do not always understand the oil spill timeframe. Need to make sure everyone understands the rapid timeframe. Top priorities from this categories: rapid image processing, shoreline assessment, UAS, drones, sensors (photo/video, IR, LiDAR, fluorosensor). Need research on drones to know which sensors to use. Not satellites.	**Shoreline oil image library and pair with training, calibration, and key words for factors that effect detection (weather, oil type, etc.)**		**Platform and Sensor Types/Rapid Image Processing: Electrooptical/I.R.:** (Hyperspectral, multispectral, fluorosensor, Polarometric/I.R. senors, LiDAR, satellites) **Misc:** Smart boom, Mr. Batski, Canines	Validation/Verification: Double blind testing, oil thickness, field testing new technology, rapid and safer shoreline assessments, methods to qualify commercially ready systems. For AI, there aren't goof training datasets
Job Aids	Build a library to train people. For using drones and sensors. Descision pyramid: is a part of the decision support tool. One thing that you do not see in manuals is the reasoning why other technologies are not being used.	**Have true shoreline subject matter expert team for detection**		**Job Aids/Training Tools**	A game that can train people on different sensors for different applications
Challenging Conditions: Submerged oil, penetrating vegetation and vegetation canopies, oil under ice/snow, buired oil, lightly colored and transluscent oils, tarmats in water and detection in low visibility conditions, variability of oil on beaches, etc.	Direction to researchers: help find where the oil is. Ties into the first category, but this one is about what is not at the surface or is hidden. We have detectors out there, but we need to also be able to delineate and characterize what is in the subsurface. Quantifying. Geophysical technologies, acoustic. Snorkle SCAT. There have been some improvements since that. Lessons learned since DWH. Some technologies used on Mississippi River.	**Combining priorities with recon strategies - submerged oil**		**AI/Rapid Image Processing**	

Shoreline Oil Spill Response Knowledge Gaps & Technological Development Opportunities					
FATE AND EFFECTS THEME					
Group A		Group B		Group C	
Topic	Notes	Topic	Notes	Topic	Notes
Modeling: Ecosystem modeling, Arctic modeling, GIS hindcasting	Ecosystem modeling could help with decisions. Need to have a good tie in about what we know about biodegradation with ecosystem modeling. This can help make better informed decisions. If the oil sits there but no longer has an effect, we may not need to clean it up. Modeling the shoreline (inter-tidal) and residual/degraded oil is important. If we continue to keep areas set aside and monitor, it can show us if leaving oil there or cleaning it up is causing damage or benefits.	Modeling: Ecosystem modeling	Ecosystem modeling still needs to be developed further, great commnunication tool, can be a quick turnaround time during an event, can include information from specialists such as biologists, etc. Trajectory modeling should be included	Top priority of longitudinal studies and focus on in-situ treatment with what we already have	

Shoreline Oil Spill Response Knowledge Gaps & Technological Development Opportunities

POLICY THEME

Group A		Group B		Group C	
Topic	**Notes**	**Topic**	**Notes**	**Topic**	**Notes**
Search engine-based website with all the information (compilation of information). Promotes interagency policy.		Training: Internet Command System training, tactics for response, best strategies and practices, pushing policy to have shoreline training for preparedness purposes, mandatory policy training at all levels	**Required shoreline response drills**, SCAT ligistics, end point conversations, "how clean is clean", coordinating exercises across regions through policy changes, requiers drill prep. Focus beyond day one and include RRT in the process. Can bring in retired RRT members to aid in drill. Call in experts about policy. Exercise shoreline cleanup component in prep guidelines. (21 votes)	**Consistency:** compiling and fine tuning policy information, sharing classified data, national policies, subject matter expert	**A catalog of people (international) and their expertise** could be something that we pull from (this can benefit those who are new as well) and this should pull from the response, planning, and NRD arena. This could also serve as an opportunity for training. This community of practice, NOAA, ITOPF, CEDRE, SINTEEF, or ICOPPR are candidates for the catalog. Something to keep in mind is how different agencies share their data. Resource contact lists can also be compiled. A question is how do we prompt discussion beginning with RRTs to form policies in various locations. A UAS shoreline working groups, canine working groups, and AI-ML working groups should come together to share and suggest their ideas involving these concepts. These topics can then be implemented into the catalog. Search engine-based website with all the information (compilation of information). Promotes interagency policy. (20 Votes)
Job aid or policy to guide a company or person to get a technology approved.		Technologies: drone authorization, incentives and policies to push new technology use during a spill. Job aid or policy to guide a company or person to get a technology approved.	Tethered UAV following untethered UAV regulation, must be within line of sight. Policy to make decision for exceptions for emergencies (22 Votes)		
Exercise shoreline cleanup component in prep guidelines		Spilling oil for research: In the environment with a federal agency permit. Increased use/better use of facilities such as Ohmsett or experimental lakes/ponds designed for this. (19 Votes)			

Shoreline Oil Spill Response Knowledge Gaps & Technological Development Opportunities					
EMERGING PRODUCTS THEME					
Group A		**Group B**		**Group C**	
Topic	**Notes**	**Topic**	**Notes**	**Topic**	**Notes**
Understand VLSFOs - research properties and weathering behavior. How do we handle the oils with a low pour point on the operational side? Research on better technologies.		Detection, response, fate, effects, and risks of emerging fuels (e.g. VLSFOs, alternative fuels, dielectric fuels) Emerging fuels: detection, response, fate, effects, and risks (Dielectric, dilbit, LSFOs, hydrogen, methanol, ammonia, etc.)	Developing fact sheets of alternative fuels by industry, used to help in response decisions. Need analytics of the products to guide response. Conduct work on methods of detection, conduct studies on fate and transport. Evaluate worst case discharge scenarios for context (risk based assessment). Understand VLSFOs - research properties and weathering behavior. How do we handle the oils with a high pour point on the operational side? Research on better technologies. There's column tests being done on these to see how they behave on sediments, etc. Responder safety is key as well as the knowledge on how to clean it up (tactics guidance). Clarity on jurisdiction is especially important... there's a list of fuels under the Oil Pollution Act, and if one isn't on that list than you can't be funded to respond. Fuels prevalent in wind farms are of interest (such as dielectric).	**Emerging fuels**: detection, response, fate, effects, and risks (Dielectric, dilbit, LSFOs, hydrogen, methanol, ammonia, etc.)	There's column tests being done on these to see how they behave on sediments, etc. **Responder safety is key as well as the knowledge on how to clean it up (tactics guidance). Clarity on jurisdiction is especially important...** there's a list of fuels under the Oil Pollution Act, and if one isn't on that list than you can't be funded to respond. **Fuels prevalent in wind farms are of interest (such as dielectric).**
Renewable and other emerging fuels research: properties, behavior, how to handle them		Tests relevant to taxa and life stages, toxicity with time, thresholds, wildlife health, recovery times, etc. for emerging products	Research on deterance techniques for these products for protected resources/wildlife. Potential of oil on water maps to enhance transport modeling and guide wildlife operations. Tiering/ learning from what is known on traditional oils. Use existing models for predicting acute toxicity. Additional compliance requirements may nessesitate additional testing. Realistic conditions and environmentally relevant toxicity testing of emerging products.		
Realistic conditions and environmentally relevant toxicity testing of emerging products.		Consultation: special places and people	AI/ChatGPT used for communication beyond special places and people		

