

The Royal Society of Canada Expert Panel on the Behaviour and Environmental Impacts of Crude Oil Released into Aqueous Environments

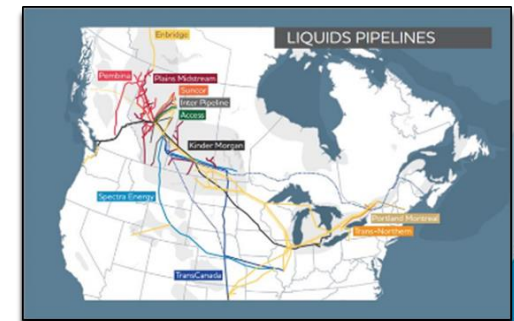
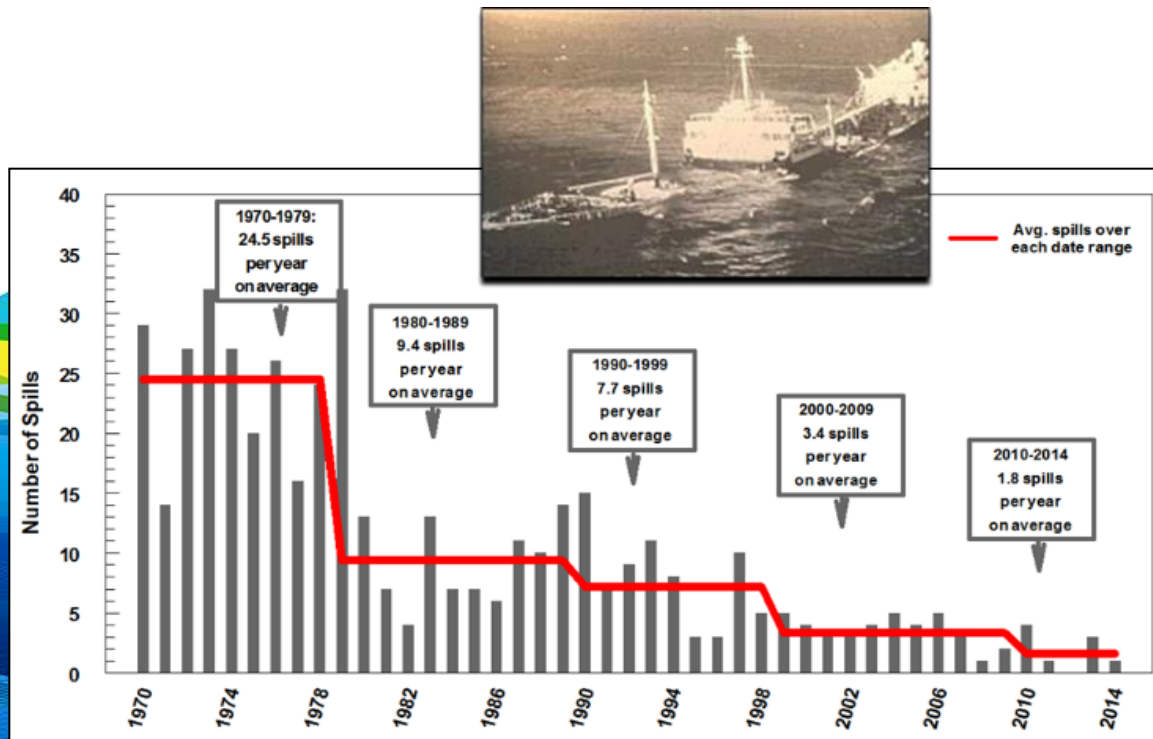
Research Recommendations and Follow-up

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Oil Spill Risks

- Canada produces some three million barrels of oil every day, importing hundreds of thousands more, and all of it travels somewhere - accidents happen
- The incidence of marine oil spills from tankers has diminished, however, there is growing concern over the risks of spills in coastal remote areas and along other transportation zones



Behaviour and Environmental Impacts of Crude Oil Released into Aqueous Environments

