REPORT IN BRIEF
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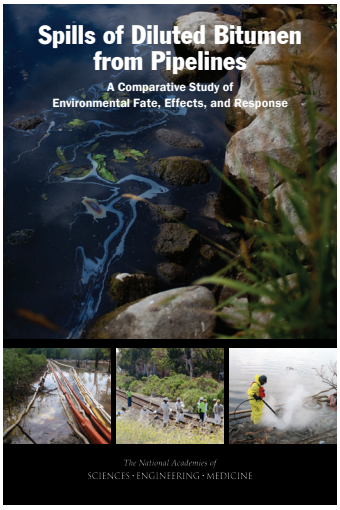
Board on Chemical Sciences and Technology
DIVISION ON EARTH AND LIFE STUDIES

Spills of Diluted Bitumen from Pipelines: A Comparative Study of Environmental Fate, Effects, and Response



Over the past decade, production and pipeline transportation of diluted bitumen from Canada's oil sands have increased as technological improvements have made these hydrocarbon resources competitive in the North American market. Responding to this trend and to recent spills of diluted bitumen, Congress asked the U.S. Department of Transportation (USDOT) to investigate potential risks of using U.S. pipelines to transport diluted bitumen to refineries. The USDOT commissioned two studies from the National Academies of Sciences, Engineering, and Medicine. The first study released in 2013 concluded that there were no causes of pipeline failure unique to the transportation of diluted bitumen compared to commonly transported crude oils. This follow-on study concludes that bitumen, if spilled, has unique properties that affect its behavior in the environment, and that these differences warrant modifications to the regulations governing diluted bitumen spill-response plans, preparedness, and cleanup.

Oil transmission pipelines deliver the vast majority of crude oil supplies to U.S. refineries. The most commonly transported products are light and medium crude oils, which account for nearly three-quarters of the crude oil transported. Technological advances in the mid-2000s have significantly increased production and pipeline transport of harder-to-access hydrocarbons, including bitumen, a thick form of petroleum that is mined or recovered from Canada's vast oil sands (see Box 1). To allow for transport to refineries throughout North America, bitumen is mixed with lighter hydrocarbons so that it can flow easily through transmission pipelines.

Diluted bitumen has been transported by pipeline for more than 40 years. Most of the pipeline systems that are currently transporting diluted bitumen originate near extraction sites in Alberta, Canada (see Figure 1). Production of bitumen is expected to increase over the next few

Box 1. What is diluted bitumen?

Oil sands, which are found in abundance in Alberta, Canada, are naturally occurring mixtures of sand, clay, water, and bitumen, a very thick (dense and viscous) form of petroleum. After bitumen is separated from the oil sands, it is combined with lighter forms of petroleum to form a product that can be transported through transmission pipelines. This engineered oil is referred to as "diluted bitumen." Common names refer to subtypes (e.g., dilbit, synbit, railbit, dilsynbit) but, for simplicity, the term diluted bitumen as used in this report encompasses all bitumen that has been mixed with lighter products.