Shoreline Oil Spill Response Knowledge Gaps & Technological Development Opportunities

Experimental Lakes

Group A		Group B		Group C	
Topic	**Notes**	**Topic**	**Notes**	**Topic**	**Notes**
Oil under ice		Testing remote sensing technologies for challenging environments (shoreline vegetation, buried oil, etc.) including testing of oil in ice.		**Experimental Lakes:** shoreline cleanup, oil under ice and sediment detection experiments, etc.	Oil under ice research using uncrewed systems has been discussed, we need to see what results come from this workshop in terms of in-situ testing. It isn't an optimal location for shoreline cleanup exercises. **We recognize the value of the lakes and if the funds are available, the topics discussed at this workshop should be made possible**
Detection of oil on lake bed and in water column		Test in-situ burn efficacy and plume dispersion anaylsis, SMART protocol testing			
Shoreline application: Surface washing agents, Surface collecting agents, Low level flushing		Spill response efficacy tests, surface washing agents tests, dispersive effectiveness, herders, monitoring shoreline vegetation health (set asides)			

Shoreline Oil Spill Response Knowledge Gaps & Technological Development Opportunities

CHANGING FUTURE THEME

Group A		Group B		Group C	
Topic	**Notes**	**Topic**	**Notes**	**Topic**	**Notes**
Emerging shoreline protection technologies (cradle to grave assessment)	Prevention of oil to shoreline is key. Boom design, rip-wrap, biofilms to minimize oil adhesion (how long can the biofilm stay there). Research and validate. Chemicals as repelants? If you put surface collecting agents into a surf, it will not work. Potential for something behind the wave line. It will work in waves, but is a matter of how long it will stay out there. **Research on what conditions it would work in, how long it can be out there, sea state, currents. Different tactics: where is it applicable and the limitations. (16 Votes)**	Challenges with climate change and impacts to infrastructure, loss of permafrost, and changes in exposure routes and habitats	Including GRPs and ESI, coastal erosion, loss of permafrost, impacts with sea level rise, evaluating new potential shoreline areas impacted by oil. Use of automated intelligence to streamline process. Resiliancy of infrastructure with increase frequency/intensity of storms (including abandon infrastructure). Shifts in natural resource/wildlife locations and occurances. Increase nunber of incidents will strain avalible resources.	**Emerging shoreline protection technologies** (cradle to grave assessment)	A goal should be keeping the fuel from the beach, specifically through the new and upcoming technologies referenced today. We need to devise new tools for protection of shorelines. A question is whether the technologies should be born from journals or R&D dollars. At this point, we are still at the testing stage. **Fresh ideas are needed (perhaps a think-tank)** from those who don't deal with remediation as often as we do (these people need to understand basic concepts). These conversations CAN'T occur during an incident. A UAS shoreline working groups, canine working groups, and AI-ML working groups should come together to **share and suggest** their ideas involving these concepts. (18 Votes)
Working with nature for innovative response techniques. Expansion of solution with range of tidal ranges	Looking more into what the efficiency is of supra tidal flooding. Flooding the supra tidal on a constant basis. Introducing the bacteria and oxygen, promoting natural biodegradation. Issues of cross contamination or loosing control of system (water sinking further in). Mechanical response issues as well as how do we do biodegradation better. Lift and float, used in gravel pits, brought the oil to the surface. Need to think through the mechanical process. Do not have a lot of time in response. **Research needed: explore different options to remove oil from supra tidal zone. Expanding and combining existing methods (mechanical and/or chemical). Testing in experimental lakes. (8 Votes)**	Education for **public** and building trust for messaging science. Need for community of trusted and respected experts (communication)	Accessible (appropriate) language to build trust, serve needs of the community, and be understood by the common public. Plan language communication and knowledge of audience and their concerns. Talking with tribes/working with tribal culture (premessaging). Get ahead of social media. Formatting and location of training materials for easy access in an incident. Identify interest groups and use proactive communication approach. New social media platforms can aid in reaching target communities. **Just in time education for public.**	**Challenges with climate change** and impacts to infrastructure, loss of permifrost, and changes in exposure routes and habitats	It's important to have a cultural change that **identifies the vulnerabilities of the infrastructure** and where the weak points are. Especially in high-risk areas such as Alaska, the USCG is underprepared for that kind of scenario. Louisiana has aging infrastructures that are susceptible as well, risk assessments activities should be performed there and in other areas to identify what is already had. **These assessments depends on different geographic locations, so perhaps we can consider one kind of assessment that's a living document and updated every few years while we observe new threats or changes in the climate**. If there are individuals who are already knowledgeable on this matter, they can be utilized for the document for a head start. The pre-assessments aid in GRSs as well.
Challenges with climate change and impacts to infrastructure, loss of permafrost, and changes in exposure routes and habitats	Changing water level impacts on pipes. Different issues in different parts of the world. An analysis (is being done in certain areas) on how to reduce our risks. Biggest gap is in Arctic environments. Canadian Arctic studies have been done on this. What is the risk of climate change to our changing sensitivities? Messaging issue as well, talking to representatives at all levels to explain the changing risks/response tactics. Have a feedback loop. More on the planning side: how is it going to change and how do we adapt? Policy implications to that. What do new strategies and equipment look like? **Research: what is the impact of climate and sea level changes on sensitivity maps/risk analyses. (16 Votes)**	Education for responders: **virtual reality for drills** training (smart gaming) (11 Votes)			