Chapters

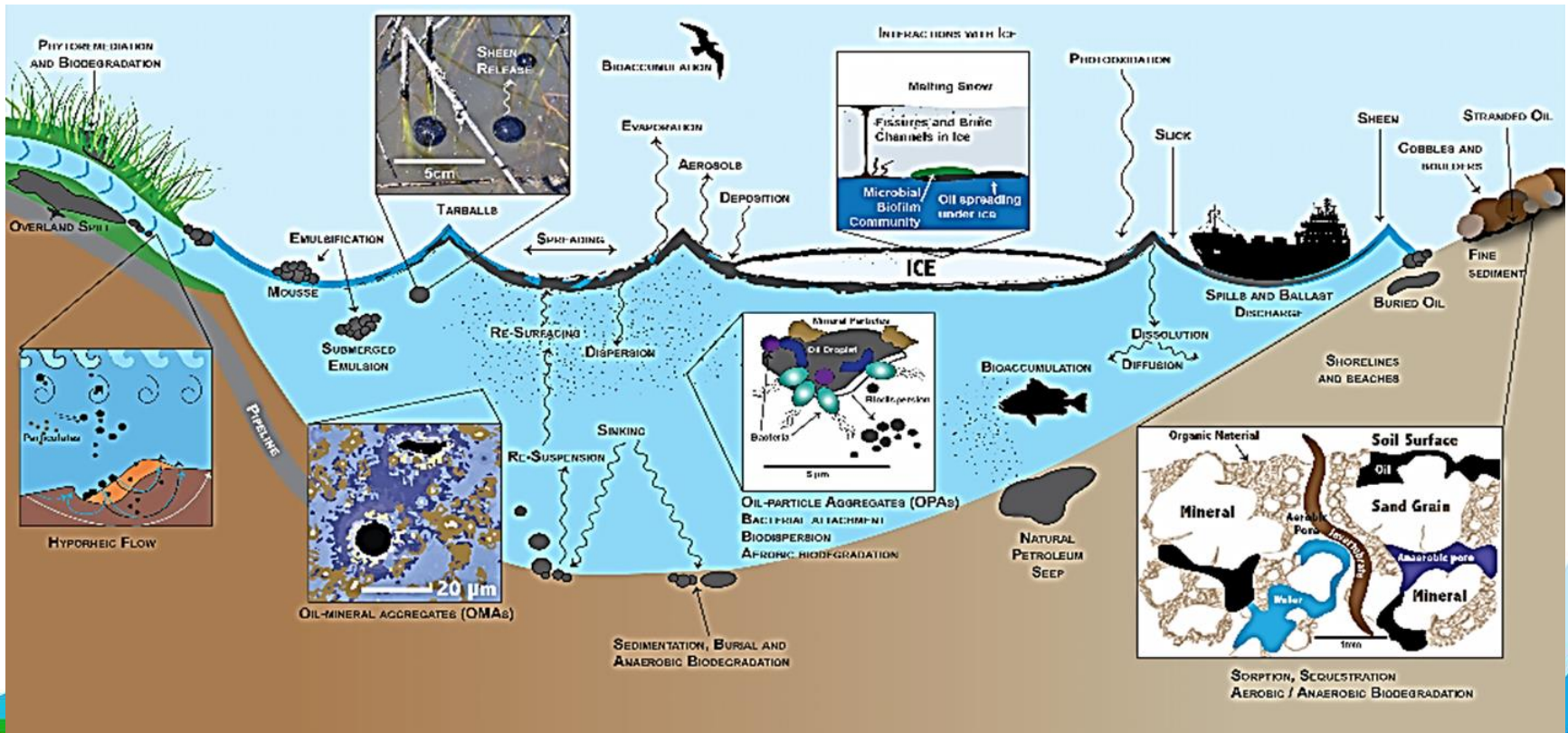
1. Introduction – context; spills in Canada
2. Chemical Composition, Properties and Behaviour of Spilled Oil
3. Effect of the Environment on the Fate and Behaviour of Oil
4. Oil Toxicity and Ecological Effects
5. Modelling of Oil Spills in Water
6. Review of Oil Spill Response Options
7. Prevention and Response Decision Making
8. Risks from Oil Spills
9. Summary and Recommendations



