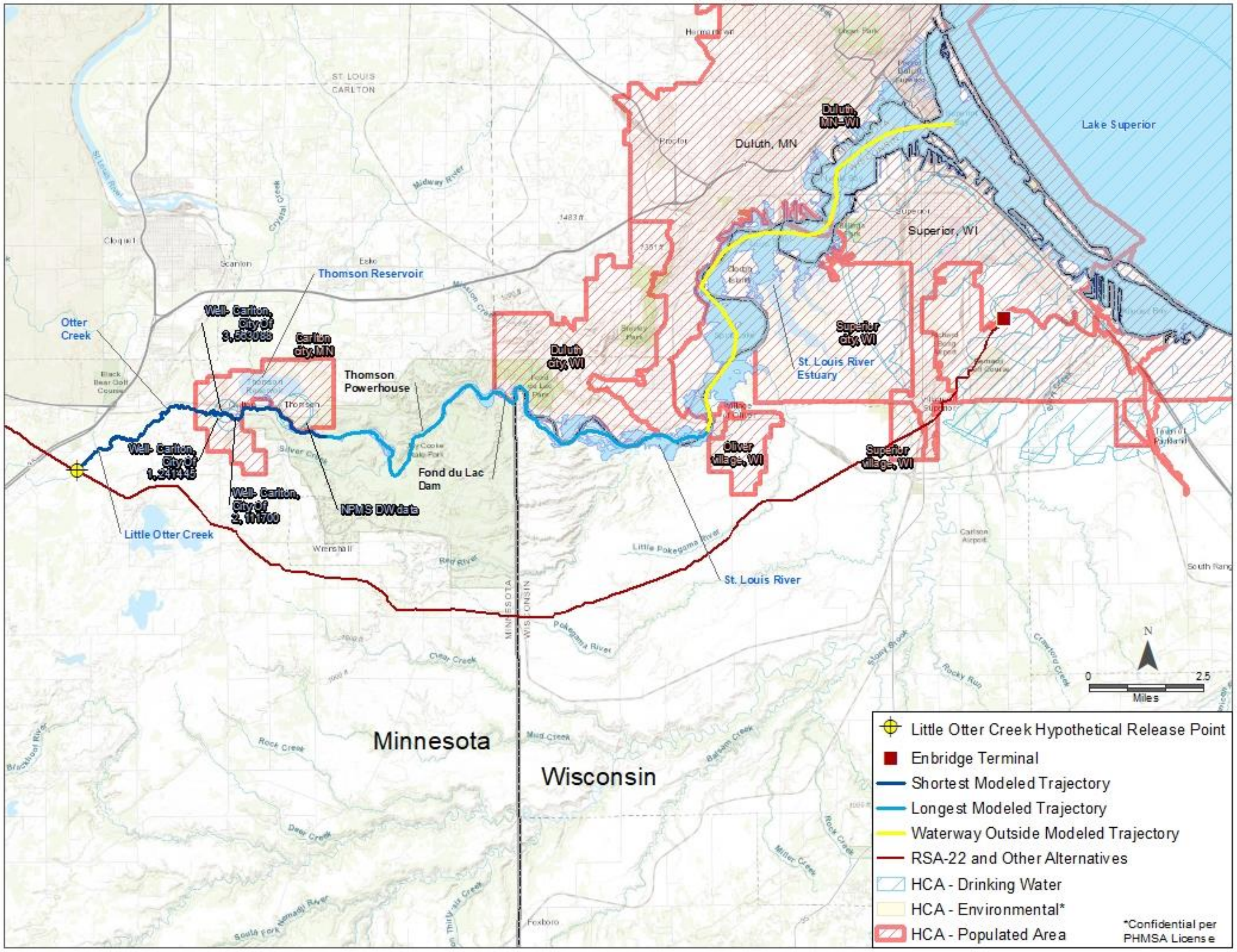


Figure 5-2 HCAs along Little Otter Creek, Otter Creek and the St. Louis River.

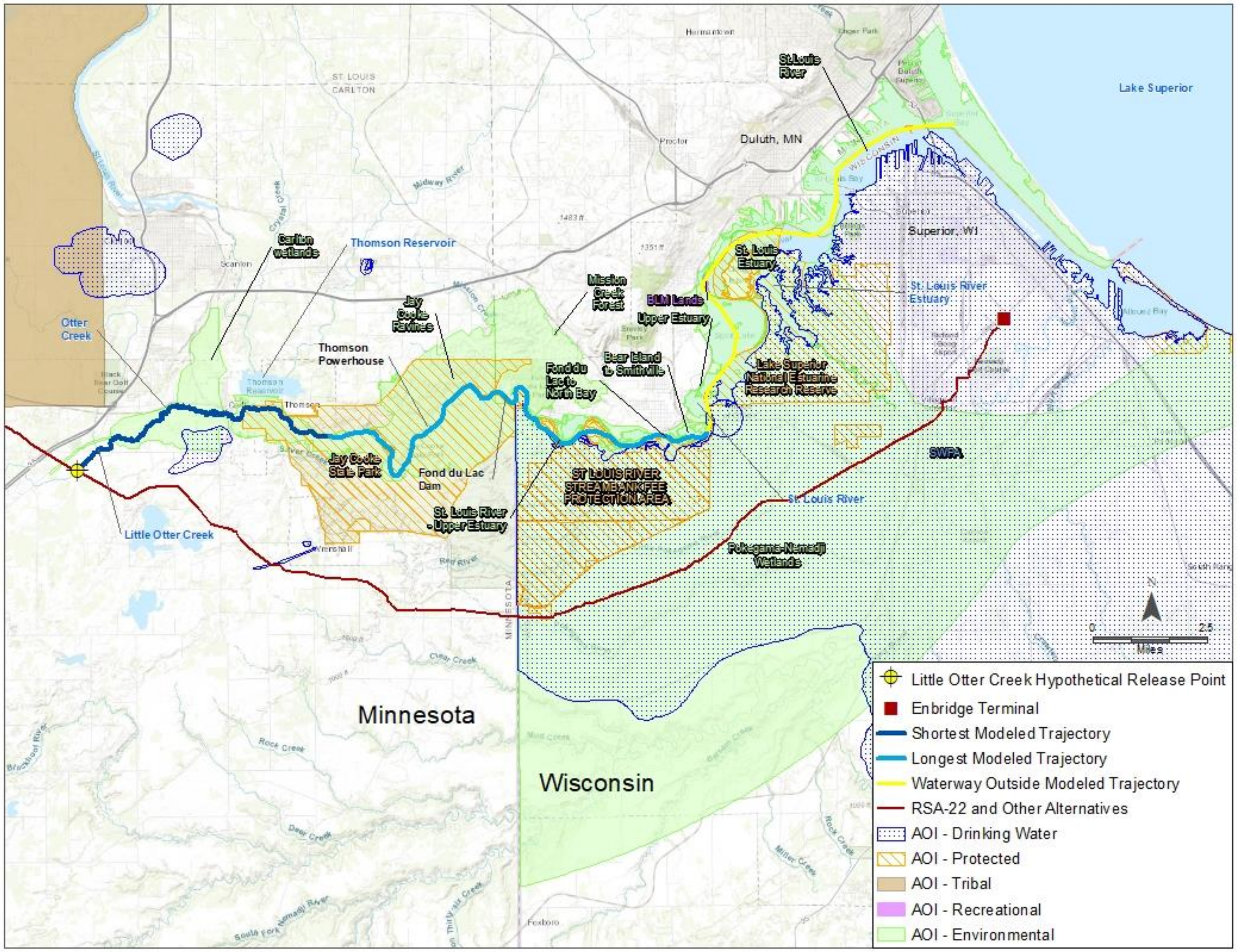


Figure 5-3 AOIs along Little Otter Creek, Otter Creek and the St. Louis River.

Table 5-2 HCAs Potentially Affected by a Release of CLB or Bakken Crude Oil at the Little Otter Creek Crossing Site.

HCA Type	HCA Subtype	Description / Locations
Populated Area	Carlton City, MN	PHMSA Populated Area https://www.npms.phmsa.dot.gov/PopulationData.aspx
Drinking Water	Well - Carlton, City of 1, 241445	Drinking water well
Drinking Water	Well - Carlton, City of 2, 111700	Drinking water well
Drinking Water	Well - Carlton, City of 3, 563088	Drinking water well
Drinking Water	NPMS DW data	https://www.npms.phmsa.dot.gov/USADWData.aspx
Populated Area	City of Duluth	PHMSA Populated Area https://www.npms.phmsa.dot.gov/PopulationData.aspx
Note: Data for the HCA analysis were obtained from the USDOT PHMSA HCA datasets during 2019.		

The principal HCAs downstream from the hypothetical crude oil release site include the populated areas of Carlton City, Minnesota. Farther downstream, the populated areas of Thomson, Minnesota; Fond du Lac, Minnesota; Duluth (including Gary - New Duluth), Minnesota; Oliver, Wisconsin; Superior Village, Wisconsin; and Superior City, Wisconsin have boundaries that contact or overlap on portions of the St. Louis River and/or St. Louis River Estuary. In addition, even outside of areas designated as HCA (populated areas), some rural dwellers have homes and/or businesses located close to Little Otter Creek, Otter Creek, the St. Louis River, or the St. Louis River Estuary.

AOIs located in proximity to Otter Creek include drinking water wells serving Carlton, Minnesota and Thomson, Minnesota. AOIs representing drinking water sources for the cities of Duluth, Minnesota and Superior, Wisconsin are also located in Lake Superior. There are no known water intakes drawing potable water directly from potentially affected reaches of Little Otter Creek, Otter Creek, or the St. Louis River.

Environmental AOIs include the Carlton Wetlands, which also include several designated complex community types (e.g., alder swamp/northern sedge meadow complex); and Jay Cooke State Park, which protects unique features of the St. Louis River, such as the extensive broad and shallow rapids and associated rocky shoreline complex communities, nearby upland woodland communities, and the Jay Cooke Ravines. Other areas of highly erodible river shoreline are protected by the St. Louis River Stream Bank Protection Area (SLR SBPA), comprising 6,674 acres of land including but not limited to the Red River Breaks, the Fond du Lac marshes, Clough Island, and located along the St. Louis River. The purpose of the SLR SPBA is to protect water quality of the St. Louis and Red rivers from streambank erosion, siltation and sedimentation, while providing opportunities for compatible outdoor recreation. Some of the important biological communities of the St. Louis River include the Fond du Lac to North Bay section, the Bear Island to Smithville section, and the estuarine marshes that occur as the river opens up into the estuary. The St. Louis River Estuary is recognized as a unique ecosystem in its own right, and is the subject of the Lake Superior National Estuarine Research Reserve. Features of the estuary range from its extensive wetlands, to Clough Island which is protected by the Nature Conservancy of Minnesota, to a variety of sites where environmental restoration activities have taken either place or are ongoing, in relation to past industrial development and habitat degradation.

Table 5-3 AOIs Potentially Affected by a Release of CLB or Bakken Crude Oil at the Little Otter Creek Crossing Site.

AOI Type	AOI Subtype	Description / Locations
Environmental	Carlton Wetlands	Minnesota County Biological Survey (MCBS) site with moderate biodiversity significance
Environmental	Native Plant Community	MN DNR Native Plant Community https://www.dnr.state.mn.us/npc/index.html
Environmental	WMn82a - Willow - Dogwood Shrub Swamp	MN DNR Native Plant Community, Willow, Dogwood Shrub Swamp https://www.dnr.state.mn.us/npc/index.html
Environmental	Jay Cooke Ravines	MCBS site with moderate biodiversity significance
Environmental	ASM_CX - Alder Swamp / Northern Sedge Meadow Complex	MN DNR Native Plant Community, Complex Community https://www.dnr.state.mn.us/npc/index.html
Environmental	RRS_CX - River / Rocky Shore Complex	MN DNR Native Plant Community, Complex Community https://www.dnr.state.mn.us/npc/index.html
Environmental	WFn55a - Black Ash - Aspen - Balsam Poplar Swamp (Northeastern)	MN DNR Native Plant Community, Wet Forest System https://www.dnr.state.mn.us/npc/index.html
Environmental	ROCW_CX - Thomson Outcrop / Cliff / Woodland Complex	MN DNR Native Plant Community, Complex Community https://www.dnr.state.mn.us/npc/index.html
Protected	Jay Cooke State Park	https://www.exploreminnesota.com/places-to-stay/615/jay-cooke-state-park
Environmental	RVx43a2 - Bedrock/Boulder Shore (River), Permanent Stream Subtype	MN DNR Native Plant Community, River Shore System https://www.dnr.state.mn.us/npc/index.html
Protected	Fee Land - Unknown	Unknown
Environmental	FDn43b - Aspen - Birch Forest	MN DNR Native Plant Community, Fire-Dependent Forest/Woodland System https://www.dnr.state.mn.us/npc/index.html