Appendix F: Literature Review

Oil Impacts to Shoreline Environments

current as of August 2023

Year	Authors	Title	Subcategory	Citation (APA)	Keywords	Summary	Links
2022	Asif, Zunaira ; Chen, Zhi ; An, Chunjiang ; Dong, Jinxin	**Environmental Impacts and Challenges Associated with Oil Spills on Shorelines**		Asif, Chen, Z., An, C., & Dong, J. (2022). Environmental Impacts and Challenges Associated with Oil Spills on Shorelines. *Journal of Marine Science and Engineering* , *10* (6), 762–. https://doi.org/10.3390/jmse10060762	shorelines; oil spill; environmental impacts; remote sensing; weathering process	This paper critically overviews the vulnerability of shorelines to oil spill impact and the implication of seasonal variations with the natural attenuation of oil. A comprehensive review of various monitoring techniques, including GIS tools and remote sensing, is discussed for tracking, and mapping oil spills. A comparison of various remote sensors shows that laser fluorosensors can detect oil on various types of substrates, including snow and ice. Moreover, current methods to prevent oil from reaching the shoreline, including physical booms, sorbents, and dispersants, are examined. The advantages and limitations of various physical, chemical, and biological treatment methods and their application suitability for different shore types are discussed.	
2022	Chen, Xinya; Bi, Huifang; Yue, Rengyu; Chen, Zihikun; An, Chunjiang	**Effects of oil characteristics on the performance of shoreline response operations: A review**		Effects of oil characteristics on the performance of shoreline response operations: A review. (2022). Frontiers in Environmental Science, 10. https://doi.org/10.3389/fenvs.2022.1033909	oil spill, oil characteristics, shoreline cleanup, shoreline response operations, biodegradation	This review therefore comprehensively investigates the characteristics of spilled oil on the shoreline and explores their effects on the effectiveness of shoreline response operations. First, the five basic groups of spilled oil (i.e., non-persistent light oils, persistent light oils, medium oils, heavy oils, and sinking oils) are discussed and each oil fraction is introduced. Three distribution scenarios of adhered oil on shorelines are also analyzed. The effects of oil characteristics, such as oil type, viscosity, evaporation, and composition, on the performance of chemical treatments, physical methods, and biodegradation are then discussed and analyzed. Finally, the article provides recommendations for future research on aspects of shoreline oiling prevention, quick responses, response tool sets, and other considerations, which may have significant implications for future decision-making and the implementation of shoreline cleanup to effectively remove stranded oil.	https://www.frontiersin.org/articles/10.3389/fenvs.2022.1033909/full
2019	Monica Wilson, Emily Maung-Douglass, Christine Hale, Melissa Partyka, Stephen Sempier, Tara Skelton, and LaDon Swann	**Impacts of Oil on Mangroves**		Wilson, M., Hale, C., Maung-Douglass, E., Partyka, M., Sempier, S., Skelton, T., & Swann, L. (2019). Impacts of oil on mangroves. GOMSG-G-19-010			
2012	Irving A. Mendelssohn, Gary L. Andersen, Donald M. Baltz, Rex H. Caffey, Kevin R. Carman, John W. Fleeger, Samantha B. Joye, Qianxin Lin, Edward Maltby, Edward B. Overton, Lawrence P. Rozas	**Oil Impacts on Coastal Wetlands: Implications for the Mississippi River Delta Ecosystem after the Deepwater Horizon Oil Spill**		Mendelssohn, Andersen, G. L., Baltz, D. M., Caffey, R. H., Carman, K. R., Fleeger, J. W., Joye, S. B., Lin, Q., Maltby, E., Overton, E. B., & Rozas, L. P. (2012). Oil Impacts on Coastal Wetlands: Implications for the Mississippi River Delta Ecosystem after the Deepwater Horizon Oil Spill. Bioscience, 62(6), 562–574. https://doi.org/10.1525/bio.2012.62.6.7	Wetlands Environmental science Ecology Coastal ecosystems Microbiology	The Deepwater Horizon explosion released an estimated 4.9 million barrels of crude oil into the Gulf of Mexico over the course of 87 days. Many kilometers of shoreline in the northern Gulf of Mexico were affected, including the fragile and ecologically important wetlands of Louisiana's Mississippi River Delta ecosystem. Here, we provide a basic overview of the chemistry and biology of oil spills in coastal wetlands and an assessment of the potential and realized effects on the ecological condition of the Mississippi River Delta and its associated flora and fauna.	https://academic.oup.com/bioscience/article/62/6/562/249195
2013	Torgeir Bakke, Jarle Klungsøyr, Steinar Sanni	**Environmental impacts of produced water and drilling waste discharges from the Norwegian offshore petroleum industry**		Torgeir Bakke, Jarle Klungsøyr, Steinar Sanni, Environmental impacts of produced water and drilling waste discharges from the Norwegian offshore petroleum industry, Marine Environmental Research, Volume 92, 2013, Pages 154-169, ISSN 0141-1136, https://doi.org/10.1016/j.marenvres.2013.09.012.	Offshore discharges Produced water Drilling waste Petroleum hydrocarbons Biomarkers Fish Benthos Environmental impact Risk assessment	This paper reviews recent research on the biological effects of such discharges with focus on the Norwegian Continental Shelf. The greatest concern is linked to effects of produced water. Alkylphenols (AP) and polyaromatic hydrocarbons (PAH) from produced water accumulate in cod and blue mussel caged near outlets, but are rapidly metabolized in cod. APs, naphtenic acids, and PAHs may disturb reproductive functions, and affect several chemical, biochemical and genetic biomarkers. Toxic concentrations seem restricted to <2 km distance. At the peakof discharge of oil-contaminated cuttings fauna disturbance was found at more than 5 km from some platforms, but is now seldom detected beyond 500 m. Water-based cuttings may seriously affect biomarkers in filter feeding bivalves, and cause elevated sediment oxygen consumption and mortality in benthic fauna. Effects levels occur within 0.5e1 km distance. The stress is mainly physical. The risk of widespread, long term impact from the operational discharges on populations and the ecosystem is presently considered low, but this cannot be verified from the published literature.	
Year	**Authors**	**Title**	**Subcategory**	**Citation (APA)**	**Keywords**	**Summary**	**Links**
2014	Erik Damgaard Christensen, Sten Esbjørn Kristensen, Rolf Deigaard	**Impact of an Offshore Wind Farm on Wave Conditions and Shoreline Development**		Christensen, E. D., Kristensen, S. E., & Deigaard, R. (2014). IMPACT OF AN OFFSHORE WIND FARM ON WAVE CONDITIONS AND SHORELINE DEVELOPMENT. Coastal Engineering Proceedings, 1(34), sediment.87. https://doi.org/10.9753/icce.v34.sediment.87	Wave energy, offshore wind farm, Spectral wind wave model, Littoral transport, and shoreline development	The influence of offshore wind farms on the wave conditions and impact on shoreline development is studied in a generic set-up of a coast and a shoreline. The objective was to estimate the impact of a typical sized offshore wind farm on a shoreline in a high wave energetic environment. Especially the shoreline's sensitivity to the distance from the OWF to the shoreline was studied. The effect of the reduced wind speed inside and on the lee side of the offshore wind farm was incorporated in a parameterized way in a spectral wind wave model. The shoreline impact was studied with a one-line model	
2002	Cooper, Bill; Beiboer, Frank	**Potential Effects of Offshore Wind Developments on Coastal Processes**		Beiboer, F.; Cooper, B. (2002). *Potential Effects of Offshore Wind Developments on Coastal Processes* (Report No. ETSU W/35/00596/00/REP). Report by ABP Marine Environmental Research Ltd (ABPmer). Report for UK Department of Trade and Industry (DTI).		This study ams to identify, review, and assess the potential efefcts on coastal processes related to the development of offshore wind farms. Coastal prorcesses include diffraction and focusing effects on waves and currents and their effects on long shore drift and errosion. The results from generic tidal, wave, and sediment modeling scenarions suggest that at a regional level, there is unlikely to be a significant effect on coastal processes. The impact of the 'reasonable worst case' is slightly more pronounced tat the typical case, but neither is at a level that should lead to any major concern.	https://www.udel.edu/udaily/2022/july/offshore-wind-farm-coastal-community-impact-surface-weather/