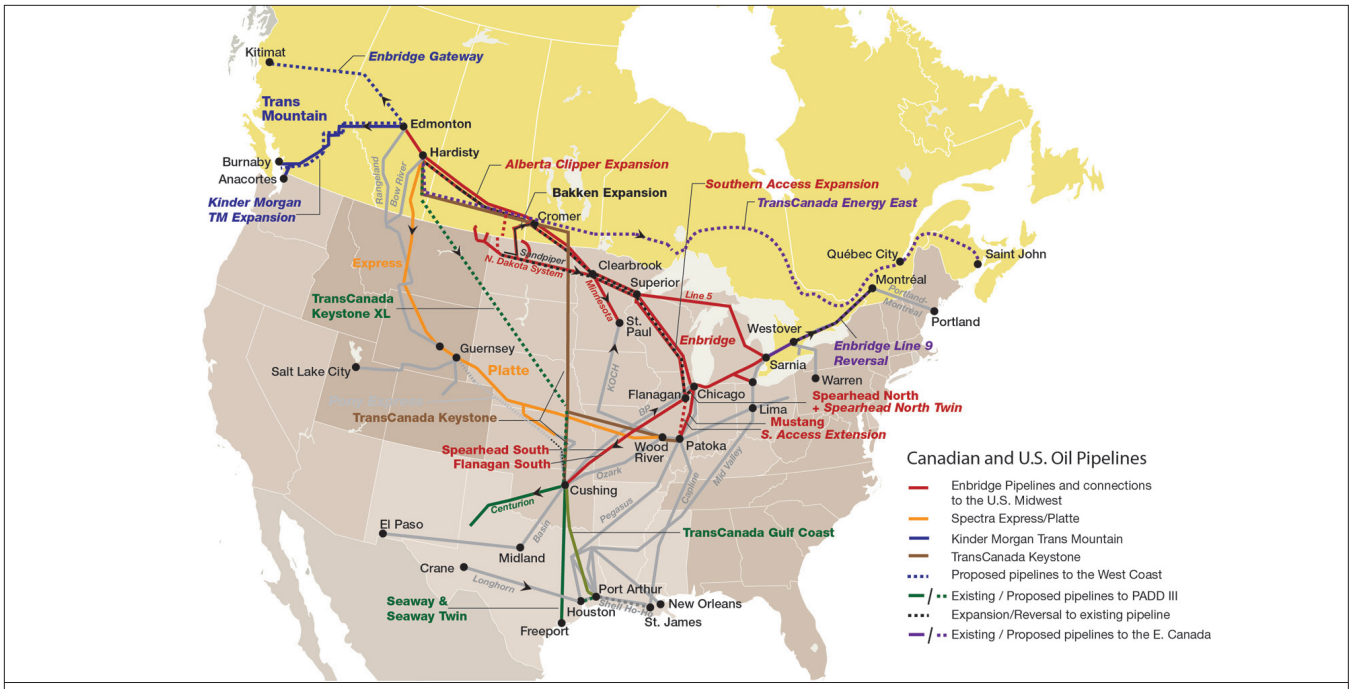


Figure 1 Existing and Proposed Canadian and U.S. Crude Oil Pipelines

decades. To accommodate potential increased volumes, pipeline operators are proposing additional lines or are reversing the flow direction or repurposing older lines to increase capacity.

Since 2004, the U.S. Department of Transportation's (USDOT) Pipeline Hazardous Materials Safety Administration (PHMSA) has been responsible for safety oversight of the transport of crude oil in transmission pipelines. The recent shift in the types of crude oil being carried in transmission pipelines, along with a major pipeline spill of diluted bitumen in Marshall, MI, in 2010 and other spills elsewhere, prompted Congress to direct USDOT to investigate whether the effects of a spill of diluted bitumen differ enough from a spill of other commonly transported crude oils to warrant modifications to regulations governing oil spill response, preparedness, and cleanup.

WEATHERING OF DILUTED BITUMEN IS A KEY DIFFERENCE

Immediately following a spill, the environmental behavior of diluted bitumen is similar to that of a commonly transported crude oil. Within hours, however, exposure to the environment begins a process referred to as "weathering." Weathering can generate a residue that resembles the initial bitumen, which is a sticky, dense, viscous material that has a strong tendency to adhere to surfaces and may form aggregates with naturally occurring particles in the water. For this reason, spills of diluted bitumen pose particular challenges when they reach fresh water bodies, where, in some cases, the oil-particle aggregates may be dense enough to submerge or sink to the bottom, greatly complicating recovery of the oil.

The rapid weathering effects unique to diluted bitumen merit special response strategies and tactics. For example, the time windows during which dispersants and in situ burning can be used effectively are significantly shorter for diluted bitumen than for commonly transported crude oils. In cases where traditional removal or containment techniques are not immediately successful, the possibility that the oil will submerge in the water column or sink to the bottom increases. This situation is highly problematic for spill response because there are limited proven techniques for detection, containment, and recovery of submerged and sunken oil.