AOI Type	AOI Subtype	Description / Locations
Environmental	FDn22d - Red Pine - White Pine Woodland (eastcentral Bedrock)	MN DNR Native Plant Community, Fire-Dependent Forest/Woodland System https://www.dnr.state.mn.us/npc/index.html
Environmental	RVx54a - Slumping Clay/Mud Slope (River)	MN DNR Native Plant Community, River Shore System https://www.dnr.state.mn.us/npc/index.htmlx
Environmental	FFn57a - Black Ash - Silver Maple Terrace Forest	MN DNR Native Plant Community, Floodplain Forest System https://www.dnr.state.mn.us/npc/index.htmlx
Environmental	MHn46b - Black Ash - Basswood Forest	MN DNR Native Plant Community, Mesic Hardwood Forest System https://www.dnr.state.mn.us/npc/index.htmlx
Environmental	MHn44b - White Pine - White Spruce - Paper Birch Forest	MN DNR Native Plant Community, Mesic Hardwood Forest System https://www.dnr.state.mn.us/npc/index.htmlx
Environmental	Mission Creek Forest	MCBS site with high biodiversity significance
Environmental	Upper Estuary	MN musky lake
Environmental	St. Louis River Estuary	Lake of Biological Significance http://stlouisriverestuary.org/map/map.php#12/46.7342/-92.1018
Environmental	St. Louis River - Upper Estuary	Lake of Biological Significance
Environmental	Saint Louis River	Public Water Basin
Protected	Lake Superior National Estuarine Research Reserve	Research Station https://lakesuperiorreserve.org/
Environmental	Pokegama-Nemadji Wetlands	Conservation Opportunity Areas Terrestrial https://www.douglascountywi.org/DocumentCenter/View/8288/Final-LS-Watershed-based-Plan-5_9_16?bidId=
Drinking Water	Source Water Protection Area	WDNR Source Water Protection Area
Protected	St. Louis River Streambank Fee Protection Area	WDNR Managed Land https://dnr.wi.gov/topic/lands/regionalplanning/superiorcoastalplain/documents/StLouisRiver.pdf
Environmental	Fond du Lac to North Bay	MCBS site with outstanding biodiversity significance
Environmental	Bear Island to Smithville	MCBS site with high biodiversity significance
Environmental	St. Louis Estuary	Conservation Opportunity Areas Terrestrial

AOI Type	AOI Subtype	Description / Locations
Environmental	MRu94a - Estuary Marsh (Lake Superior)	Marsh System; Lake Superior Coastal Marsh
Note: Data for the AOI analysis were derived from multiple datasets provided on the Minnesota Geospatial Commons website, USGS Protected Areas Database of the United States, Minnesota Department of Transportation, and WDNR.		

5.1.3 Selection of Key Ecological and Human Environment Receptors for Little Otter Creek Scenario

Considering environmental characteristics of the Little Otter Creek, Otter Creek, the St. Louis River, and the St. Louis River Estuary, the potential interactions of released crude oil with key ecological and human environment receptors were screened to identify key receptors for the subsequent environmental effects analysis. The rationale and results of this screening step are provided in Table 5-4.

Table 5-4 Key Ecological and Human Environment Receptors for the Little Otter Creek Crossing Site.

Receptor	Relevance for Inclusion as an Environmental Receptor for the Little Otter Creek Scenario	Selected (Y/N)
Terrestrial Receptors		
Soils	Low. An assumption made in the fate modeling for this scenario is that released oil would enter directly into Little Otter Creek with no holdup of oil on land. Any oil that reaches soil would be physically remediated to established standards.	N
Groundwater	Low. An assumption made in the fate modeling for this scenario is that released oil would enter directly into Little Otter Creek with no holdup of oil on land. In the event of an actual oil release, effects on groundwater quality would be localized and/or negligible.	N
Terrestrial Vegetation	Low. An assumption made in the fate modeling for this scenario is that released oil would enter directly into Little Otter Creek with no holdup of oil on land. Any oil that reaches soil would be physically remediated and vegetative cover would be restored as part of the clean-up process.	N
Aquatic Receptors		
Rivers (Little Otter Creek, Otter Creek, and St. Louis River, Fond du Lac Headpond)	High. An assumption made in the fate modeling for this scenario is that released oil would enter directly into Little Otter Creek with subsequent physical transport downstream to include Otter Creek and the St. Louis River, including the Fond du Lac Headpond.	Y
Estuary (St. Louis River Estuary)	High. The St. Louis River transitions into the St. Louis River Estuary between Fond du Lac and Gary - New Duluth, MN. Released oil could be transported into the St. Louis River Estuary, and the transitional zone, where the watercourse becomes wider and water velocities drop, would provide depositional areas where crude oil could accumulate in sediment.	Y

Receptor	Relevance for Inclusion as an Environmental Receptor for the Little Otter Creek Scenario	Selected (Y/N)
Lakes (Lake Superior)	Low. Modeling of crude oil transport in Little Otter Creek, Otter Creek and the St. Louis River indicates that while crude oil could approach the St. Louis River Estuary within 24 hours of release, it would remain approximately 13 miles from Lake Superior. The physical characteristics of the St. Louis River Estuary, including the barrier bar and constricted outlets into Lake Superior make it highly unlikely that a crude oil release into Little Otter Creek would reach Lake Superior.	N
Sediment	High. An assumption made in the fate modeling for this scenario is that released oil would enter directly into Little Otter Creek with subsequent physical transport downriver in Otter Creek and the St. Louis River, towards the estuary. There is potential for interaction and/or deposition of crude oil residues to sediments.	Y
Shoreline and Riparian Areas	High. An assumption made in the fate modeling for this scenario is that released oil would enter directly into Little Otter Creek with subsequent physical transport downstream. There is potential for interaction with shoreline and riparian habitat of Little Otter Creek, Otter Creek, the St. Louis River, and the St. Louis River Estuary.	Y
Wetlands	High. An assumption made in the fate modeling for this scenario is that released oil would enter directly into Little Otter Creek with subsequent physical transport downstream. There is potential for wetland habitat along Little Otter Creek and Otter Creek, and in the upper St. Louis River Estuary to be affected by an oil release.	Y
Aquatic Plants	High. Aquatic plant community development is present in Little Otter Creek and Otter Creek, and abundantly in the upper St. Louis River Estuary. Shallow, high-energy portions of the St. Louis River will not support aquatic plant communities.	Y
Benthic Invertebrates	High. Little Otter Creek, Otter Creek, the St. Louis River, and the St. Louis River Estuary support benthic invertebrate communities.	Y
Fish	High. Little Otter Creek, Otter Creek, the St. Louis River, and the St. Louis River Estuary support fish communities.	Y

Receptor	Relevance for Inclusion as an Environmental Receptor for the Little Otter Creek Scenario	Selected (Y/N)
Semi-Aquatic Wildlife Receptors		
Amphibians and Reptiles	High. Little Otter Creek, Otter Creek, the St. Louis River, and the St. Louis River Estuary support herptile communities.	Y
Birds	High. Little Otter Creek, Otter Creek, the St. Louis River, and the St. Louis River Estuary support bird communities, and in addition, the St. Louis River Estuary is an Important Bird Area.	Y
Semi-aquatic Mammals	High. Little Otter Creek, Otter Creek, the St. Louis River, and the St. Louis River Estuary support semi-aquatic mammals.	Y
Human and Socio-Economic Receptors		
Air Quality	High. From the hypothetical release site, Little Otter Creek and Otter Creek run through the community of Carlton, MN, and a number of homes are located near the watercourse. The St. Louis River below the Thomson Reservoir is not directly developed, although homes in the community of Thomson are located close to the river. Jay Cooke State Park, which has seasonal campgrounds, is also located downstream of the Thomson Reservoir. The Fond du Lac reservoir is located below the state park, and the communities of Fond du Lac, MN and Gary - New Duluth, MN (part of Duluth) and Oliver, WI, are located downstream from the Fond du Lac Dam. Still farther downstream are Superior Village and Superior City, WI, and most of the urban area of Duluth.	Y
Human Receptors	High. Effects on air quality or the presence of crude oil residues in aquatic and riparian habitat have the potential to temporarily affect human health. Drinking water for the communities of Carlton, MN and Thomson, MN, is drawn from groundwater sources by city owned and operated wells. Other urban areas within the Study Area are supplied with drinking water by the Cities of Duluth, MN, and Superior, WI. These cities draw their drinking water supplies from intakes located in Lake Superior.	Y

Receptor	Relevance for Inclusion as an Environmental Receptor for the Little Otter Creek Scenario	Selected (Y/N)
Public Use of Natural Resources	Downstream of the hypothetical release site, the St. Louis River flows through largely natural habitats. The St. Louis River is subject to flow regulation to support the operation of the Thomson Dam Powerhouse, as well as the Fond du Lac Dam and Powerhouse. However, most of the riverbank habitat remains in a largely natural (and protected) state. Jay Cooke State Park provides substantial recreational opportunities, as do other properties such as Clough Island in the St. Louis River Estuary. The river and associated wetland and riparian habitats provide opportunities for recreation, fishing and hunting that are in proximity to the urban areas of Duluth and Superior. It is assumed that wild rice may be present in shallow-water areas of the St. Louis River Estuary. The Fond du Lac Indian Reservation, the land-base for the Fond du Lac Band of Lake Superior Chippewa, is located to the north and west of the hypothetical spill site and is crossed by the proposed alignment of the Line 3 replacement pipeline. The people of the Fond du Lac Band of Lake Superior Chippewa traditionally occupied territory that included the St. Louis River and Estuary, and it is assumed that traditional harvest of plants (including wild rice), fish, mammals and birds may be practiced anywhere within the area depicted on Figure 5-1.	Y

5.1.4 Modeled Conditions at the Release Site

A description of key modeling assumptions for the environmental effects analysis for the Little Otter Creek scenario is provided in this Section.

As described in Section 4.1.1, Little Otter Creek and Otter Creek are characterized by a variety of slow moving to moderately flowing sections until the stream approaches the confluence with St. Louis River, where the gradient becomes steeper and flow becomes more rapid (see Figure 2-2 for land surface elevation information). The St. Louis River below the Thomson Reservoir is fast-flowing, with a moderate to high gradient, and much exposed bedrock giving rise to riffles, cascades, and small waterfalls that extend about 3.2 miles (5 km) through Jay Cooke State Park, before transitioning to a series of riffle and pool sections leading into the Fond du Lac Headpond. This high energy environment creates turbulence that will entrain crude oil into the water column of the river. The Fond du Lac Headpond presents a typically calm environment where sediment-associated crude oil could settle to the bottom, and where submerged or entrained crude oil could rise to the surface to form slicks before reaching the dam itself. At the dam, flow that does not pass through the powerhouse is allowed to spill, again creating turbulent conditions that will entrain slicks or liquid crude oil into the water column as small droplets. Below the Fond du Lac Dam, the river remains moderately flowing with occasional faster flowing sections until it reaches Mud Lake and Spirit Lake in the estuary. Water flows in the estuary resemble flows more typical of shallow lakes, although short-term variations in the level of Lake Superior (e.g., seiche conditions set up by wind) can cause apparent flow-reversal.

As described in Chapter 3.0, OILMAPLand and SIMAP both provide an indication of the downstream extent of oiling and mass balance of oil within the 24 hour modeled period. A longer time period was not modeled as it was assumed that emergency response measures to prevent or reduce further downstream transport of released oil would be in place within the 24 hour period. The SIMAP modeling software also can quantify the amount of crude oil that is likely to become entrained into or dissolved in the water column or deposited to sediments as a result of the turbulent conditions.

The two crude oil types provide bounding cases for oils that range from light (e.g., Bakken crude oil having low viscosity and density) to heavy (e.g., CLB, heavy diluted bitumen crude oil types having higher viscosity and density). Seasonal variations in river flow velocity, temperature, wind speed, and snow and ice cover were all considered at the release site. A summary of key variables is provided in Table 5-5.

Table 5-5 Environmental and Hydrodynamic Conditions for the Three Modeled Periods at the Little Otter Creek Crossing.

Season	Month	Air Temperature (°C / °F)	Wind Speed (m/s)	Average River Velocity (m/s)
Low river flow (Winter)	January	-12.1 / 10.2	4.74	0.30
Average river flow (Summer)	Late July/August	18.8 / 65.8	3.80	0.37
High river flow (Spring)	April	4.2 / 39.6	4.96	0.48
Note: a velocity of 1 m/s is equivalent to 2.25 miles per hour.				

The highest average flow velocities of Little Otter Creek, Otter Creek and the St. Louis River coincide with the spring freshet (i.e., April), a result of rising temperatures and snowmelt. Average river flow would typically occur in summer and fall seasons. A period in late July and August, months with generally warm and dry conditions, was selected to represent the maximum amount of evaporation. The lowest flow rate occurs in winter (January), and was typified by freezing conditions and probable ice cover on water in Little Otter Creek and Otter Creek, in the Fond du Lac Headpond, and in the St. Louis River Estuary. Water flows in the section of the St. Louis River between the Thomson Dam and the Thomson Powerhouse are subject to flow regulation to supply the electrical generating station. This means that flows during the winter may be very low in that section of the river (as the maximum available quantity of water will be diverted to the generation of electricity). Flows in this section can also be expected to vary throughout the day, as it is convenient to operate hydro-electric generating stations in a “peaking” mode, to meet periods of maximum demand. Owing to the steep gradient, sections of the St. Louis River between the Thomson Reservoir and the Fond du Lac Headpond may remain open to the atmosphere even during the winter. Similarly, a section of the river below the Fond du Lac Dam may remain open during the winter, due to the high velocity of water in the tailrace.