2009	Waage, Melissa; Chase, Alison	**Avoid Unnecessary Risks from Offshore Drilling**				Healthy oceans are critically important to marine life and to coastal communities whose economies rely on tourism and fishing. Opening up new offshore areas to drilling risks permanent damage to our oceans and beaches without reducing our dependence on oil. When oil spills occur they can bring catastrophic harm to marine life and devastating losses for local businesses. Even routine exploration and drilling activities bring harm to many marine species. The Administration and Congress must work together to assess the environmental impacts of offshore drilling before making key decisions about offshore oil and gas activities in new areas or Alaska.	Natural Resources Defense Council
2016	Moore, Jon	**Impacts of Oil Spills on Shorelines**		Moore, Jon. (2016). Impacts of oil spills on shorelines. Good practice guidelines for incident management and emergency response personnel..		Ymnx%LUL%uwt{nijx%fs%t{jw{nj|%tk%mt|%tnq%xunqqx%hfs%nrufhy%ts%rfwnsj%fsi%jxyzfwnsj%xmtwjqnsjx%fsi%mt|% vznhpq~%ymj~%hfs%wjht{jw3%Ymj%ithzrjsy%ijxhwngjx%ymj%kfyj%tk%tnq%ts%inkkjwjsy%xmtw ymfy%fwj%wjqj{fsy%yt%nrufhyx%fsi%wjht{jw~1%ytljymjw%|nym%ymj%jhtqtlnhfq%nrufhyx%tk%tnq%ts%xmtwjqnsjx3%Ny%[illegible] hzwwjsy%gjxy%uwfhynhj%ns%xmtwjqnsj%hqjfs2zu1%fsi%xzrrfwn¡jx%xtrj%tk%ymj%kzsifrjsyfq%fuuwtfhmjx%fsi% wjvznwjrjsyx%tk%nrufhy%fxxjxxrjsy3%F{fnqfgqj%fy?%myyu?44|||3nunjhf3twl4wjxtzwhjx4ltti2uwfhynhj4nrufhyx2tk2 tnq2xunqqx2ts2xmtwjqnsjx2ltti2uwfhynhj2lznijqnsjx2ktw2nshnijsy2rfsfljrjsy2fsi2jrjwljsh~2wjxutsxj2 ujwxtssjq4	IPIECA, International Association of Oil and Gas Producers
2022	Golbazi, Maryam ; Archer, Cristina L ; Alessandrini, Stefano	**Surface impacts of large offshore wind farms**		Golbazi, Archer, C. L., & Alessandrini, S. (2022). Surface impacts of large offshore wind farms. Environmental Research Letters, 17(6), 64021–. https://doi.org/10.1088/1748-9326/ac6e49	Offshore wind Surface temperature Wind turbine Wind farm impacts Wind energy	Future offshore wind farms around the world will be built with wind turbines of size and capacity never seen before (with diameter and hub height exceeding 150 and 100 m, respectively, and rated power exceeding 10 MW). Their potential impacts at the surface have not yet been studied. Here we conduct high-resolution numerical simulations using a mesoscale model with a wind farm parameterization and compare scenarios with and without offshore wind farms equipped with these 'extreme-scale' wind turbines. Wind speed, turbulence, friction velocity, and sensible heat fluxes are slightly reduced at the surface, like with conventional wind turbines. But, while the warming found below the rotor in stable atmospheric conditions extends to the surface with conventional wind turbines, with extreme-scale ones it does not reach the surface, where instead minimal cooling is found. Overall, the surface meteorological impacts of large offshore wind farms equipped with extreme-scale turbines are statistically significant but negligible in magnitude.	

Year	Authors	Title	Subcategory	Citation (APA)	Keywords	Summary	Links
2017	Michel, Jacqueline ; Fegley, Stephen R. ; Dahlin, Jeffrey A. ; Wood, Chip	**Oil spill response-related injuries on sand beaches: when shoreline treatment extends the impacts beyond the oil**		Michel, Fegley, S. R., Dahlin, J. A., & Wood, C. (2017). Oil spill response-related injuries on sand beaches: when shoreline treatment extends the impacts beyond the oil. Marine Ecology. Progress Series (Halstenbek), 576, 203–218. https://doi.org/10.3354/meps11917	Deepwater Horizon Oil spill Sand beach Shoreline Treatment Shoreline cleanup Impact Recovery	Studies of oil spills on sand beaches have focused traditionally on the effects of shortterm oil exposure, with recovery of sand beach macrobenthic communities occurring within severalweeks to several years. The Deepwater Horizon spill resulted in chronic, multi-year re-oiling and up to 4 yr of extensive and often intensive treatments. Of the 965 km of sand beaches that were oiled, shoreline treatment was documented on 683 km. Intensive mechanical treatment was conducted from 9 to 45 mo after the initial oiling on 32.4 km of shoreline in Louisiana, and deep beach excavation/sifting and tilling was conducted along 60.5 km in Louisiana, Alabama, and Florida, often along contiguous lengths of beach. Recovery of sand beach invertebrate communities from the combined effects of oiling and treatment would likely be delayed by 2 to 6 yr after the last response action was completed. We introduce the concept of 'Response Injury' categories that reflect both intensity and frequency of beach treatment methods. We use the literature on similar types of disturbances to sand beach communities (foot traffic, vehicular traffic, wrack removal, beach nourishment) to describe the expected impacts. Temporal patterns of responserelated disturbances can affect seasonal recruitment of organisms and the overall rate of ecosystem recovery from both oil exposure and treatment disturbance. This concept provides a framework for specifically assessing response-related impacts in future spills, which has not been considered in previous injury assessments.	
2020	Barron, Mace G. ; Vivian, Deborah N. ; Heintz, Ron A. ; Yim, Un Hyuk	**Long-Term Ecological Impacts from Oil Spills: Comparison of Exxon Valdez, Hebei Spirit, and Deepwater Horizon**		Barron, 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		The long-term ecological impacts of the Exxon Valdez oil spill (EVOS) are compared to two extensively studied and more recent large spills: Deepwater Horizon (DWH) and the Hebei Spirit oil spill (HSOS). Each of the three spills differed in magnitude and duration of oil released, environmental conditions, ecological communities, response and clean up measures, and ecological recovery. The EVOS began on March 24, 1989 and released 40.8 million liters of Alaska North Slope crude oil into the cold, nearly pristine environment of Prince William Sound, Alaska. EVOS oiled wildlife and rocky intertidal shorelines and exposed early life stages of fish to embryotoxic levels of polycyclic aromatic hydrocarbons (PAH). Long-term impacts following EVOS were observed on seabirds, sea otters, killer whales, and subtidal communities. The DWH spill began on April 10, 2010 and released 507 million liters of light Louisiana crude oil from 1600 m on the ocean floor into the Gulf of Mexico over an 87-day period. The DWH spill exposed a diversity of complex aquatic communities in the deep ocean, offshore pelagic areas, and coastal environments. Large scale persistent ecological effects included impacts to deep ocean corals, failed recruitment of oysters over multiple years, damage to coastal wetlands, and reduced dolphin, sea turtle, and seabird populations. The HSOS began on December 7, 2007 and released approximately 13 million liters of Middle Eastern crude oils into ecologically sensitive areas of the Taean area of western Korea. Environmental conditions and the extensive initial cleanup of HSOS oil stranded on shorelines limited the long-term impacts to changes in composition and abundance of intertidal benthic communities. Comparison of EVOS, DWH, and HSOS show the importance and complexity of the interactions among environment, oil spill dynamics, the affected ecological systems, and response actions.	