Figure 2 compares the properties relevant to the transport, fate, and effects, as well as the potential environmental outcomes of a spill of diluted bitumen compared to spills of commonly transported light and medium crude oils. The majority of the properties and outcomes that are different (of more or less concern) are associated not with freshly spilled diluted bitumen, but with the weathered bitumen residue that forms within days after a diluted bitumen spill. Given these greater levels of concern for weathered diluted bitumen, spills of diluted bitumen should elicit unique, immediate actions in response.

RECOMMENDATIONS FOR IMPROVED OIL SPILL RESPONSE AND PLANNING

A comprehensive and focused approach to diluted bitumen across the oil spill response community is needed to improve preparedness for spills of diluted bitumen and to spur more effective cleanup and mitigation measures when these spills occur. The following recommendations are designed to achieve this goal.

Oil Spill Response Planning

Recommendation 1: To strengthen the preparedness for pipeline releases of oil from pipelines, the Part 194 regulations implemented by PHMSA should be modified so that spill response plans are effective in anticipating and ensuring an adequate response to spills of diluted bitumen. These modifications should

a. Require the plan to identify all of the transported crude oils using industry-standard names, such as Cold Lake Blend, and to include safety data sheets for each of the named crude oils. Both the plan and the associated safety data sheets should include spill-relevant properties and considerations;

b. Require that plans adequately describe the areas most sensitive to the effects of a diluted bitumen spill, including the water bodies potentially at risk;

c. Require that plans describe in sufficient detail response activities and resources to mitigate the impacts of spills of diluted bitumen, including capabilities for detection, containment, and recovery of submerged and sunken oil;

d. Require that PHMSA consult with the U.S. Environmental Protection Agency (USEPA) and/or the U.S. Coast Guard (USCG) to obtain their input on whether response plans are adequate for spills of diluted bitumen;

e. Require that PHMSA conduct reviews of both the completeness and the adequacy of spill response plans for pipelines carrying diluted bitumen;

f. Require operators to provide to PHMSA, and to make publicly

	Property	Potential Outcomes	Level of Concern Relative to Commonly Transported Crude Oils: Diluted Bitumen	Level of Concern Relative to Commonly Transported Crude Oils: Weathered Diluted Bitumen
Transport	Density	• Movement in suspension or as bedload	SAME	MORE
	Adhesion	• Movement in suspension or as bedload (oil particle aggregates)	MORE	MORE
	Viscosity	• Movement as droplets • Spreading on land • Groundwater contamination	SAME	LESS
	Solubility	• Mobility and toxicity in water	SAME	LESS
	BTEX	• Toxicity (water and air emissions)	LESS	LESS
Fate	Density	• Sinking • Burial	SAME	MORE
	Adhesion	• Sinking after sediment interaction • Surface coating	SAME	MORE
	Viscosity	• Penetration	LESS	LESS
	Percentage of light fraction	• Air emissions	SAME	LESS
	Flammability	• Fire or explosion risk	SAME	LESS
	Biodegradability	• Persistence	MORE	MORE
	Burn residue	• Quantity of residue • Residue sinking	MORE	MORE
Effects	Density	• Impaired water quality from oil in the water column and sheening	SAME	MORE
	Adhesion	• Fouling and coating	MORE	MORE
	BTEX components	• Contaminated drinking water • Respiratory problems/disease	SAME	LESS
	HMW components	• Trophic transfer/food web • Aquatic toxicity	UNKNOWN	
	LMW components	• Aquatic toxicity	UNKNOWN	
		• Taste/odor concerns in drinking water	SAME	LESS