Summary of the RSC Report

- Oils transported in Canada represent a chemical continuum, from light shale oils to diluted bitumens and heavy fuel oils
- The unique properties of each oil, and where it spills, determines its environmental behaviour and fate
- Although oil type is important, oil spill impacts, including the effectiveness of an oil spill response, depend mainly on the environmental characteristics and conditions where the spill takes place and the time lost before remedial operations

Fate and Behaviour of Oil Spilled in the Aquatic Environment



Each spill is unique due to:

- Variety and complexity of environmental processes (physical, chemical and biological)
- Different fates and different timescales (immediate to decades or centuries)
- Differences in the type of oil and type of environment and prevailing conditions

Primary Oil Spill Response Options



Natural recovery

- Natural attenuation, Evaporation, Photooxidation, Biodegradation

Physical response methods

- Containment and recovery, Physical dispersion (OMA), in situ burning (ISB), etc.

Biological and chemical methods

- Bioremediation, Phytoremediation, Chemical dispersion, Solidifiers, Herding agents

Case Studies: Understanding the Significance of Site-Specific Factors



Arrow Spill: Heavy fuel oil on cobble beaches; fate & persistence; 'set asides'



Exxon Valdez Spill: Clean-up impacts; species diversity; diversity of impacts (e.g., fish recruitment)



Pine River Pipeline Spill: sour crude; oil movement downstream; remote area; clean-up impacts



Deepwater Horizon: Deepwater oil plumes; effects on fitness of fish; dispersant interactions



Wabamun Lake Spill: Closed system; sinking oil; clean-up impacts; multiple stressors; ecosystem services



Kalamazoo River: Fate & behaviour of dilbit; sediment contamination

Conclusions and Research Challenges Identified from the Case Studies

- **Delayed response** was a critical factor affecting the consequences of spills
- It's always a **combination of factors** which determine the consequences - oil type, response time, environmental characteristics, and effects of clean-up operations
- The **lack of pre-spill baseline data** seriously limits the ability to predict or monitor long-term effects
- Validation of oil spill response techniques is hampered by inadequate methods for **measuring the effectiveness of response measures**



- The presence of **long-term stresses from other sources** (natural and human-related) may tax the capacity of ecosystems to be resilient to shocks of oil spills
- **Post-spill monitoring** must be conducted according to standardized protocols

1. Understanding of Environmental Impacts from Crude Oil Spills in High-risk and Poorly Understood Areas

Marine

- Assess the risks of deep sea blowouts (e.g., subsurface oil plumes, residual oil in sediments) and the effectiveness of available and emerging response strategies

Arctic

- Complex interactions among physical, chemical and biological factors unique to Arctic conditions in the presence of different types of spilled crude oil
- Evaluate risks associated with the transport of petroleum hydrocarbons in the Arctic (i.e., ships and pipelines)