2020	Charles A. Schutte1,2 & John M. Marton1,3 & Anne E. Bernhard4 & Anne E. Giblin5 & Brian J. Roberts1	**No Evidence for Long-term Impacts of Oil Spill Contamination on Salt Marsh Soil Nitrogen Cycling Processes**	Schutte, Marton, J. M., Bernhard, A. E., Giblin, A. E., & Roberts, B. J. (2020). No Evidence for Long-term Impacts of Oil Spill Contamination on Salt Marsh Soil Nitrogen Cycling Processes. Estuaries and Coasts, 43(4), 865–879. https://doi.org/10.1007/s12237-020-00699-z	Salt marsh . Nitrogen cycle . Oil spill . Nitrification . Denitrification	Salt marshes are important sites of nitrogen cycling and removal that straddle the land/ocean interface, allowing them to intercept human-derived nitrogen before it reaches coastal waters where it causes problems like hypoxia and harmful algal blooms. In 2010, the Deepwater Horizon oil spill released an estimated five million barrels of crude oil into the Gulf of Mexico, significantly contaminating coastal wetlands over approximately 800 km of shoreline.We investigated microbial nitrogen cycling processes in soil from four salt marshes in Terrebonne Bay, Louisiana, USA that were either exposed or not exposed to Deepwater Horizon oil over the course of 1 year (2013–2014), 2.5–3.5 years post-spill. Specifically, we measured nitrification and denitrification potentials, nitrogen cycling functional gene abundances (nirS, bacterial and archaeal amoA), and soil physical and chemical properties.We show that variation in nitrification and denitrification potentials was independent of site oil exposure. Large yearto- year differences in springtime nitrification potentials were inversely related to plant live belowground biomass, indicating that competition for nitrogen is likely an important control on nitrification. There were positive correlations between nitrification potentials and both soil extractable nitrate concentrations and denitrification potentials, supporting the idea that denitrification is coupled with nitrification. We found no evidence that there was a long-term impact of oil exposure on salt marsh soil microbial nitrogen cycling processes and the nitrogen removal ecosystem service they provide. It is important to note, however, that these impacts could have been masked by high background variability in process rates or loss of oil exposed soil to coastal erosion.
2018	Sarah-Marie E. Baxter1 & Marie E. DeLorenzo2 & Peter B. Key2 & Katy W. Chung2 & Emily Pisarski2 & Barbara Beckingham3 & Michael H. Fulton2	**Toxicity comparison of the shoreline cleaners Accell Clean® and PES-51® in two life stages of the grass shrimp, Palaemonetes pugio**	Baxter, DeLorenzo, M. E., Key, P. B., Chung, K. W., Pisarski, E., Beckingham, B., & Fulton, M. H. (2018). Toxicity comparison of the shoreline cleaners Accell Clean® and PES-51® in two life stages of the grass shrimp, Palaemonetes pugio. Environmental Science and Pollution Research International, 25(11), 10926–10936. https://doi.org/10.1007/s11356-018-1370-2	Shoreline cleaner . Oil . Grass shrimp . Accell CleanSWA® . PES-51® . Larval development	Oil spills are a significant source of coastal pollution. Shoreline cleaners, used to remove oil from surfaces during spill response and remediation, may also act as toxins. Adult and larval grass shrimp, Palaemonetes pugio, were tested for lethal and sublethal impacts from two shoreline cleaners, Accell Clean SWA® and PES-51®, alone and in combination with crude oil using Chemically Enhanced Water Accommodated Fractions (CEWAFs). Median lethal toxicity values determined for the individual cleaners were similar. However, when tested in mixture with oil as CEWAFs, Accell Clean SWA resulted in greater hydrocarbon concentrations in the water column and greater toxicity than PES-51. Increased glutathione levels were observed for adult shrimp exposed to Accell Clean SWA, and glutathione was elevated in shrimp exposed to both CEWAFs. Larval shrimp development was delayed after exposure to both CEWAFs. These findings may have implications for managing and mitigating oil spills.
2022	D Abigail Renegar Paul A Schuler Anthony H Knap Richard E Dodge	**Tropical Oil Pollution Investigations in Coastal Systems: A Synopsis of Impacts and Recovery**	Renegar, D. A., Schuler, P. A., Knap, A. H., & Dodge, R. E. (2022). TRopical Oil Pollution Investigations in Coastal Systems [TROPICS]: A synopsis of impacts and recovery. Marine pollution bulletin, 181, 113880. https://doi.org/10.1016/j.marpolbul.2022.113880	Coral reefs Dispersed oil Mangroves Oil spill Seagrasses TROPICS field experiment	The TRopical Oil Pollution Investigations in Coastal Systems (TROPICS) experiment, conducted on the Caribbean coast of Panama, has become one of the most comprehensive field experiments examining the long-term impacts of oil and dispersed oil exposures in nearshore tropical marine environments. From the initial experiment through more than three decades of study and data collection visits, the intertidal and subtidal communities have exhibited significantly different impact and recovery regimes, depending on whether the sites were exposed to crude oil only or crude oil treated with a chemical dispersant. This review provides a synopsis of the original experiment and a cumulative summary of the results and observations, illustrating the environmental and ecosystem trade-offs of chemical dispersant use in mangrove, seagrass, and coral reef environments.
1987	Edward H. Owens John R. Harper Wishart Robson Paul D. Boehm	**Fate and Persistence of Crude Oil Stranded on a Sheltered Beach**	Owens, Harper, J. R., Robson, W., & Boehm, P. D. (1987). Fate and Persistence of Crude Oil Stranded on a Sheltered Beach. *Arctic* , *40* (5), 109–123. https://doi.org/10.14430/arctic1807		
2021		**Coastline in-situ burning of oil spills in the Arctic. Studies of the environmental impacts on the littoral zone community**	Susse Wegeberg, Janne Fritt-Rasmussen, Ole Geertz-Hansen, Jozef Wiktor, Lonnie Bogø-Wilms, Morten Birch Larsen, Lars Renvald, Kim Gustavson, Coastline in-situ burning of oil spills in the Arctic. Studies of the environmental impacts on the littoral zone community, Marine Pollution Bulletin, Volume 173, Part B, 2021, 113128, ISSN 0025-326X, https://doi.org/10.1016/j.marpolbul.2021.113128.	Oil spill response Arctic Coastline in-situ burning Environmental effects Tidal community Littoral zone	In-situ burning (ISB) has been an oil combat technique studied since the 1950s. However, burning of the oil on the sea surface along the coastline, coastline ISB (cISB), is novel and was tested for the first time in the Arctic along a rocky coast in the summer 2017. A light crude oil was burned and effects of the cISB operation on the littoral zone communities investigated. The impact on macroalgal vegetation and associated fauna was analysed in three littoral zone levels. The analyses revealed limited effects on the littoral community, and that variation between sample plots and years in macroalgal biomass and coverage, as well as fauna biomass and abundance was higher than the impact from cISB. Therefore, it is concluded that cISB in the Arctic along a rocky shore may be an oil spill response option with relatively low environmental side effects for the specific oil type used.