	Technique	Potential Outcomes	Level of Concern Relative to Commonly Transported Crude Oils: Diluted Bitumen	Level of Concern Relative to Commonly Transported Crude Oils: Weathered Diluted Bitumen
Response Operations	Worker/public safety from explosion risk/ VOCs	• Public evacuation • Worker respiratory protection/ personal safety	SAME	LESS
	Booming/ skimming	• More difficult due to changes in viscosity/density	SAME	MORE
	In situ burning	• Narrow window of opportunity/ residue sinking	MORE	MORE
	Dispersants	• Narrow window of opportunity	MORE	MORE
	Surface cleaning agents	• More aggressive removal to meet cleanup endpoints	MORE	MORE
	Submerged/ sunken oil detection/ recovery	• More complex response • Less effective recovery for submerged/sunken oil	SAME	MORE
	Waste generation	• Higher removal volumes from residue persistence	MORE	MORE
		• Sunken oil recovery	SAME	

The relative level of concern for diluted bitumen is

Less Same More

when compared to commonly transported crudes.

Figure 2 Spill Hazards: Diluted Bitumen Relative to Commonly Transported Crude Oils

available on their websites, annual reports that indicate the volumes of diluted bitumen, light, medium, heavy, and any other crude oils carried by individual pipelines and the pipeline sections transporting them; and

g. Require that plans specify procedures by which the pipeline operator will (*i*) identify the source and industry-standard name of any spilled diluted bitumen to a designated Federal On-Scene Coordinator, or equivalent state official, within 6 hours after detection of a spill and (*ii*) if requested, provide a 1-L sample drawn from the batch of oil spilled within 24 hours of the spill, together with specific compositional information on the diluent.

Oil Spill Response

Recommendation 2: USEPA, USCG, and the oil and pipeline industry should support the development of effective techniques for detection, containment, and recovery of submerged and sunken oils in aquatic environments.

Recommendation 3: USEPA, USCG, and state and local governments should adopt the use of industry-standard names for crude oils, including diluted bitumen, in their oversight of oil spill response planning.

USCG Classification System

Recommendation 4: USCG should revise its oil-grouping classifications to more accurately reflect the properties of diluted bitumen and to recognize it as a potentially nonfloating oil after evaporation of the diluent. PHMSA and USEPA should incorporate these revisions into their planning and regulations.

Advanced Predictive Modeling

Recommendation 5: The National Oceanic and Atmospheric Administration should lead an effort to acquire all data that are relevant to advanced predictive modeling for spills of diluted bitumen being transported by pipeline.

Improved Coordination

Recommendation 6: USEPA, USCG, PHMSA, and state and local governments should increase coordination and share lessons learned to improve the area contingency planning process and to strengthen preparedness for spills of diluted bitumen. These agencies should jointly conduct announced and unannounced exercises for spills of diluted bitumen.

Improved Understanding of Adhesion

Recommendation 7: USEPA should develop a standard for quantifying and reporting adhesion because it is a key property of fresh and weathered diluted bitumen. The procedure should be compatible with the quantity of the custodial sample collected by pipeline operators.

RESEARCH PRIORITIES

Although many differences between diluted bitumen and commonly transported crudes are well established, there remain areas of uncertainty that hamper effective spill response planning and response to spills. These uncertainties span a range of issues, including diluted bitumen's behavior in the environment under different conditions, its detection when submerged or sunken, and the best response strategies for mitigating the impacts of submerged and sunken oil. These research priorities, discussed in Chapter 7, apply broadly to the research community.

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The Academies appointed the above committee of experts to address the specific task requested by the U.S. Department of Transportation. The members volunteered their time for this activity; their report is peer-reviewed and the final product signed off by both the committee members and the National Academies. This report brief was prepared by the National Research Council based on the committee's report.

For more information, contact the Board on Chemical Sciences and Technology at (202) 334-2156 or visit **http://dels.nas.edu/bcst**. Copies of *Spills of Diluted Bitumen from Pipelines: A Comparative Study of Environmental Fate, Effects, and Response* are available from the National Academies Press, 500 Fifth Street, NW, Washington, D.C. 20001; (800) 624-6242; or as free PDFs at **www.nap.edu**.