5.1.5 Summary of Predicted Downstream Transport of Bakken and Cold Lake Crude Oils Within Little Otter Creek

Summaries of the predicted downstream trajectories and mass balance for Cold Lake and Bakken crude oils, under the three seasonal scenarios, are provided in Figures 5-4 and 5-5, respectively. These simulations are assumed to provide bounding conditions for a release of light and heavy crude oil types. The fate of most types of crude oil, if released, would lie within the envelope of predictions for the Bakken and Cold Lake crude oil types. The Cold Lake crude oil (a type of diluted bitumen) was assumed to be CLSB for the high and average river flow scenarios, and to be CLWB for the low river flow (winter) scenario. The amount and type of diluents used in the Cold Lake crude oil blends is seasonally adjusted to maintain specifications for viscosity and density. The combined maximum simulation duration using the OILMAPLand and SIMAP models was 24 hours, with results being examined at intervals at 6, 12, 18 and 24 hours. It was assumed that emergency response measures to prevent or reduce further downstream transport of released oil would be in place within 24 hours following a release of crude oil.

Symbols on the drawings indicate the seasonal river flow condition (high, corresponding to spring freshet; average, corresponding to typical summer and fall conditions; and low, corresponding to winter flow). Numbers associated with the symbols indicate the predicted location of the leading edge of the released oil in the river after 6, 12, 18 or 24 hours. Tables inserted within the Figures also provide information on the mass balance (i.e., oil remaining on the surface of the river, evaporated to the atmosphere, dissolved in the water column, deposited to sediment, adhering to river banks, or decaying through photo-oxidation and biodegradation) of the released oil at relevant points in time after the start of the release.

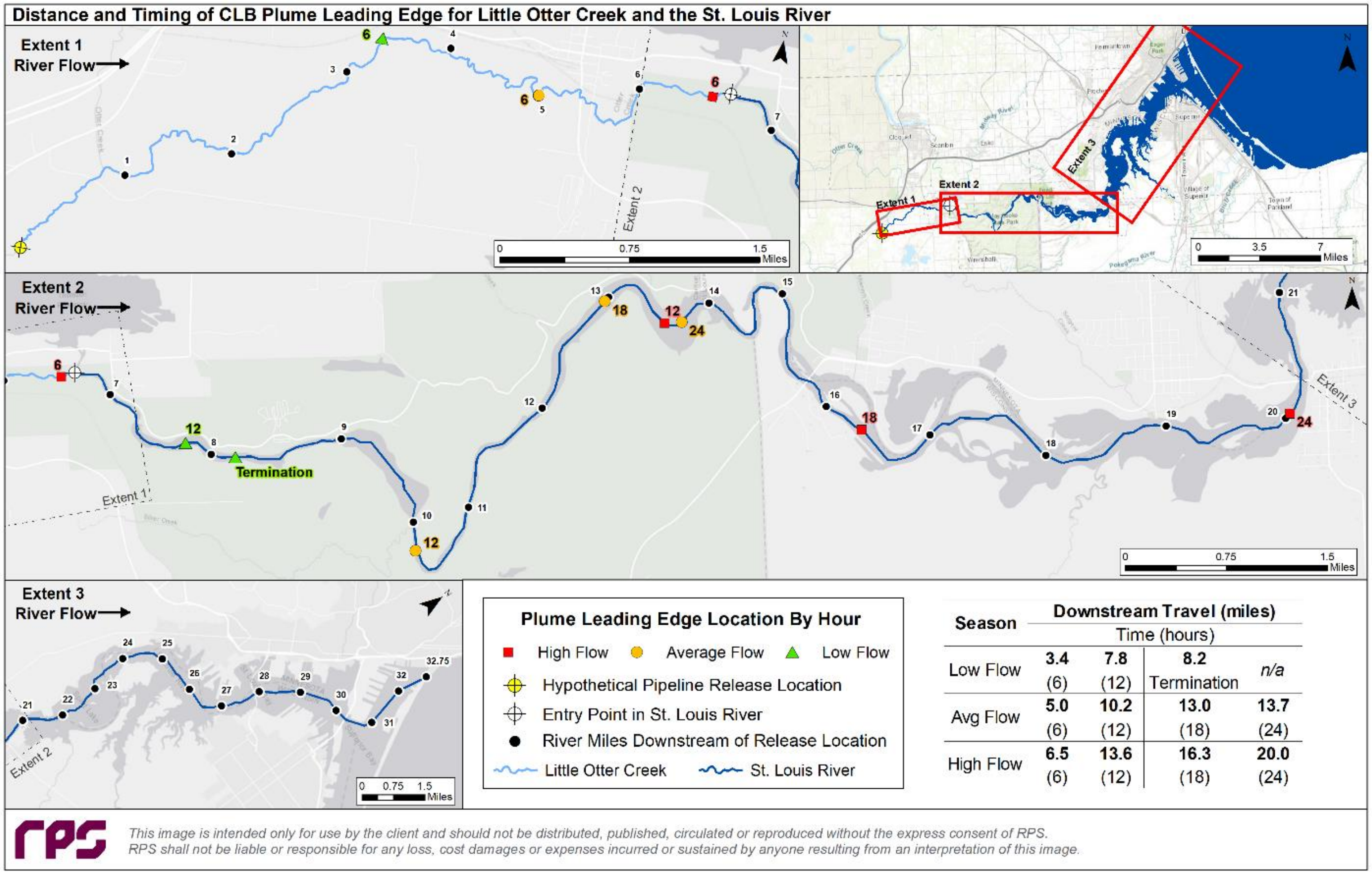
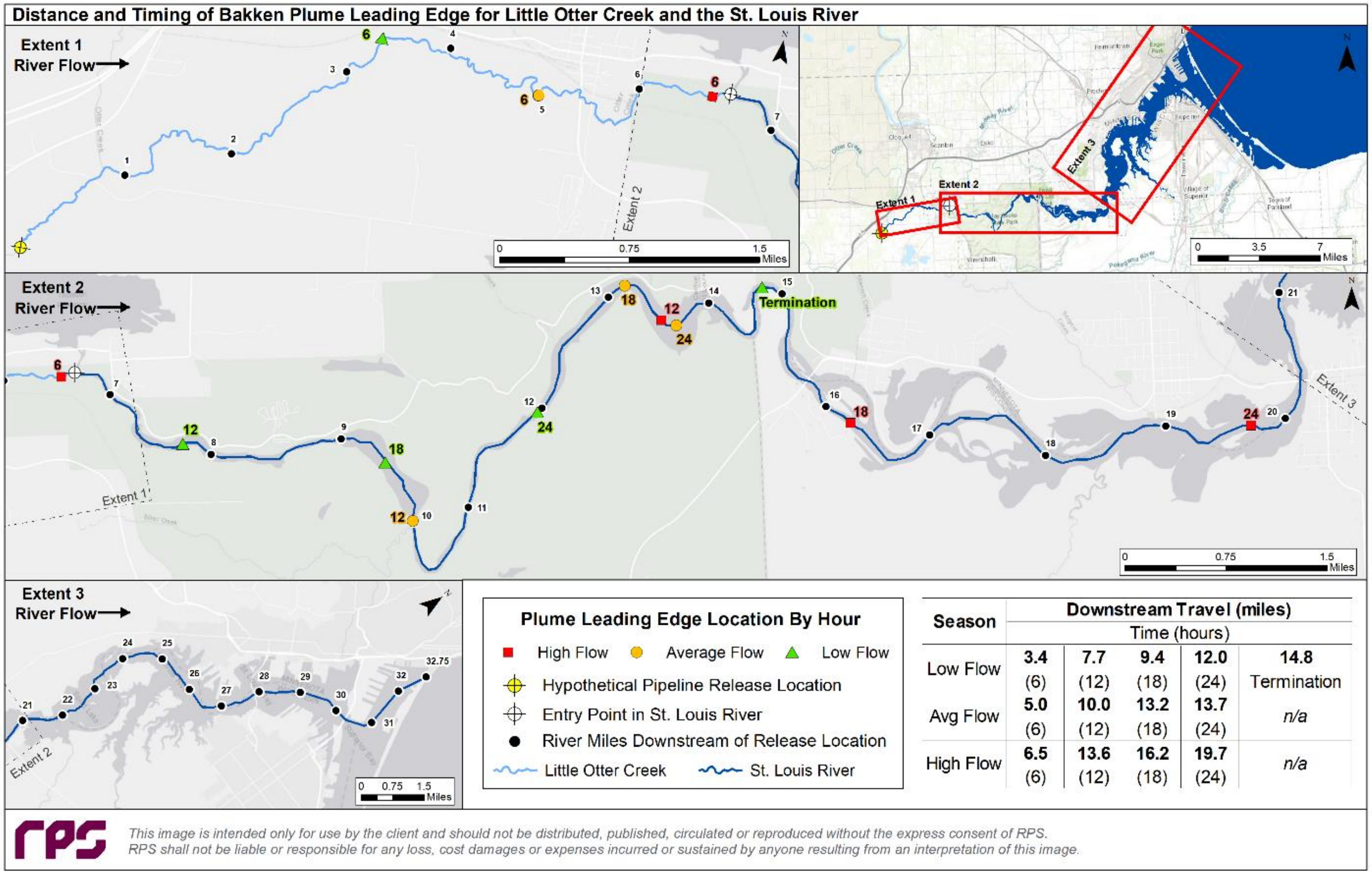


Figure 5-4 Predicted Downstream Transport of CLB Oil from Little Otter Creek.



Season	Downstream Travel (miles) Time (hours)				
Low Flow	**3.4** (6)	**7.7** (12)	**9.4** (18)	**12.0** (24)	**14.8** Termination
Avg Flow	**5.0** (6)	**10.0** (12)	**13.2** (18)	**13.7** (24)	*n/a*
High Flow	**6.5** (6)	**13.6** (12)	**16.2** (18)	**19.7** (24)	*n/a*

Figure 5-5 Predicted Downstream Transport of Bakken Crude Oil from Little Otter Creek.

5.1.5.1 Trajectory Summary for High River Flow (Spring) Period

Under the high river flow scenario, CLB crude oil was predicted to travel 6.5, 13.6, 16.3 and 20.0 miles downstream in Little Otter Creek and the St. Louis River after approximately 6, 12, 18 and 24 hours respectively (Figure 5-4). By 24 hours after the hypothetical release, 1,639 m^3 of the 2,068 m^3 released was predicted to have left Otter Creek and entered the St. Louis river.

Within Little Otter Creek and Otter Creek, most (79.3%) of the remaining crude oil was predicted to remain on the surface of the water, with 1.1% having evaporated, and 19.6% remaining adhered to the shoreline. In the St. Louis River, most (60.9%) of the oil was predicted to be on the water surface 24 hours after the release, with 18.2% adhering to the shoreline, 17.6% having evaporated from the surface of the St. Louis River, 2.5% remaining entrained in the water column, 0.5% having decayed, and 0.3% having been deposited to sediment (see Section 3.2.1).

Under the high river flow scenario, Bakken crude oil was predicted to follow the same general downstream transport pattern as CLB (Figure 5-5). By 24 hours after the hypothetical release, 1,624 m^3 of the 2,068 m^3 released was predicted to have left Little Otter Creek and Otter Creek and entered the St. Louis River. Within Little Otter Creek and Otter Creek, most (78.6%) of the remaining crude oil was predicted to remain on the surface of the water, with 18.4% having evaporated, and 3.0% remaining adhered to the shoreline. In the St. Louis River, most (44.1%) of the oil was predicted to have evaporated by 24 hours after the release, with 38.3% remaining on the water surface, 13.3% adhering to shoreline, 3.8% remaining entrained in the water column, 0.4% having decayed, and <0.01% having been deposited to sediment (Section 3.2.2).

As the hypothetical releases move through the series of rapids below the Thomson Reservoir and through Jay Cooke State Park; as well as over the Fond du Lac Dam, it was expected and confirmed by modeling that there would be substantial entrainment of crude oil into the river water, with subsequent re-surfacing of entrained oil in more quiescent river reaches at downstream locations. Given in-stream flows and other factors, the remaining oil from the hypothetical releases was predicted to encounter these areas approximately 7 hours and 20 hours (0.3 and 0.8 days) after the hypothetical release of CLB or Bakken crude.