2022	B´erang`ere P´equin Qinhong Cai Kenneth Lee Charles W. Greer	**Natural attenuation of oil in marine environments: A review**	Bérangère Péquin, Qinhong Cai, Kenneth Lee, Charles W. Greer, Natural attenuation of oil in marine environments: A review, Marine Pollution Bulletin, Volume 176, 2022, 113464, ISSN 0025-326X, https://doi.org/10.1016/j.marpolbul.2022.113464.	Oil Natural attenuation Microbial communities Seawater Biodegradation Marine environment	Natural attenuation is an important process for oil spill management in marine environments. Natural attenuation affects the fate of oil by physical, chemical, and biological processes, which include evaporation, dispersion, dissolution, photo-oxidation, emulsification, oil particle aggregation, and biodegradation. This review examines the cumulative knowledge regarding these natural attenuation processes as well as their simulation and prediction using modelling approaches. An in-depth discussion is provided on how oil type, microbial community and environmental factors contribute to the biodegradation process. It describes how our understanding of the structure and function of indigenous oil degrading microbial communities in the marine environment has been advanced by the application of next generation sequencing tools. The synergetic and/or antagonist effects of oil spill countermeasures such as the application of chemical dispersants, in-situ burning and nutrient enrichment on natural attenuation were explored. Several knowledgegaps were identified regarding the synergetic and/or antagonistic effects of active response countermeasures on the natural attenuation/biodegradation process. This review highlighted the need for field data on both the effectiveness and potential detrimental effects of oil spill response options to support modelling and decisionmaking on their selection and application.
2022	Markus Huettel	**Oil Pollution of Beaches**	Markus Huettel, Oil pollution of beaches, Current Opinion in Chemical Engineering, Volume 36, 2022, 100803, ISSN 2211-3398, https://doi.org/10.1016/j.coche.2022.100803.		Oil contamination of beaches causes significant damage as these ecosystems are unique habitats that provide foraging and nesting grounds for a variety of animals including endangered species, and play pivotal roles in shore line protection and coastal economies. Even small oil spills in the ocean result in sizable slicks that currents transport to sandy beaches that line a third of the global shoreline. Weathering during transit reduces the degradability, viscosity and density of the oil, influencing its fate at the shore. While photolysis, biodegradation, tidal pumping, and seasonal sediment movement facilitate relatively rapid removal of stranded oil from sandy beaches of temperate and warm climes, thick buried oil layers persist for decades in armored gravel beaches of cold shores, emphasizing the controls of beach morphodynamics, biodegradation, and climate in the recovery from beach oil pollution.
2022	Michel C. Boufadel Tamay Özgökmen Scott A. Socolofsky Vassiliki H. Kourafalou Ruixue Liu Kenneth Lee	**Oil Transport Following the *Deepwater Horizon* Blowout**	Boufadel MC, Özgökmen T, Socolofsky SA, Kourafalou VH, Liu R, Lee K. Oil Transport Following the *Deepwater Horizon* Blowout. Ann Rev Mar Sci. 2023 Jan 16;15:67-93. doi: 10.1146/annurev-marine-040821-104411. Epub 2022 Jun 30. PMID: 35773215.	oil spreading dispersion droplet formation eddy diffusivity	The Deepwater Horizon oil spill in the Gulf of Mexico in 2010 was the largest in US history, covering more than 1,000 km of shorelines and causing losses that exceeded $50 billion.While oil transformation processes are understood at the laboratory scale, the extent of the Deepwater Horizon spill made it challenging to integrate these processes in the field. This review tracks the Deepwater Horizon oil during its journey from the Mississippi Canyon block 252 (MC252) wellhead, first discussing the formation of the oil and gas plume and the ensuing oil droplet size distribution, then focusing on the behavior of the oil on the water surface with and without waves. It then reports on massive drifter experiments in the Gulf of Mexico and the impact of the Mississippi River on the oil transport. Finally, it concludes by addressing the formation of oil–particle aggregates. Although physical processes lend themselves to numerical modeling, we attempted to elucidate them without using advanced modeling, as our goal is to enhance communication among scientists, engineers, and other entities interested in oil spills.
2014	Sandra Fernández-Fernández Ana M. Bernabeu Daniel Rey Ana P. Mucha C. Marisa R. Almeida Frédéric Bouchette	**The Effect of Sand Composition on the degredation of buried oil**	Fernández-Fernández S, Bernabeu AM, Rey D, Mucha AP, Almeida CMR, Bouchette F. The effect of sand composition on the degradation of buried oil. Mar Pollut Bull. 2014 Sep 15;86(1-2):391-401. doi: 10.1016/j.marpolbul.2014.06.040. Epub 2014 Jul 17. PMID: 25044040.	Oil spill Buried oil Sandy beaches Mineralogical composition Oil degradation Scanning electron microscope	The potential effects of the mineralogical composition of sediment on the degradation of oil buried on sandy beaches were investigated. Toward that purpose, a laboratory experiment was carried out with sandy sediment collected along NW Iberian Peninsula beaches, tar-balls from the Prestige oil spill (NW Spain) and seawater. The results indicate that the mineralogical composition is important for the physical appearance of the oil (tar-balls or oil coatings). This finding prompted a reassessment of the current sequence of degradation for buried oil based on compositional factors. Moreover, the halo development of the oil coatings might be enhanced by the carbonate concentration of the sand. These findings open new prospects for future monitoring and management programs for oiled sandy beaches.
2019	Michel Boufadel Xiaolong Geng Chinjiang An Edward Owens Zhi Chen Kenneth Lee Elliott Taylor Roger C. Prince	**A Review on the Factors Affecting the Deposition, Retention, and Biodegredation of Oil Stranded on Beached and Guidelines for Designing Laboratory Experiments**	Boufadel, M., Geng, X., An, C. et al. A Review on the Factors Affecting the Deposition, Retention, and Biodegradation of Oil Stranded on Beaches and Guidelines for Designing Laboratory Experiments. Curr Pollution Rep 5, 407–423 (2019). https://doi.org/10.1007/s40726-019-00129-0	Oil Spills Bioremediation Biodegredation Beach Dynamics Laboratory Experiment Environmental Factors	The distribution and persistence of oil within the matrix of a beach depends on the oil and beach properties, the presence of fines in the water column, and beach hydrodynamics and biochemistry. In this review, we attempted to provide an assessment of the journey of oil from offshore oil spills until it deposits within beaches. In particular, we addressed the disparity of spatial scales between microscopic processes, such as the formation of oil particle ggregates and oil biodegradation, and large-scale forcings, such as the tide. While aerobic biodegradation can remove more than 80% of the oil mass from the environment, its rate depends on the pore water concentration of oxygen and nutrients, both of them vary across the beach and with time. For this reason, we discussed in details the methods used for measuring water properties in situ and ex situ. We also noted that existing first-order decay models for oil biodegradation are expedient, but might not capture impacts of water chemistry on oil biodegradation. We found that there is a need to treat the beach–nearshore system as one unit rather than two separate entities. Scaling down largescale hydrodynamics requires a coarser porous medium in the laboratory. Unfortunately, this implies that microscopicscale processes cannot be reproduced in such a setup, and one needs a separate system for simulating small-scale processes. Our findings of large spatio-temporal variability in pore-water properties suggest that major advancements in addressing oil spills on beaches require holistic approaches that combine hydrodynamics with biochemistry and oil chemistry