Freshwater

- Fate and effects of oil spilled in freshwater ecosystems

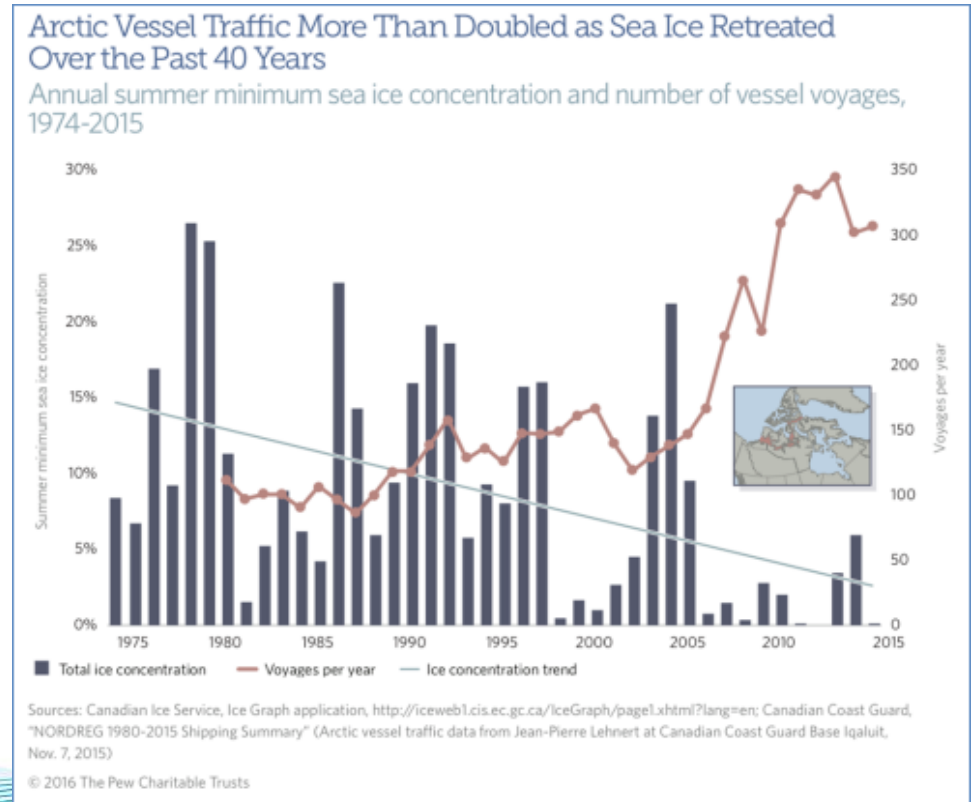
Risk of Arctic Oil Spills and Oil Spill Response Challenges

Climate change increasing Arctic accessibility for commercial activities

- Oil and gas
- Shipping
- Fishing?
- Tourism

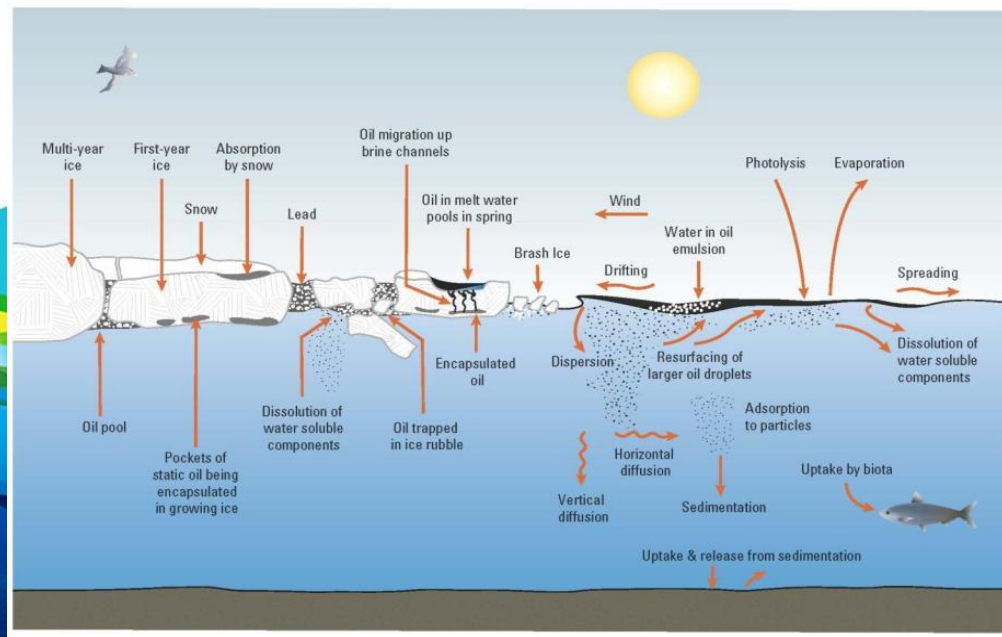
Challenges:

- Extreme weather
- Vast distances
- Lack of infrastructure
- A vast shoreline habitat
- Vulnerable Arctic species, ecosystems, cultures



Potential risks to Arctic Environments

- Under similar test conditions, there is little difference in oil toxicity between temperate & Arctic species
- Data from temperate species can provide a first approximation of risks to Arctic species
- Impacts of oil spills in Arctic ecosystems are driven more by factors that influence the exposure of organisms to oil than by differences in sensitivity to oil



Arctic Infrastructure Challenges

- Effective oil spill response requires improved:
 - Communications, transportation, traffic monitoring systems
 - Stronger supply chains, pre-deployed response equipment
 - Improved port and air access
 - Personnel, berthing, housing, waste and medical support facilities
 - Human & organizational infrastructure—tribal liaisons, training
 - Integrated scientific and traditional knowledge
 - Improved funding for development, deployment, and maintenance of temporary and/or permanent infrastructure



2. Improved Understanding of Effects of Oil Spills on Aquatic Organisms, Communities and Ecosystems

- Develop improved *methods to detect and track spilled oil* and to **predict potential effects**
- Study *effects on aquatic species at the level of populations, communities and ecosystems*
- Understand the indirect *effects of oil spills on ecological processes* (trophic level interactions)
- Investigate the cumulative and interactive *effects of co-exposure to oil and other human induced and natural environmental stressors*
- *Study the resilience and recovery of aquatic ecosystems* affected by oil spills
- Investigate the socioeconomic impacts of oil spills, as a first step in implementing an *ecosystem services* approach to oil spill impact assessments



3. National Program for Baseline Research and Monitoring

- Collect and evaluate **baseline information from high-risk, poorly understood areas**
- **Continue work on ecosystem sensitivity maps**, including the identification of highly-valued species and vulnerable habitats, prioritized according to recent relative risk assessments
- **Understand the natural variability** of population and community metrics (e.g., abundance, diversity, productivity) across physical and chemical gradients, as well as across time
- Develop a **network to provide baseline data** to support decision making during oil spill response operations



4. Controlled Field Trials to Study Spill Behaviour and Effects

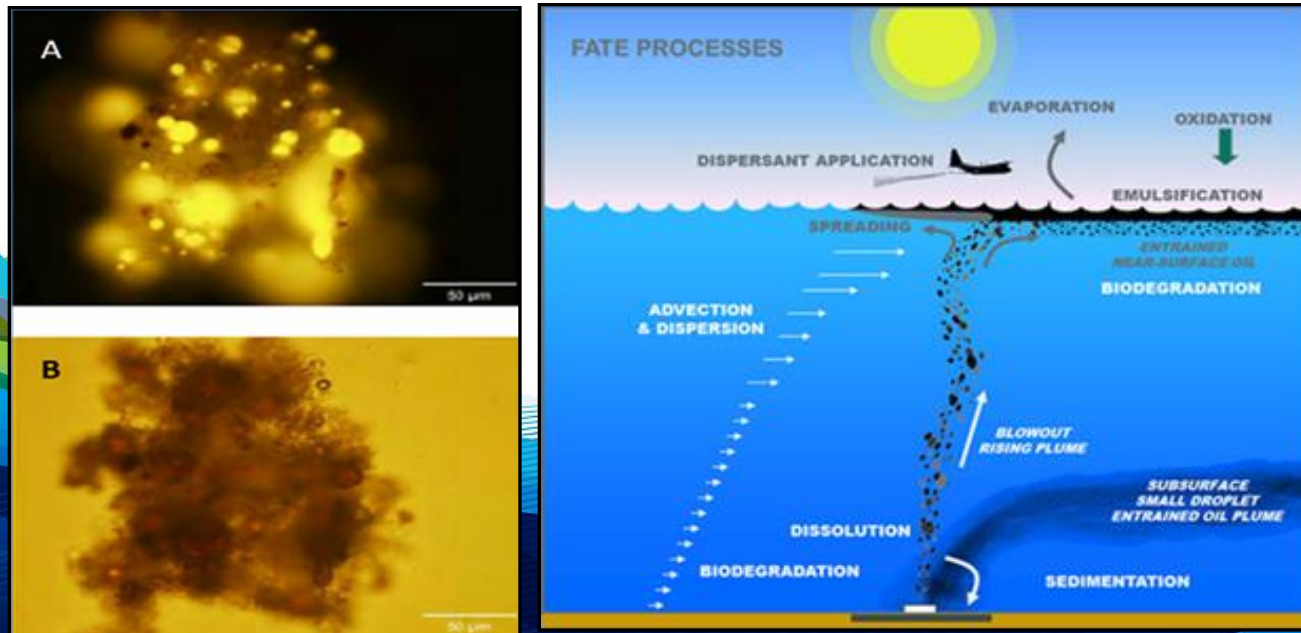
Controlled field experiments on oil spills with rigorous statistical designs