Figures 5-6 and 5-7 present the maximum modeled total dissolved hydrocarbon concentrations in river water for CLB and Bakken crude oils at any time during the first 24 hours of simulation for the high river flow conditions. These drawings show that peak total dissolved hydrocarbon concentrations[2] frequently exceed 5,000 µg/L (ppb) throughout the St. Louis River from the confluence with Otter Creek, to areas downstream from the Fond du Lac Dam, with slightly lower concentrations (2,000 to 5,000 µg/L) prevailing for CLB crude oil as the flow approaches Oliver, WI. Predicted total dissolved hydrocarbon concentrations tend to be slightly higher overall for the Bakken crude oil type than for the CLB. The high modeled concentrations are a consequence of the turbulent flow of water in the St. Louis River, as well as the passage of floating and submerged crude oil over the Fond du Lac Dam. It is important to emphasize

[2] Dissolved hydrocarbons broadly include BTEX compounds, aromatic hydrocarbons and some lower molecular weight aliphatic hydrocarbon compounds; these compounds are collectively responsible for toxicity caused by non-polar narcosis in exposed aquatic organisms.

that the results shown in Figures 5-6 and 5-7 represent transient peak concentrations that would be short-lived (i.e., hours) as the bulk of the released crude oil moves down-river and is subsequently flushed by clean water.

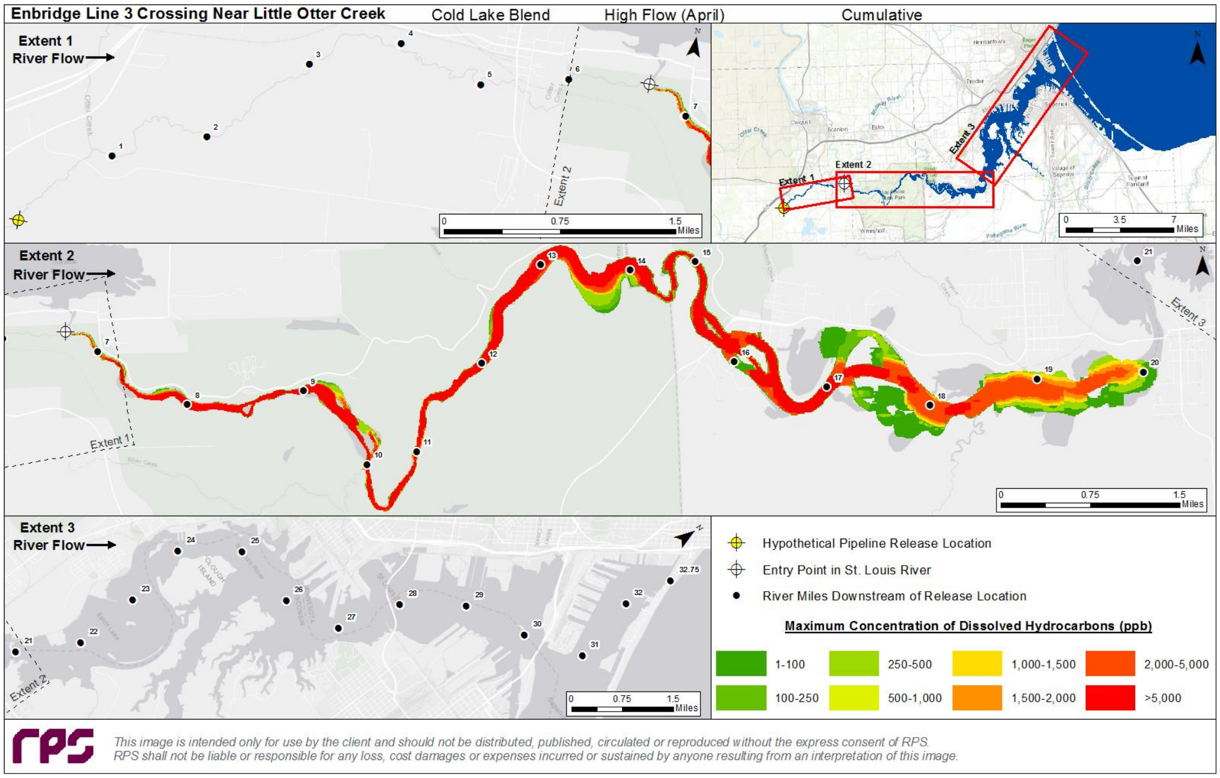


Figure 5-6 Maximum Modeled Total Dissolved Hydrocarbon Concentrations in River Water for CLB Oil During High Flow.

At the end of the 24 hour simulation, most of the floating CLB was predicted to be located between the Fond du Lac Dam and Bear Island (near Gary - New Duluth, Minnesota; see Figure 4-6), and be present as heavy black oil (>1.0 mm thickness) slicks and globules at the water surface. Slicks of Bakken crude oil were predicted to be generally thinner overall (i.e., black oil and dark brown sheens predominating with thicknesses between 0.01 and 1 mm, see Figure 4-29).

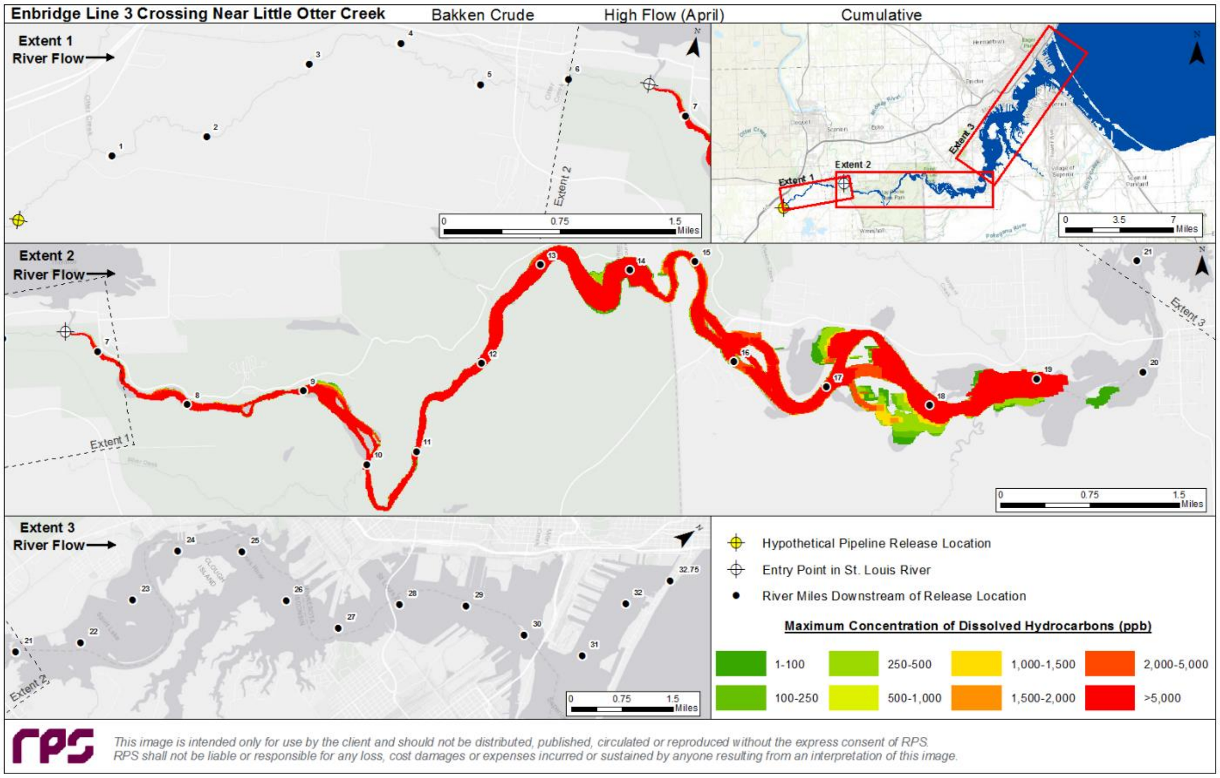


Figure 5-7 Maximum Modeled Total Dissolved Hydrocarbon Concentrations in River Water for Bakken Crude Oil During High Flow.

Extensive shoreline oiling (>500 g/m^2) was predicted for CLB and Bakken crude oil throughout Little Otter Creek and Otter Creek (where the riparian habitat is largely marshy), and into the St. Louis River (see Figures 4-8 and 4-31). In the section of rapids (and primarily exposed bedrock shoreline type) between the Thomson Reservoir and the Fond du Lac Headpond, more irregular or patchy oiling of shoreline was predicted. Both heavy shoreline oiling and deposition of crude oil to sediments were predicted within the Fond du Lac Headpond, and below the Fond du Lac Dam as the river transitions into the estuary. Accumulation of crude oil in sediment was generally predicted to be light after 24 hours (<0.5 g/m^2); however, considerably greater accumulations in sediment might be expected to develop over time, particularly in the sediments of the Fond du Lac Headpond, and in the upper estuary as oil particle aggregates are deposited in the slower moving water.

5.1.5.2 Trajectory Summary for Average River Flow (Summer) Period

Under the average river flow scenario, CLB was predicted to travel 5.0, 10.2, 13.0 and 13.7 miles downstream in Little Otter Creek, Otter Creek and the St. Louis River after approximately 6, 12, 18 and 24 hours respectively (Figure 5-4). By 24 hours after the hypothetical release, 1,614 m^3 of the 2,068 m^3 released was predicted to have left Little Otter Creek and entered the St. Louis river.

Within Little Otter Creek and Otter Creek, most (78.1%) of the remaining crude oil was predicted to remain on the surface of the water, with 1.7% having evaporated, and 20.3% remaining adhered to the shoreline. In the St. Louis River, most (78.4%) of the oil was predicted to be on the water surface 24 hours after the release, with 1.5% adhering to the shoreline, 19.3% having evaporated from the surface of the St. Louis River, 0.2% remaining entrained in the water column, 0.5% having decayed, and 0.1% having been deposited to sediment (see Section 3.2.1).

Bakken crude oil was predicted to follow the same general downstream transport pattern as CLB (Figure 5-5). By 24 hours after the hypothetical release, 1,476 m^3 of the 2,068 m^3 released was predicted to have left Little Otter Creek and entered the St. Louis river. Within Little Otter Creek and Otter Creek, most (71.4%) of the remaining crude oil was predicted to remain on the surface of the water, with 25.6% having evaporated, and 3.0% remaining adhered to the shoreline. In the St. Louis River, much (44.7%) of the oil was predicted to have evaporated by 24 hours after the release, with most 51.9% still remaining on the water surface, 0.9% adhering to shoreline, 2.1% remaining entrained in the water column, 0.4% having decayed, and <0.01% having been deposited to sediment (see Section 3.2.2).

A key difference between the high and average river flow scenarios, is that in the high river flow scenario, much of the crude oil passes over the Fond du Lac Dam before 24 hours have elapsed, whereas in the average river flow scenario, the leading edge of the crude oil remains above the Fond du Lac Dam over the modeled duration. This difference strongly influences the predicted fate of CLB and Bakken crude oil types. However, as described for high river flows, the movement of released oil through the series of rapids below the Thomson Reservoir and through Jay Cooke State Park approximately 7 to 12 hours after the hypothetical release of CLB or Bakken crude is predicted to result in substantial entrainment of crude oil into the river water, with subsequent re-surfacing of entrained oil in more quiescent river reaches.

Figures 5-8 and 5-9 present the maximum modeled total dissolved hydrocarbon concentrations in river water for CLB and Bakken crude oils at any time during the first 24 hours of simulation for average river flow conditions. These drawings show that peak total dissolved hydrocarbon concentrations frequently exceed 5,000 µg/L (ppb) throughout the St. Louis River from the confluence with Otter Creek, to the Fond du Lac Headpond. Predicted total dissolved hydrocarbon concentrations tend to be slightly higher overall for the Bakken crude oil type than for the CLB. The high modeled concentrations are a consequence of the turbulent flow of water in the St. Louis River. It is important to emphasize that the results shown in Figures 5-8 and 5-9 represent transient peak concentrations that would be short-lived (i.e., hours) as the bulk of the released crude oil moves down-river and is subsequently flushed by clean water.

At the end of the 24 hour simulation, most of the floating CLB was predicted to be located a short distance upstream of the Fond du Lac Dam, and to be present as heavy black oil (>1.0 mm thickness, see Figure 4-14) slicks and globules at the water surface. Slicks of Bakken crude oil (see Figure 4-36) were predicted to be present as heavy black oil, with lesser amounts of black oil and dark brown oil associated with the leading and trailing edges of the slick.