Year	Authors	Title	Subcategory	Citation (APA)	Keywords	Summary	Links
2021	Xiaolong Geng Charbel Abou Khalil Roger C. Prince Kenneth Lee Chinjiang An Michel C. Boufadel	**Hypersaline Pore Water in Gulf of Mexico Beaches Prevented Efficient Biodegredation of Deepwater Horizon Beached Oil**		Geng X, Khalil CA, Prince RC, Lee K, An C, Boufadel MC. Hypersaline Pore Water in Gulf of Mexico Beaches Prevented Efficient Biodegradation of Deepwater Horizon Beached Oil. Environ Sci Technol. 2021 Oct 19;55(20):13792-13801. doi: 10.1021/acs.est.1c02760. Epub 2021 Oct 7. PMID: 34617733.	Deepwater Horizon Oil Spill Gulf Beaches Oil Biodegredation Hypersaline Condition Capillary Potential Beach Hydrodynamics Evaporation	The 2010 Deepwater Horizon (DWH) blowout released 3.19 million barrels (435 000 tons) of crude oil into the Gulf of Mexico. Driven by currents and wind, an estimated 22 000 tons of spilled oil were deposited onto the Northeastern Gulf shorelines, adversely impacting the ecosystems and economies of the Gulf coast regions. In this work we present field work conducted at the Gulf beaches in three U.S. States during 2010−2011: Louisiana, Alabama, and Florida, to explore endogenous mechanisms that control persistence and biodegradation of the C252-oil deposited within beach sediments as deep as 50 cm. The work involved over 1500 measurements incorporating oil chemistry, hydrocarbondegrading microbial populations, nutrient and DO concentrations, and intrinsic beach properties. We found that intrinsic beach capillarity along with groundwater depth provides primary controls on aeration and infiltration of near-surface sediments, thereby modulating moisture and redox conditions within the oil-contaminated zone. In addition, atmosphere−ocean−groundwater interactions created hypersaline sediment environments near the beach surface at all the studied sites. The fact that the ilcontaminated sediments retained near or above 20% moisture content and were also eutrophic and aerobic suggests that the imiting factor for oil biodegradation is the hypersaline environment due to evaporation, a fact not reported in prior studies. These results highlight the importance of beach porewater hydrodynamics in generating unique hypersaline sediment environments that inhibited oil decomposition along the Gulf shorelines following DWH.	
2015	Xiaolong Geng Michel C. Boufadel Kenneth Lee Stewart Abrams Makram Suidan	**Biodegredation of subsurface oil in a tidally influenced sand beach: Impact of hyfraulics and interaction with pore water chemistry**		Geng, Xiaolong & Boufadel, Michel & Lee, Kenneth & Abrams, Stewart & Suidan, Makram. (2015). Biodegradation of subsurface oil in a tidally influenced sand beach: Impact of hydraulics and interaction with pore water chemistry: Subsurface oil biodegradation in a tidally-influenced beach. Water Resources Research. 51. 10.1002/2014WR016870.		The aerobic biodegradation of oil in tidally influenced beaches was investigated numerically in this work using realistic beach and tide conditions. A numerical model BIOMARUN, coupling a multipleMonod kinetic model BIOB to a density-dependent variably saturated groundwater flow model 2-D MARUN, was used to simulate the biodegradation of low-solubility hydrocarbon and transport processes of associated solute species (i.e., oxygen and nitrogen) in a tidally influenced beach environment. It was found that different limiting factors affect different portions of the beach. In the upper intertidal zone, where the inland incoming nutrient concentration was large (1.2 mg N/L), oil biodegradation occurred deeper in the beach (i.e., 0.3 m below the surface). In the midintertidal zone, a reversal was noted where the biodegradation was fast at shallow locations (i.e., 0.1 m below the surface), and it was due to the decrease of oxygen with depthdue to consumption, which made oxygen the limiting factor for biodegradation. Oxygen concentration in the midintertidal zone exhibited two peaks as a function of time. One peak was associated with the high tide, when dissolved oxygen laden seawater filled the beach and a second oxygen peak was observed during low tides, and it was due to pore oxygen replenishment from the atmosphere. The effect of the capillary fringe (CF) height was investigated, and it was found that there is an optimal CF for the maximum biodegradation of oil in the beach. Too large a CF (i.e., very fine material) would attenuate oxygen replenishment (either from seawater or the atmosphere), while too small a CF (i.e., very coarse material) would reduce the interaction between microorganisms and oil in the upper intertidal zone due to rapid reduction in the soil moisture at low tide.	
2022	T Prabhakar Clement Gerald F John	**A perspective on the state of Deepwater Horizon oil spill related tarball contamination and its impacts on alabama beaches**				The Deepwater Horizon (DWH) accident spilled over 785 million liters of crude oil into the Gulf of Mexico (GOM). A substantial fraction of the spilled oil impacted the northern GOM shoreline, including Alabama beaches. The eached oil was in the form of brownish-orange, water-in-oil emulsion, commonly known as mousse. Although significant remediation efforts were undertaken to clean the contaminated beaches, oil residues in the form of tarballs continue to contaminate various GOM beaches. This study reviews recent literature related to the DWH tarball contamination problem and its impacts on GOM beaches, primarily focusing on the beaches located in Alabama. Though the DWH oil spill is an unfortunate disaster, for researchers it constitutes a large-scale experiment conducted on a natural system. This anthropogenic experiment has taught scientists numerous useful lessons and has also posed several challenging questions, some of which are discussed in this review.	
2023	Troy Baker, NOAA and Jamie Holmes, Jeff Morris, Heather Forth, Fabrizio Bonatesta of Abt Associates	Per- and Polyfluorinated Alkyl Substances (PFAS) in Aqueous Firefighting Foam (AFFF)				The goal of this brief is to provide scientists and decision-makers responding to flammable-liquid fire threats with knowledge and resources to evaluate the potential adverse effects of AFFF and reduce risks to human health and the environment. This science brief contains: • An overview of the many "families" of PFAS and their chemistry • A summary of the general types of Class B (flammable–liquid) firefighting foams, including fluorinated and fluorine–free foams • An overview of the fate, transport, and toxicity of PFAS in AFFF • Best practices and tradeoff evaluations to consider when responding to Class B fire threats that require foam • Suggestions for future work to address data gaps.	httpshttps://universitysystemnh-my.sharepoint.com/:b:/g/personal/kathym_usnh_edu/EUvsZeALkwlLo66GFyxlh64B4oa4yWrY1hLKPwoFjgdlBA?e=896Grm://universitysystemnh-my.sharepoint.com/:b:/g/personal/kathym_usnh_edu/EUvsZeALkwlLo66GFyxlh64B4oa4yWrY1hLKPwoFjgdlBA?e=896Grm