- Sanctioned by the Federal Government through a new permitting system
- Test a spectrum of **oil types** at a **variety of sites** representing different coastal marine and freshwater ecosystems and **conditions**
- Validate standardized methods for detailed chemical analysis of poorly-characterized oil components that will *improve our understanding of oil weathering processes* within the environment
- Develop and validate *new oil spill response measures*



4. Controlled Field Trials to Study Spill Behaviour and Effects

- Develop contingency funds to support research on the fate, behaviour and effects following “*spills of opportunity*”
- Build knowledge on the *influence of natural weathering* processes, various *spill response measures*, and the *rate and extent of habitat recovery*



5. Improve the Efficacy of Spill Response Technologies and Strategies

- To develop, refine and validate *improved methods for contaminated-site remediation* following oil spills
- Study the *efficacy and environmental impacts of conventional and new oil spill remediation options*, particularly in Arctic and freshwater ecosystems
- To address the long-standing remediation question “how clean is clean?”
 - *Identify endpoint benchmarks* for treatment
 - Consideration of impacts on *ecosystem services*



Arctic Oil Spill Countermeasures

- Specific R&D needs:
 - Improved ignition methods for in situ burning
 - Dispersant effectiveness at low temperatures
 - Understanding limits of mechanical recovery
 - Improved under-ice detection and response
 - Integrating remote sensing and observational techniques for detection and tracking
 - Determining/verifying hydrocarbon biodegradation rates
 - Evaluating the toxicity of dispersants and chemically dispersed oil on key Arctic marine species

Responding to Oil Spills in the U.S. Arctic marine Environment, National Research Council of the National Academies, 2014

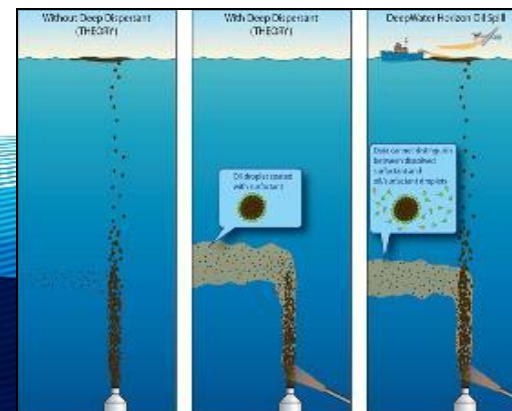
Alternative Response Measures (ARMs) / Spill Treating Agents / Chemical Dispersants

Chemical dispersants facilitate oil dilution and microbial degradation

- Dispersion can reduce the oil exposure of surface and shoreline species but increase the exposure of algae, invertebrates and fish
- *The potential impacts of deep water oil dispersion at well blow-outs remain controversial*

Dispersant use approvals in the Arctic should be based on sound science:

- *Research on fates and effects of chemically-dispersed oil in the environment*
- *Experiments using Arctic-like oils*
- *Toxicity tests of chemically-dispersed oil at realistic concentrations and exposures*
- *Use of representative Arctic species at appropriate conditions*