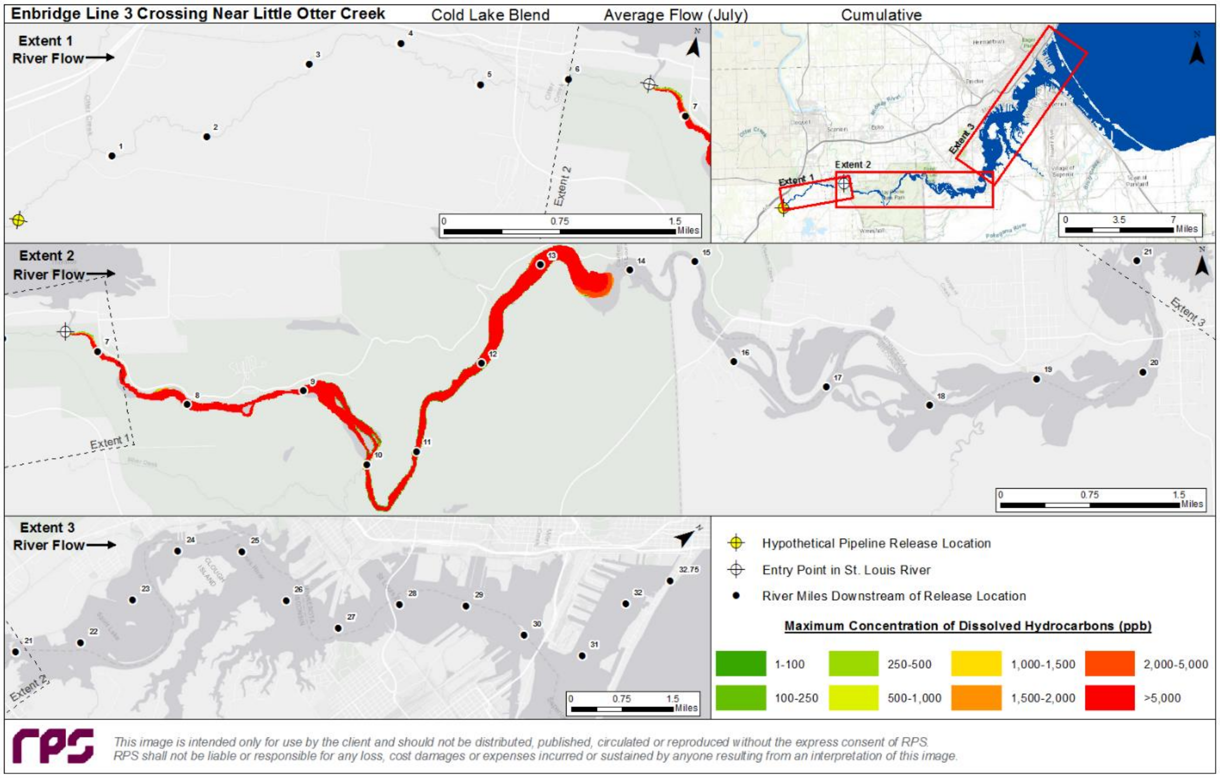


Figure 5-8 Maximum Modeled Total Dissolved Hydrocarbon Concentrations in River Water for CLB Oil During Average Flow.

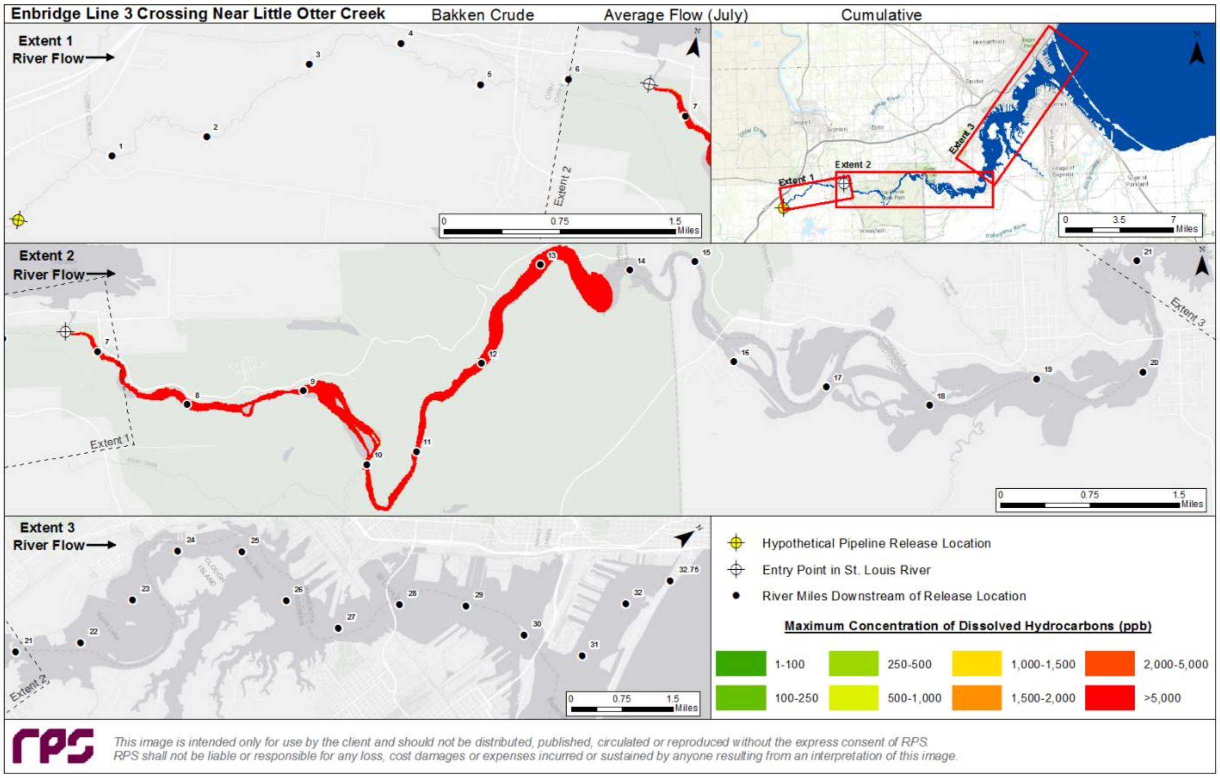


Figure 5-9 Maximum Modeled Total Dissolved Hydrocarbon Concentrations in River Water for Bakken Crude Oil During Average Flow.

Extensive shoreline oiling (>500 g/m^2) was predicted for CLB and Bakken crude oil throughout Little Otter Creek and Otter Creek (where the riparian habitat is largely marshy), and into the St. Louis River (see Figures 4-16 and 4-38). In the section of rapids (and primarily exposed bedrock shoreline type) between the Thomson Reservoir and the Fond du Lac Headpond, more continuous oiling of shoreline was predicted for CLB, whereas irregular or patchy oiling of shoreline was predicted for Bakken. Both heavy shoreline oiling and deposition of crude oil to sediments were predicted within the Fond du Lac Headpond. Accumulation of crude oil in sediment was generally predicted to be light after 24 hours (<0.5 g/m^2); however, considerably greater accumulations in sediment might be expected to develop over time, particularly in the sediments of the Fond du Lac Headpond, and in the upper estuary due to the settling out of oil particle aggregates in the slower moving water.

5.1.5.3 Trajectory Summary During Low River Flow (Winter) Period

Under the low river flow scenario, CLB was predicted to travel 3.4 and 7.8 miles downstream in Little Otter Creek, Otter Creek and the St. Louis River after approximately 6 and 12 hours respectively, and to effectively stop moving at a distance of 8.2 miles downstream within 18 hours of release (Figure 5-4). By 24 hours after the hypothetical release, 820 m^3 of the 2,068 m^3 released was predicted to have left Little Otter Creek and entered the St. Louis River.

Within Little Otter Creek and Otter Creek, most (>99.9%) of the remaining crude oil was predicted to be found on the surface of the water (under the ice) or adhering to the stream banks. Practically none (<0.01%) of the oil would evaporate, as the stream would be uniformly ice-covered. In the St. Louis River, most (99.2%) of the oil was predicted to be on the water surface (under ice) 24 hours after the release, with <0.01% adhering to the shoreline, <0.01% having evaporated from the surface of the St. Louis River, 0.5% remaining entrained in the water column, 0.3% having decayed, and <0.01% having been deposited to sediment (see Section 3.2.1).

Bakken crude oil was predicted to follow the same general downstream transport pattern as CLB (Figure 5-5). Under the low river flow scenario, Bakken crude oil was predicted to travel 3.4, 7.7, 9.4 and 12.0 miles downstream in Little Otter Creek, Otter Creek and the St. Louis River after approximately 6, 12, 18 and 24 hours. By 24 hours after the hypothetical release, 1,844 m^3 of the 2,068 m^3 released was predicted to have left Little Otter Creek and entered the St. Louis river. Within Little Otter Creek and Otter Creek, most (>99.9%) of the remaining crude oil was predicted to remain on the surface of the water (under the ice) or adhering to shorelines, with <0.01% having evaporated. In the St. Louis River, much (99.5%) of the oil was predicted to remain on the water surface (under ice), with <0.01% having evaporated, <0.1% adhering to shoreline, 0.3% remaining entrained in the water column, 0.2% having decayed, and <0.01% having been deposited to sediment (see Section 3.2.2).

Under the low river flow scenario and after 24 hours, most of the CLB and Bakken crude oil is predicted to remain in Little Otter Creek and Otter Creek due to low water flow. As a result, downstream transport within the St. Louis River is predicted to be substantially reduced when compared to the other scenarios. In addition, winter ice cover is assumed to limit evaporation of volatile constituents of the crude oil into the atmosphere. While this assumption is reasonable for Little Otter Creek and Otter Creek, it may not be completely valid for the upper portion of the St. Louis River, where rapids and cascades may remain as open water even during cold periods. Therefore, some evaporation of volatile constituents of the crude oil would be expected to occur in the St. Louis River.

Figures 5-10 and 5-11 present the maximum modeled total dissolved hydrocarbon concentrations in river water for CLB and Bakken crude oils, respectively, at any time during the first 24 hours of simulation under low river flow conditions. These drawings show that peak total dissolved hydrocarbon concentrations frequently exceed 5,000 µg/L (ppb) throughout the St. Louis River from the confluence with Otter Creek, to upper end of the Fond du Lac Headpond. Predicted total dissolved hydrocarbon concentrations tend to be slightly higher overall for the Bakken crude oil type than for the CLB. The high modeled concentrations are a consequence of the turbulent flow of water in the St. Louis River. It is important to emphasize that the results shown in Figures 5-10 and 5-11 represent transient peak concentrations that would be short-lived (i.e., hours) as the bulk of the released crude oil moves down-river and is subsequently flushed by clean water.

At the end of the 24 hour simulation, most of the floating CLB was predicted to be located a short distance downstream of the confluence of Otter Creek and the St. Louis River, and be present as heavy black oil (>1.0 mm thickness, see Figure 4-21) slicks and globules at the ice-water interface. Slicks of Bakken crude oil were predicted to be present farther downstream (the leading edge entering the Fond du Lac Headpond, see Figure 4-43) as heavy black oil. For both crude oil types, but particularly for the more viscous CLB, the interaction of “floating” oil with ice on the river surface causes drag, which retards its downstream movement relative to the downstream movement of the entrained and dissolved crude oil. This differential is particularly noticeable for the CLB oil in winter, compared to the high and average river flows during the ice free season.

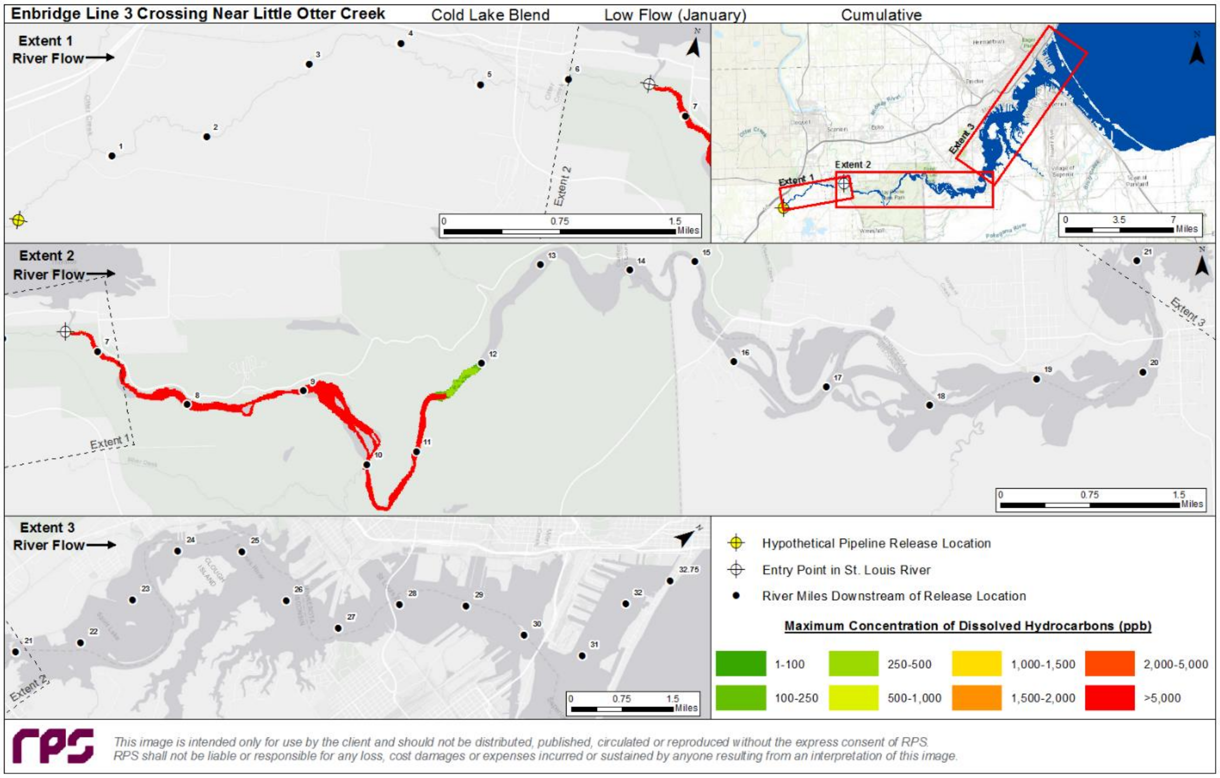


Figure 5-10 Maximum Modeled Total Dissolved Hydrocarbon Concentrations in River Water for CLB Oil During Low Flow.