Appendix G: Post Workshop Summary Overview

Shoreline Oil Spill Response Knowledge Gaps and Technological Development Opportunities

May 9-11, 2023

In May of 2023, BSEE partnered with NOAA OR&R and UNH CRRC to host a workshop entitled "Shoreline Oil Spill Response Knowledge Gaps and Technological Development Opportunities". Over the course of the three days, there were 49 participants of which 19 participated virtually. The purpose of this workshop was to identify unknown gaps and opportunities in response technologies and scientific research associated with oil spill shoreline response. This included the exploration of the current state of the science of oil spill research associated with impacts, potential and realized, of crude oil effects to shoreline environments and aid in the identification of countermeasures and response alternatives that may become part of the oil spill response toolbox.

Objectives

1. Identify gaps in the current state of the science from impacts to shorelines from impacts to crude oil and dielectric fluids from offshore facilities through focused workgroup activities and breakout sessions.

2. Identify operational constraints of shoreline techniques using data visualization platforms and case study examples.

Overview

This in person workshop was held over the course of three days at NOAA's Western Regional offices in Seattle, Washington. Day one of the workshop consisted of three plenary panels: *Response, Detection,* and *Fate and Effects* that discussed knowledge gaps and opportunities for scientific research and technology improvements that related to these areas of oil spill shoreline response. Following the panels, the in person participants were broken up into breakout groups to discuss the knowledge gaps and technology needs that were brough up during the plenary presentation and subsequent Q&A sessions. For every plenary topic, the groups prioritized up to thee knowledge gaps / needs. The day concluded with all breakout groups presenting their top priorities and a vote was held to select the top priorities of all participants, in-person and virtual. (*See below*).

Day two of the workshop followed the same format of presentations and breakout group prioritization as day one with three new plenary panels: *Policy, Emerging Oils/Products and Experimental Lakes*, and *Changing Future.* The third day consisted of the breakout groups taking the top three priorities from each of the 6 plenary sessions and creating a research project to address each of the knowledge gaps and technology needs. More information will be forthcoming in the official workshop report.

Shoreline Oil Spill Response and Technology Priorities

RESPONSE	DETECTION	FATE AND EFFECTS	EMERGING OILS/ PRODUCTS	EXPERIMENTAL LAKES	CHANGING FUTURE
Response technologies (crewed/uncrewed) to be developed/repurposed specifically for cleanups	Platform/sensor type evaluations for shoreline detection + rapid image processing & interpretation by SMEs	Ecosystem Modeling	Detection, response, fate, effects, and risks of emerging fuels	Oil under ice nearshore	Think Tank/incubator for new ideas on specific shoreline topics
Set asides, monitoring, longitudinal studies. Assessing risk for residual oil/ clean up endpoints that may generate controversy	Detection of oil for challenging conditions		Realistic conditions and environmentally relevant toxicity testing of emerging products	Remote Sensing/ Detection of oil on shorelines and nearshore	Emerging shoreline protection technologies
Research on how best to communicate shoreline response technologies to the public	Develop job aids/ training tools for oil detection on shorelines			Shoreline Efficacy Testing of Techniques: Surface washing agents, Herders, Set Asides, In-Situ Burning, etc.	Challenges with climate change and impacts to infrastructure, loss of permafrost, and changes in exposure routes and habitats

For more information, please visit the CRRC website: https://crrc.unh.edu/resource/shoreline-response-gaps

Appendix H: Technical Summary

REPORT TITLE: Shoreline Oil Spill Response Knowledge Gaps and Technological Development Opportunities

CONTRACT NUMBER(S): E22PG00010,

FISCAL YEARS(S) OF PROJECT FUNDING: FY2023

CUMULATIVE PROJECT COST: $75,000.00

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PRINCIPAL INVESTIGATOR(S)*:

KEY WORDS: shoreline, oil spill, response, clean-up, R&D, research

* The affiliation of the Principal Investigators(s) may be different than that listed for Project Manager(s).

Department of the Interior (DOI)
The Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors the Nation's trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

Bureau of Safety and Environmental Enforcement (BSEE)
The mission of the Bureau of Safety and Environmental Enforcement works to promote safety, protect the environment, and conserve resources offshore through vigorous regulatory oversight and enforcement.

BSEE Oil Spill Preparedness Program
BSEE administers a robust Oil Spill Preparedness Program through its Oil Spill Preparedness Division (OSPD) to ensure owners and operators of offshore facilities are ready to mitigate and respond to substantial threats of actual oil spills that may result from their activities. The Program draws its mandate and purpose from the Federal Water Pollution Control Act of October 18, 1972, as amended, and the Oil Pollution Act of 1990 (October 18, 1991). It is framed by the regulations in 30 CFR Part 254 – *Oil Spill Response Requirements for Facilities Located Seaward of the Coastline,* and 40 CFR Part 300 – *National Oil and Hazardous Substances Pollution Contingency Plan*. Acknowledging these authorities and their associated responsibilities, BSEE established the program with three primary and interdependent roles:

- Preparedness Verification,
- Oil Spill Response Research, and
- Management of Ohmsett - the National Oil Spill Response Research and Renewable Energy Test Facility.

The research conducted for this Program aims to improve oil spill response and preparedness by advancing the state of the science and the technologies needed for these emergencies. The research supports the Bureau's needs while ensuring the highest level of scientific integrity by adhering to BSEE's peer review protocols. The proposal, selection, research, review, collaboration, production, and dissemination of OSPD's technical reports and studies follows the appropriate requirements and guidance such as the Federal Acquisition Regulation and the Department of Interior's policies on scientific and scholarly conduct.