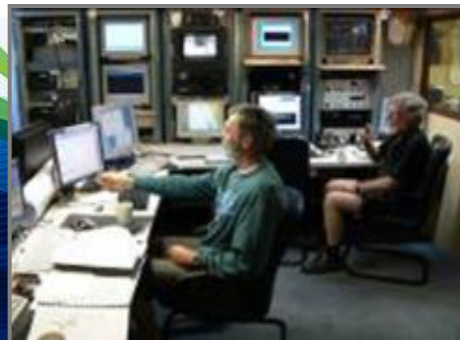


Net Environmental Benefit Analysis (NEBA) Processes

- Identify effective countermeasures, analyze environmental trade-offs
 - Protect sensitive/important ecosystem components
 - Include information on oil transport, fate, and effects
 - Knowledge of operational limits
 - Weigh pros and cons of each countermeasure
 - Consider logistical constraints and cleanup intensity
- Process should involve regulators, resource managers, health authorities, technical specialists, scientific experts, and local experts.

6. Improve Spill Prevention and Response Decision Support Systems

- **Advance environmental forensics, remote sensing and in-situ measurement, early warning and diagnosis, and biological monitoring** to improve spill prevention and decision making
- Develop methods for the derivation of comprehensive **mass balances** for spilled and recovered oil
- Develop **modelling methods to simulate and optimize individual and collective clean-up processes** to support response decision-making
- **Coordinate a comprehensive national database** to provide data on the fate, behaviour and effects of various types of oil spilled



6. Improve Spill Prevention and Decision Support Systems

Involve Indigenous peoples from all parts of Canada in the development of research protocols, oil spill preparedness, clean-up and remediation, including long-term “spill of opportunity” investigations

- Application of ***local knowledge*** and historic conditions in preparedness planning
- Traditional use values important for ***restoration of ecosystem services***
- ***Training and employment opportunities*** regarding clean-up, restoration and monitoring
- ***Definition of benchmarks for acceptable levels of residual oil***



7. Enhancement of Oil Spill Risk Assessments in Canada

- ***Follow-up relative risk assessments*** are needed to build upon the Transport Canada assessments of marine spills, focusing on high-sensitivity areas
- A comprehensive national database with consideration of:
 - Efficacy of oil spill countermeasures over a range of environmental conditions
 - Traditional uses of resources
 - Human activities that could affect relative risk (e.g. mining)



7. Enhancement of Oil Spill Risk Assessments in Canada

- **Update and refine risk assessment methods:**
 - Analyses of **seasonal differences** in fate, transport and effects of oil (particularly for spills in winter)
 - Use **species sensitivity distributions (SSDs) and acute and chronic aquatic organism sensitivities** for measured concentrations of total petroleum hydrocarbons to support risk assessments of oil spills
 - **Extend models of chronic toxicity** to a wide array of species and environmental and life history variables
 - **Credible spill scenarios** relevant and comparable to actual spill incidents
- **Include socioeconomic impacts**, including but not limited to human health and community well-being