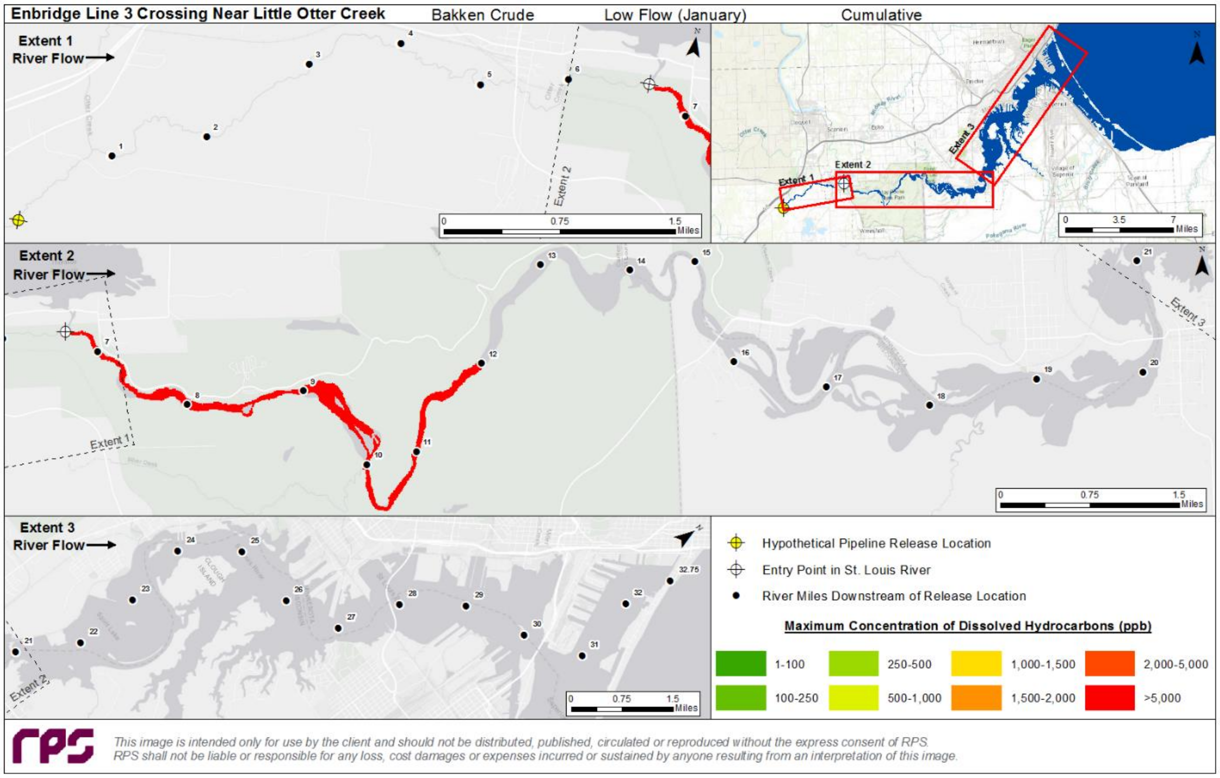


Figure 5-11 Maximum Modeled Total Dissolved Hydrocarbon Concentrations in River Water for Bakken Crude Oil During Low Flow.

Extensive shoreline oiling (>500 g/m^2) was predicted for CLB crude oil throughout Little Otter Creek, Otter Creek, and into the upper portion of the St. Louis River (see Figure 4-23). For the Bakken crude oil, more discontinuous oiling of shorelines was predicted to occur as far downstream as the Fond du Lac Headpond, with some deposition of crude oil to sediment in the upper section of the headpond (see Figure 4-45). Accumulation of crude oil in sediment was generally predicted to be light after 24 hours (<0.5 g/m^2); however, considerably greater accumulations in sediment might be expected to develop over time, particularly in the sediments of the Fond du Lac Headpond due to settling of oil particle aggregates in the slower moving water.

5.2 Qualitative EHHRA for Hypothetical Crude Oil Release at Little Otter Creek

While a large release of crude oil is unlikely (see Stantec et al. 2017; Chapter 4.0), potential environmental effects of a crude oil release on relevant ecological and human environment receptors are described here, taking into consideration the predicted geographic extent of released Bakken or CLB crude oil types over the 24 hour simulation period. Effects of season (including temperature, river flow conditions, and receptor presence/absence and sensitivity) are also considered. Rationale supporting the approach to the effects analysis are provided in Stantec et al. (2017; Section 7.1 and Table 7-8).

5.2.1 Terrestrial Receptors

For this hypothetical release site and seasonal scenarios, crude oil is assumed to enter directly into Little Otter Creek with no overland flow. Environmental effects on soils, terrestrial vegetation and groundwater quality are assumed to be localized, limited in spatial extent, and readily remediated to generally accepted standards using conventional clean-up techniques. The environmental effects of a crude oil release on terrestrial receptors are not considered further for this representative site.

5.2.2 Aquatic Receptors

The aquatic environmental and ecological receptors that were considered in the assessment of the Little Otter Creek site include water and sediment quality in Little Otter Creek, Otter Creek and the St. Louis River (including the Fond du Lac Headpond), extending in some cases as far as the upper St. Louis River Estuary, as well as shoreline and riparian habitats (including wetlands), aquatic plants, benthic invertebrates and fish. None of the crude oil fate and transport scenarios were predicted to result in oil reaching Lake Superior (see Section 3).

Di Toro et al. (2000) and French McCay (2002) stressed that the dissolved hydrocarbon concentration expected to be lethal to 50% of exposed individuals (the LC_{50}) is specific to the particular chemical constituents present, the degree of partitioning of aromatic and aliphatic hydrocarbons into the dissolved phase, the sensitivity of the species of interest to hydrocarbon exposure, and the duration and temperature of exposure. Each of these factors can have significant influence on the apparent toxicity of hydrocarbon mixtures in water, through the mechanism known as non-polar narcosis. French McCay identified a value of 224 µg/L as a benchmark for sensitive aquatic species exposed indefinitely to total dissolved hydrocarbon compounds from crude oil. For species of average sensitivity, a threshold of 1,869 ppb was reported. Given that exposure to peak dissolved hydrocarbon concentrations in this scenario would be of short duration (i.e., typically less than one day), higher concentrations (perhaps 2 to 3 times higher) would be required to result in the death of even sensitive species. A threshold value of 500 µg/L was used in this assessment as a conservative benchmark for acute toxicity in aquatic organisms exposed to total dissolved hydrocarbon compounds in water for 24 hours or less (i.e., this concentration is approximately double the threshold for long-term exposure).

Chronic exposure to PAHs, or exposure during a critical life stage, can cause adverse effects to aquatic organisms via different mechanisms, at considerably lower concentrations. The most sensitive endpoints appear to include a suite of developmental effects on fish eggs and embryos (blue sac disease) which can be induced by exposure to total PAH concentrations as low as 1 µg/L shortly after fertilization. Similarly, photo-activation of certain PAH compounds by ultraviolet (UV) light to induce free radical formation in biological tissues (where the PAH compounds have accumulated) can be lethal to small or weakly pigmented aquatic organisms at total PAH concentrations around 1 µg/L. However, the penetration of UV light into water can be markedly reduced by suspended particulate matter or the presence of dissolved organic substances in the water.

For aquatic plants and riparian/wetland vegetation it was assumed that contact between green plant tissues and fresh crude oil would result in the death of plant tissues. However, protected tissues (e.g., those covered with a protective layer of bark, or buried in the ground) might not be affected. This is consistent with observations of oiling of tree trunks without any evidence of adverse effects, or re-growth of perennial vegetation and shrubs from surviving rootstocks following the death of green plant tissues contacted by crude oil.

5.2.2.1 Little Otter Creek and Otter Creek

In Little Otter Creek and Otter Creek, the effects of a crude oil release on aquatic receptors would be similar to effects that were previously predicted for sections of the Mosquito Creek or Sandy River representative sites (Stantec et al. 2017, Sections 7.2 and 7.4). Both of those scenarios describe the potential environmental effects and risks of crude oil spills to small, slow-flowing streams with marshy riparian habitat. Crude oil released into Little Otter Creek during the spring (high river flow) or summer (average river flow) seasons is predicted to travel downstream, interacting with seasonal shoreline areas and riparian marsh. Relatively little (<2%) of the CLB would evaporate from the surface of the creek, although a more substantial fraction of the Bakken crude oil (18.4 to 25.6%) would be expected to evaporate before reaching the St. Louis River. Based on OILMAPLand simulations, CLB and Bakken crude oil were predicted to follow similar downstream transport patterns within the creeks. Both types of oil were predicted to reach the St. Louis River approximately 6.6 miles downstream between 6 and 8 hours after a release. During the winter (low river flow) period, Little Otter Creek and Otter Creek would be covered with ice, and flow would require about 10 hours to transport released crude oil from the pipeline crossing to the confluence with the St. Louis River. The released crude oil would move with gravity and water flow along the underside of the ice, having little contact with stream banks although often in close proximity or in direct contact with stream sediments. Owing to the lack of evaporative losses of low molecular weight hydrocarbons, there would be more potential for high concentrations of dissolved hydrocarbons in the stream water.

The effects of crude oil releases on benthic invertebrates and fish depend on the characteristics of the released oil and environmental conditions at the time of the release. Acute toxicity to fish is commonly but not always observed in association with crude oil releases, and is an indicator that, at least briefly, concentrations of dissolved hydrocarbons (particularly mono-aromatic hydrocarbons, some low molecular weight PAHs, and short-chain aliphatic hydrocarbons) are sufficiently high to cause acute toxicity due to narcosis. Light oils have low viscosity relative to heavier oils. Turbulence in flowing water could potentially disperse light oil as small droplets in the water column, increasing the potential for toxic fractions of the light oil to dissolve into the water column. As a result of the flow conditions, and the relatively small volume of flow in Little Otter Creek and Otter Creek providing dilution to dissolved hydrocarbons, the potential for acute toxicity to fish and benthic invertebrates would be high in all seasons, for both types of crude oil. Therefore, it is likely that under all scenarios, a full-bore pipeline rupture at the Little Otter Creek crossing site would kill most or all of the fish in the reaches of the creeks leading to the St. Louis River. It is also likely that there would be substantial mortality of benthic invertebrate fauna (e.g., aquatic insects, crustaceans, and mollusks) in these creek reaches.

There would also be high potential for acute or chronic effects of released crude oil on fish eggs and embryos in Little Otter Creek and Otter Creek (i.e., induction of deformities or mortality collectively termed blue sac disease). Many of the fish species present (e.g., cyprinids) would spawn in the spring and early summer. The eggs and embryos of these species, if not killed outright, could be exposed to total PAH concentrations in the river water that could be sufficiently high to induce deformities or cause mortality. In addition, if salmonid fish are present and potentially spawning in the lower (higher gradient) reach of Otter

Creek, then overwintering trout eggs and embryos could be damaged or killed following a release during the winter season.

The potential for phototoxicity caused by an interaction of UV light with PAHs accumulated in fish tissues would be greatest for a crude oil release in summer due to high light intensity and long day length, and lowest in the winter due to ice and snow cover that would attenuate light. Small fish that are lightly pigmented or transparent (i.e., embryos, larval and juvenile fish) are most susceptible to phototoxicity. Eggs or larval fish buried in the stream bed would not be at immediate risk of phototoxicity, but could be harmed following emergence. The risk of phototoxicity could be partially mitigated by periods of high concentrations of suspended sediment and dissolved organic carbon present in the water, as these substances would limit light penetration into the water.

For a hypothetical release under spring freshet conditions, it is likely that most aquatic plants would still be dormant or submerged, and that environmental effects on this receptor type would be minimal. Submerged aquatic plants would be less vulnerable, as they would be exposed primarily to dissolved hydrocarbons, and are not considered likely to be among the more sensitive groups of aquatic biota to such exposure. However, flooded riparian areas and wetland habitats would also be exposed to the released oil under spring freshet conditions, and if not properly remediated, crude oil residues would be likely to kill or suppress the growth of plants in these areas. This could affect the biological integrity and productivity of the habitat, and potentially lead to erosion and further damage to the habitat. Later in the summer (under average river flow conditions), floating aquatic plants would be killed by exposure to crude oil. Although the stream banks would be subject to oiling, most of the riparian habitat would not be directly affected by oil exposure. Wild rice was not observed growing along Little Otter Creek or Otter Creek when the area was visited during the summer of 2019. During the winter (low river flow) period, aquatic plants would be dormant (persisting as seeds or rootstocks in the stream bed), and the riparian vegetation would not be exposed to oil. Therefore, direct effects of crude oil exposure on aquatic plants would be minimal for a release in the winter.

Entrainment of small crude oil droplets in the water column enhances the potential for light crude oils to interact with suspended sediment particles in the water column, resulting in the formation of oil-particle aggregates (OPAs). Such aggregates may subsequently be preferentially deposited in areas of still or slowly moving water. Formation of true OPAs is generally less likely to occur with heavy crude oils such as diluted bitumen, as the viscosity of the oil precludes the ready formation of fine droplets in the water column (Zhou et al. 2015). However, heavy oils would contact and bind to sediment particles along the shoreline, and some accumulation of both light and heavy oils in depositional areas of Little Otter Creek and Otter Creek is likely, although the precise mechanisms of deposition may vary. Neither crude oil type is likely to reach a density greater than that of the water and sink directly to the sediment within the first few days following release. However, the OILMAPLand simulations show high potential for retention of crude oil (particularly the CLB crude oil) as a result of contact with the creek banks, and subsequent deposition of OPA to the creek bed is also highly likely (with implications for chronic effects on aquatic life, if not remediated).

5.2.2.2 St. Louis River and Fond du Lac Headpond

The section of the St. Louis River flowing through Jay Cooke State Park (i.e., a fast-flowing river in a rocky gorge before it meets the Fond du Lac Headpond) is in many respects an extreme river type. Fast-flowing and shallow, with many large and smaller cascades over bedrock ridges, the river has an effective width of over 200 m in places and is narrow and constricted in others. These conditions prevail over about 4.5 river miles (7.2 km) before the river gradient becomes lower, the flow slower, the depth increases, and the river transitions into the Fond Du Lac Headpond, which is more lake-like. Although some aspects of the Fond du Lac Headpond and Fond du Lac Dam resemble aspects of the Mississippi River at Little Falls scenario (Stantec et al. 2017, Section 7.8), the St. Louis River is much smaller than the Mississippi River, and the effects of a crude oil release on aquatic receptors in the St. Louis River would be qualitatively more severe than those predicted for the other representative release sites in Minnesota (Stantec et al. 2017).

After entering the St. Louis River, downstream transport under average and high river flow conditions would be rapid, with limited shoreline retention of oil due to the steeper gradients and rocky channel type. Both crude oil types are predicted to reach the Fond du Lac Headpond within 24 hours of release. Although turbulent flow in the upper St. Louis River is expected to entrain most of the released oil into the water, re-surfacing of oil would occur in the Fond du Lac Headpond. In the high river flow scenario, both types of oil are predicted to pass over the Fond du Lac Dam and continue moving downstream to reach the upper St. Louis River Estuary. Considerable deposition of submerged and particle-associated crude oil to sediments in the Fond du Lac Headpond is expected. Under the winter (low river flow) scenario, the Bakken crude oil was predicted to reach the upper end of the Fond du Lac Headpond (Figure 5-5), whereas the CLB crude oil release was predicted to terminate in the St. Louis River above the headpond within 18 hours post-release (Figure 5-4). However, for both oil types it is reasonable to assume that if emergency response measures are delayed during winter, that continued downstream transport over a period greater than 24 hours would result in deposition of crude oil to sediments in the Fond du Lac Headpond. For the Bakken crude oil, it is possible that some would pass over the Fond du Lac Dam and continue to move towards the St. Louis River Estuary in the days following the initial release.

The effects of crude oil releases on benthic invertebrates and fish depend on the characteristics of the released oil and environmental conditions at the time of the release. However, the extremely turbulent flow expected in the St. Louis River below the Thomson Reservoir in all seasons suggests that both CLB and Bakken crude oils would be entrained into the water column as small droplets, leading to the rapid dissolution of low molecular weight hydrocarbons, including monocyclic aromatic hydrocarbons and PAHs, into the water. The potential for acute toxicity to fish and benthic invertebrates would be very high for both types of crude oil. The SIMAP simulations indicate that dissolved total petroleum hydrocarbon concentrations may exceed 5,000 µg/L throughout the reach of the St. Louis River below the Thomson Reservoir, including the Fond du Lac Headpond. Therefore, it is likely that acute toxicity to fish and other forms of aquatic life would occur throughout the St. Louis River below the Thomson Reservoir, and in the Fond du Lac Headpond.

The nature of the aquatic habitat in the St. Louis River below the Thomson Reservoir (i.e., bedrock-controlled) is such that little crude oil would be retained long-term on shorelines or in the bottom substrates. The St. Louis River is expected to provide spawning habitat for walleye and other fish species in the spring, in habitats that range from white-water below falls and dams in rivers, to boulder or coarse gravel shoals in lakes (Scott and Crossman 1973). Crude oil droplets could potentially be driven or drawn into these substrate types but would be expected to weather rapidly due to ongoing water flow, or to be flushed out by subsequent high-flow events. Therefore, there would be potential for adverse effects of released crude oil on fish eggs and embryos in the St. Louis River (i.e., induction of deformities or mortality collectively termed blue sac disease). It is not likely that such effects would persist more than a year following a release, as a result of the gradual weathering of the toxic compounds, and periodic flushing by high river flows. However, sediment-associated crude oil residues would likely accumulate and persist in the sediments of the Fond du Lac Headpond, resulting in chronic effects on the benthic invertebrate community, as well as fish communities in the headpond.

The potential for phototoxicity, caused by an interaction of UV light with PAHs accumulated in fish tissues, would be greatest for a crude oil release in summer due to high light intensity and long day length. As little crude oil is expected to persist in the St. Louis River between the Thomson Reservoir and the Fond du Lac Headpond, and this reach is continually flushed with fresh water released from the Thomson Reservoir, the potential for photoxicity (subsequent to the initial mortality event) is considered low. However, the accumulation of sediment-associated crude oil residues in the Fond du Lac Headpond in the days and weeks following a release to Little Otter Creek would also create conditions that could lead to biological uptake of PAH compounds. This could lead to episodes of phototoxicity when small organisms (e.g., zooplankton or small fish) are exposed to high light intensity.

The St. Louis River between the Thomson Reservoir and the Fond du Lac Headpond provides little habitat for submerged aquatic plants. This is due to the predominant bedrock substrate type, and also to seasonal high river flow events that would scour the substrates. Further, the Fond du Lac Headpond is a drowned river valley with steeply rising (and often eroding and unstable) walls. The Fond du Lac Dam is approximately 75 ft (23 m) tall at its face. The combination of a rapid drop-off and narrow, unstable littoral zone limits the potential for submerged aquatic vegetation to develop within the headpond. Therefore, given the limited development of aquatic plant communities in St. Louis River between the Thomson Reservoir and the Fond du Lac Headpond, no significant effects on the regional distribution and abundance of aquatic plant communities are expected if a crude oil spill were to occur. Wild rice is not expected to be present in the headpond.

During the winter (low river flow) period, the St. Louis River below the Thomson Reservoir would be partially ice-covered, with open areas where water cascades are present. The low winter flow rates would confine the river to its lowest elevation channels, leaving many of the secondary (higher elevation) flow paths through the rocky channel in a dry or frozen condition. The released crude oil would move with gravity and water flow both in the water column and (for floating oil) along the underside of the ice. Oil would be mixed into the water column in areas of rapids and cascades, and these areas would also provide some opportunities for evaporation of some volatile constituents (although the SIMAP model conservatively assumed full ice cover, and negligible evaporation). Crude oil would contact and potentially coat some of the rocky substrate in the river channel, although it could subsequently become dislodged and continue to move downstream during the spring freshet. Toxicity to benthic invertebrates, fish and any overwintering fish eggs deposited in the river bed (e.g., brook trout or brown trout) would be highly likely for both crude oil types.

5.2.2.3 St. Louis River Estuary

The St. Louis River Estuary is here considered to begin at Oliver, Wisconsin, where the river narrows before entering Mud Lake; however, the section of the St. Louis River between the Fond du Lac Dam and Oliver contains numerous small islands, back-channels and wetlands, and is considered to be integral with the estuary from an ecological perspective. None of the modeled scenarios indicated crude oil transport past Oliver, Wisconsin during the 24-hour period of simulation.

Oil passing the Fond du Lac Dam would continue down a short river section towards the St. Louis River Estuary. The habitat present in this section of the river, and the potential effects of crude oil releases on aquatic life, would resemble aspects of the Mississippi River at Ball Club (Stantec et al. 2017; Section 7.3), the Sandy River (Stantec et al. 2017; Section 7.4) and the Mississippi River at Little Falls (Stantec et al. 2017; Section 7.8) representative sites. Simulations at each of these sites involved crude oil moving down-river and entering a lake-like environment with wetland aspects. In addition, the Mississippi River at Little Falls scenario involves crude oil passing over dams.

During high river flow conditions, the Little Otter Creek simulations for both CLB and Bakken crude oil indicated that the leading edge of the crude oil plume would approach Oliver, Wisconsin after 24 hours. For both the average and low river flow scenarios, it was predicted that the leading edge of the crude oil plumes would remain above the Fond du Lac Dam after 24 hours.

The effects of a crude oil release on benthic invertebrates and fish would depend on the characteristics of the released oil, and environmental conditions at the time of the release. The potential for entrainment of CLB and Bakken crude oil into the water column of the St. Louis River below the Fond du Lac Dam during high river flow conditions was predicted to be high. In addition, oil that might re-surface within relatively quiescent waters of the Fond du Lac Headpond would be re-entrained under high-energy conditions when passing over the dam. The re-entrained oil would facilitate further dissolution of hydrocarbon constituents into the water. The potential for high concentrations of dissolved total petroleum hydrocarbon (>2,000 µg/L) would extend through much of the reach of the St. Louis River between the Fond du Lac Dam and Oliver, Wisconsin. Dissolved hydrocarbon concentrations would tend to be slightly higher overall for the Bakken crude oil than for the CLB.

The Fond du Lac Dam is a barrier to the upstream movement of fish that would historically have had access to the river from the St. Louis River Estuary and Lake Superior. As a result, the section of the St. Louis River below the Fond du Lac Dam is important spawning habitat for a variety of fish species, including lake sturgeon (*Acipenser fulvescens*) which has been the subject of a long-term habitat restoration program to achieve natural reproduction in this area. Lake sturgeon spawn in spring or early summer in the rocky habitat below the Fond du Lac Dam. At other times, mature individuals probably occupy habitat farther out in the estuary, or in Lake Superior. The SIMAP model indicates a high likelihood of dissolved total petroleum hydrocarbon concentrations that would be toxic to fish and other aquatic life (including fish eggs and embryos) in the St. Louis River between the Fond du Lac Dam and Oliver, Wisconsin.

Some of the entrained crude oil in the water column could interact with suspended particulate matter or bottom sediments leading to the deposition of crude oil to sediment. This would only occur during the spring freshet, as the Fond du Lac Dam would be an effective trap for sediment-associated crude oil moving downstream in the water column or as bedload. Therefore, only crude oil that passed over the Fond du Lac Dam as slicks or globules of oil would be available to interact with sediments below the dam. Under the high river flow scenario for CLB and Bakken crude oils, substantial oiling of the bed sediment would be expected in the upper St. Louis River Estuary, as water velocity drops off, and in backwater areas. In addition, crude oil could be driven or drawn into spawning gravels in the area immediately below the dam. The SIMAP model simulations for the CLB crude oil (Figure 4-8) show deposition to sediment at intensities of 0.01 to 0.5 g/m^2, although certain areas might experience considerably higher deposition (>500 g/m^2). Impingement of CLB crude oil on shorelines could also be heavy (>500 g/m^2) below the Fond du Lac Dam. Broadly similar results were also predicted for the Bakken crude oil (Figure 4-31).

With limited mixing of crude oil into river bed sediments to a depth of less than 0.5 inch, crude oil deposition of less than 0.1 g/m^2 is likely to be undetectable and without any ecological consequence. Crude oil deposition to sediment of <1 g/m^2 would result in sediment hydrocarbon concentrations that would be <100 ppm (mg/kg). These low concentrations would be unlikely to result in significant environmental effects on fish, benthic invertebrates, or other aquatic life.