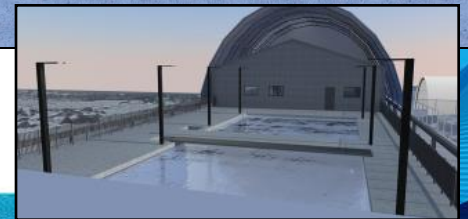
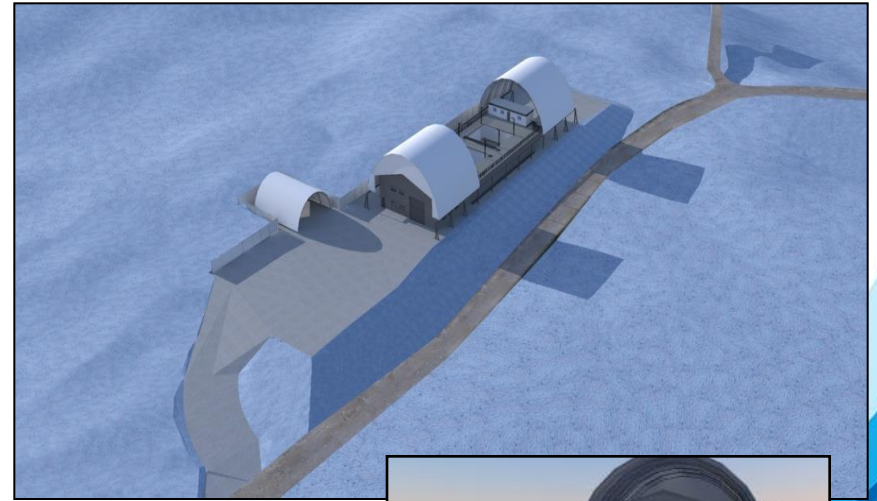


The Churchill Marine Observatory (CMO):

A New Canadian Research Facility Dedicated to the Studies of Detection, Impact and Mitigation of Oil Spills in Ice-Covered Arctic Waters

Controlled testing of the ocean, sea ice system response to oil, LNG, and associated contaminants, to address three key scientific questions:

- 1) Detection of oil/contaminants in sea ice**
- 2) Impacts of oil/contaminants spills on the marine ecosystem**
- 3) Mitigation of oil/contaminant spills within the marine system**



Oceans Protection Plan

Canada's Oceans Protection Plan (OPP) is a comprehensive, transformative \$1.5B strategy to *build a world-leading marine safety system to protect Canada's marine ecosystems, while enabling inclusive economic growth*

Key measures that constitute a world-leading regime include:

- Leading-edge research on oil spill clean-up technologies
- Enhanced oil spill preparedness and response
- A greater role for Indigenous groups in the marine safety regime
- Partnerships and continuous improvements to:
 - Our understanding of how oil spills behave and their environmental impacts
 - Current and alternative mitigation strategies
 - Monitoring and assessment of ecological Recovery



Oil Spill Research Initiative

- A Multi-Partner OPP Program Initiative led by DFO with TC, ECCC, NRCan and CCG to enhance Canada's level of preparedness and response capability
- Consistent with recommendations of the recent US NAS Committee Report "Responding to Oil Spills in the U.S. Arctic Marine Environment" and Canada's TC Tanker Safety Expert Panel and Royal Society of Canada Expert Panel reports – *to create an integrated national/international research program to enhance science-based decision making during oil spill response operations.*



**A REVIEW OF CANADA'S SHIP-SOURCE
OIL SPILL PREPAREDNESS AND RESPONSE REGIME
Setting the Course for the Future**

https://www.tc.gc.ca/media/documents/mosprr/transport_canada_tanker_report_accessible_eng.pdf

The Multi-Partner Oil Spill Technology Research Initiative

- Funding of national and international partners in government, academia and industry under Grants and Contributions (G&C) starting in fiscal year 2018-19
- Advisory Committee established that includes national/international experts from government, industry, oil spill response organizations, academia, indigenous groups, and other relevant parties

Partnership Development

- Research partnerships will be established with *clients and stakeholders* to address key knowledge gaps and operational priorities
- Strengthen existing national/international research partnerships
- Strengthen interactions and coordination within GoC institutions
- Identify and liaise with leading Canadian and International academic and private sector agencies and “science networks,” involved in oil spill research
- Discuss research partnerships within industry funded programs at the national and international level

Program Outcomes and Impact

- Delivery of core oil spill research to improve Canada's oil spill preparedness and response regime
- Public confidence in Canada's ability to respond to and remediate oil spills
- Innovation and technology transfer to the private sector agencies involved in oil spill response operations and product commercialization
- DFO leveraged research will reduce duplication of effort between industry, academia and government agencies
- Enhance research capability/expertise, quality of advice and coordination within the Government of Canada
- Education of highly qualified personnel in oil spill research