Crude oil deposition to sediment of >50 g/m^2 would be expected to cause reduced community diversity, biomass and productivity. As a result, based on the SIMAP model results, the predicted crude oil deposition to sediments is not expected to be toxic to benthic invertebrates, except in areas of high deposition. The experience of the heavy crude oil spill to the Kalamazoo River near Marshall, MI, in 2010 indicates that crude oil tends to accumulate in areas where the river flow transitions from moving to still water (such as the upper portions of impounded areas). The experience of the Lac Megantic spill of Bakken crude oil in Quebec was similar, with Bakken crude oil accumulating in the sediment of pools in the river. As a result, the upper part of the St. Louis River Estuary, where water flow transitions from rapidly flowing to near standing water conditions would be particularly vulnerable to the accumulation of crude oil residues in sediment.

The potential for chronic effects of released crude oil on fish eggs and embryos below the Fond du Lac Dam under high river flow conditions is expected to be high. Many different fish species (including but not limited to lake sturgeon, walleye, northern pike, suckers, and many minnow species) spawn in the spring, either in gravels associated with fast water, or in vegetated floodplains and shallow waters of rivers, marshes, and bays of larger lakes. A crude oil spill during the spring freshet period could have serious consequences for reproductive success, with the potential for effects to persist where crude oil enters depositional sediments.

The risk of phototoxicity in this section of the St. Louis River and estuary would be partially mitigated by the suspended sediment and DOC, which would absorb and limit the penetration of UV light into the water column. This risk would potentially persist for months following a crude oil release during the spring freshet, with small and young-of-the-year fish being most at risk.

The habitat below the Fond du Lac Dam becomes increasingly important to aquatic plants, as the river opens up into a series of islands with areas of back-channel and wetlands. Most aquatic plants would remain in a dormant state during the spring freshet and, therefore, would avoid direct contact with fresh crude oil. A crude oil release in the summer (average river flow) or winter (low-flow) periods would be unlikely to result in large amounts of fresh crude oil entering the estuary. Therefore, effects on aquatic plants in the estuary would be largely limited to effects on shorelines in the spring (high-flow) season.

5.2.2.4 Summary of Crude Oil Release Effects on Aquatic Receptors

For both crude oil types, it was predicted that there would be extensive mortality of fish in Little Otter Creek and Otter Creek under all seasonal scenarios, owing to the small dimensions of the creek sections, and the large amount of oil that could enter Little Otter Creek.

The St. Louis River is fast flowing and turbulent, which would entrain crude oil into the water column as small droplets, enhancing the dissolution of low molecular weight and aromatic hydrocarbons into the river water. This would result in a high potential for mortality of fish and other aquatic life throughout the reach leading to the Fond du Lac Headpond, and to some extent within the headpond. For the high river flow scenarios, where floating oil was predicted to be carried over the crest of the Fond du Lac Dam, additional mortality of fish and other aquatic life would be expected in the St. Louis River and Estuary below the dam, as far downstream as Oliver, Wisconsin.

In addition to direct effects on fish and other aquatic life, a crude oil release in the spring, summer or fall could lead to deposition of crude oil to bottom substrates. In turn, this can damage spawning habitats , with the potential for mortality of fish eggs and embryos. A release in the spring would be of particular concern, as it could affect habitat that has been restored below the Fond du Lac Dam to support the recovery of Lake Sturgeon, as well as other important spawning habitats throughout the system. Deposition of crude oil to bottom substrates in fast-flowing areas would be expected to have short-term effects on the habitat, due to rapid weathering of the oil, and periodic flushing of the substrates. However, deposition of crude oil to soft sediments in Little Otter Creek, Otter Creek, the Fond du Lac Headpond, or the St. Louis River Estuary, could result in medium to long-term effects depending on the oil type, and the nature of the substrates.

Aquatic plant communities in Little Otter Creek and Otter Creek would be adversely affected by a crude oil release. In spring, high water levels would allow crude oil to enter and be deposited in the riparian wetland areas, where it could persist and be damaging to plants. In summer, plants actively growing in the creeks and on active shorelines would be killed, although the potential for oil to enter the riparian wetland zones would be much lower. In winter, plants would be dormant, but residual oil could enter the riparian areas during the spring melt period.

Aquatic plant communities are sparse in the St. Louis River below the Thomson dam, and effects would be minor regardless of season. Aquatic plant communities also are not well developed along the shores of the Fond du Lac headpond. A crude oil release in the spring could result in oil passing over the Fond du Lac Dam, and being transported into the upper St. Louis River Estuary, where aquatic plant communities and wetlands are well developed. High water conditions would promote entry of crude oil into the wetlands, where it would be retained and cause damage to aquatic plant communities and wetland function.

5.2.3 Wildlife Receptors

Habitat along Little Otter Creek, Otter Creek, the St. Louis River, and the St. Louis River Estuary downstream of the hypothetical release site supports amphibians (e.g., frogs, salamander), reptiles (e.g., turtles, snakes), birds (e.g., ducks, geese, shorebirds, raptors), and semi-aquatic mammals (e.g., muskrat, beaver, mink and otter). Details on predicted environmental effects for these wildlife groups are provided below.

5.2.3.1 Amphibians and Reptiles

According to the Amphibian and Reptile Survey of Minnesota (https://www.mnherps.com/), the area west of Duluth (including the St. Louis River and estuary) supports a wide variety of amphibian and reptile species, including: American toad, spring peeper, leopard frog, wood frog, mink frog and green frog; as well as blue spotted salamander, eastern tiger salamander, spotted salamander (special concern), four-toed salamander (special concern), and red-backed salamander. The red-backed salamander is a special case, as it lives and reproduces entirely in moist terrestrial habitats and does not inhabit aquatic environments; as a result, it is unlikely that a crude oil release directly to Little Otter Creek would affect this species. Turtles recently reported from the area include Blanding's turtle (threatened), snapping turtle, spiny softshell turtle, and wood turtle (threatened). A variety of snake species are also recorded from the area, although they would occupy principally terrestrial habitats, and would not be particularly susceptible to crude oil exposure. Several of the herptile species listed above are considered to be of conservation concern in Minnesota. Areas that would provide high quality habitat for amphibians and aquatic reptile species include Little Otter Creek, Otter Creek, the Fond du Lac Headpond, and the St. Louis River Estuary. Stantec et al. 2017, Section 7.1.3.5 provides a summary of the sensitivity and effects of crude oil exposure on amphibian and reptile receptors.

Amphibians have delicate epithelial tissues that would be damaged (i.e., chemically burned) if contacted by fresh crude oil (Bakken or CLB) containing abundant low-molecular weight hydrocarbons, including mono-aromatic hydrocarbons. Amphibian eggs are laid in water and, like fish eggs and embryos, would be susceptible to acute toxicity, developmental effects, or phototoxicity. Moderately weathered CLB would be sticky and could physically trap small amphibians and reptiles. Contact with highly weathered crude oil, particularly weathered CLB which would no longer be sticky would be relatively harmless.

Some turtle species, including the threatened wood turtle, are more terrestrial than aquatic in their habitat use during the spring, summer and fall periods, and would have low risk of contacting crude oil released into little Otter Creek and associated downstream areas. The remaining turtle species likely to be present have more aquatic habitat preferences. Individual animals of these species would be at risk of be exposed to crude oil. Turtles appear to be relatively tolerant of external crude oil exposure and, although these animals are likely to become oiled, mortality of turtles as a result of this exposure is not likely.

Snakes are primarily terrestrial and are less intimately associated with aquatic environments. As a result, exposure of snakes to released crude oils would be limited, and like turtles, they are expected to display a degree of tolerance to crude oil exposure.

Amphibians and reptiles undergo a winter dormancy period when temperatures drop below approximately 41 to 45ºF. This typically involves burrowing down into muddy areas or the creek bed to avoid freezing. Their location buried in mud or bottom substrates would provide a measure of protection from direct contact with floating oil, which would subsequently be flushed out of the creeks by spring freshet. In addition, the low metabolic rate of hibernating herptile species would provide a measure of protection from short-term exposure to dissolved hydrocarbons. Therefore, during the winter (and likely up until April or May when winter ice is gone), these organisms would have little exposure to released oil moving on the water surface or within the water column.

An accidental release of crude oil (CLB or Bakken) into Little Otter Creek and Otter Creek during the spring freshet period would have adverse effects on amphibians in the creek, and potentially out into the floodplain areas. Due to their sensitive skin, which also functions as a respiratory surface, exposure to both floating crude oil and dissolved low molecular weight hydrocarbons is likely to be acutely toxic to amphibians including frogs and salamanders. Reptiles such as turtles would not likely die as a result of short-term exposure to dissolved hydrocarbons and are relatively tolerant of external oil exposure. Turtles in Little Otter Creek and Otter Creek would be likely to survive, particularly if they were subsequently rescued, cleaned, and rehabilitated before release.

An accidental release of crude oil (CLB or Bakken) into Little Otter Creek and Otter Creek during the average river flow period (summer and fall) would have adverse effects on amphibians in the creek, but not in moist floodplain areas. Therefore, the loss of amphibians from floodplain habitat would be less than during the high river flow period. Reptiles exposed to crude oil in the creek, such as turtles, would likely survive, particularly if they were subsequently rescued, cleaned, and rehabilitated before release. Turtles vary in their degree of adaptation to the aquatic environment. During winter, the direct effects of a crude oil spill on amphibians and reptiles in Little Otter Creek and Otter Creek would be minimal given their overwintering behaviors (e.g., hibernation) and distribution relative to where crude oil would be located.

The fast-moving waters of the St. Louis River below the Thomson Reservoir offers only limited habitat for amphibians and turtles. A lack of suitable spawning habitat (which typically occurs in slow-moving or still water) would limit amphibian populations. Limited opportunities for over-wintering habitat would also potentially limit herptile populations. As in Otter Creek, high concentrations of dissolved hydrocarbons in all seasons would be potentially lethal to amphibians. Turtles would be more likely to survive exposure in this habitat, particularly as most of the crude oil would be mixed into the water column and would pass through quickly.

The Fond du Lac Headpond would provide habitat for amphibians and turtles, although this would be limited by the generally steep bottom slopes and narrow littoral zone of the reservoir. As elsewhere, the high total dissolved hydrocarbon concentrations, and the potential for amphibians to contact re-surfacing crude oil in the headpond, would create conditions likely to be lethal to amphibians in the spring (high river flow) and summer (average river flow) seasons. Over-wintering amphibians would have little exposure to crude oil. Turtles in the Fond du Lac Headpond would likely survive exposure to crude oil.

There is excellent habitat for amphibians and turtles in the river reach below the Fond du Lac Headpond, and in the upper portion of the St. Louis River Estuary, during the spring (high-flow) season. This area of habitat was not predicted to be affected by released crude oil in the first 24 hours following a release in the summer (average river flow) or winter (low river flow) seasons. For both Bakken and CLB crude oil types, predicted high concentrations of total dissolved hydrocarbons in some parts of the estuary could be lethal to adult amphibians as well as their developing eggs and free-swimming larvae. The potential for developmental effects or phototoxicity would also be present. However, not all of the estuary would be affected, and backwater areas and side-channels of the estuary between Gary - New Duluth, Minnesota, and Oliver, Wisconsin, would be subject to lower exposure concentrations than the main channel. As elsewhere, turtles would be likely to survive short-term exposure to crude oil.

5.2.3.2 Birds

Aquatic and semi-aquatic birds are those that use rivers, lakes, wetlands, and riparian areas as components of their habitat, particularly for nesting and feeding. These birds belong to a variety of guilds including but not limited to waterfowl, divers, gulls and terns, raptors, shorebirds, waders, and some songbirds. They have a variety of dietary preferences, including piscivory, insectivory, omnivory, and herbivory.

If exposed to external oiling, the ability of birds to maintain body temperature may be compromised, leading to death as a result of hypothermia. Even if they survive their initial exposure to crude oil, the exposure may require an increase in metabolic rate to survive. In turn, this may compromise other life functions such as reproduction or growth. Birds that survive external oiling may experience toxicological stresses as a result of ingesting crude oil residues while preening or attempting to clean and restore the normal properties and functions of feathers. Birds can also transfer potentially lethal quantities of crude oil residue from their feathers to the external surface of eggs, resulting in death of developing embryos.

The aquatic and semi-aquatic bird species likely to be found along the affected watercourse segments would be directly related to the habitat present. Whereas the St. Louis River Estuary has been designated an IBA and represents an area of national or international importance for a wide variety of migrating and resident bird species, the more upstream portions of Little Otter Creek, Otter Creek, and the St. Louis River would not attract large concentrations of aquatic or semi-aquatic birds. Therefore, the potential effects of a crude oil release at the Little Otter Creek crossing site on birds would depend to a great extent on the seasonal timing of the release, as well as how far down into the St. Louis River Estuary crude oil would be transported as surface oil (e.g., slicks or other forms of floating oil).

Unlike many other vertebrate receptors, aquatic bird species in the northern temperate zone are nearly all seasonal migrant species which leave their summer (and often breeding) habitat in the fall for wintering areas farther south where they can find open-water habitat. However, some birds (e.g., Canada goose) will opportunistically remain in freezing conditions if there is reliable open water and a source of food available). Timely capture and rehabilitation of oiled birds may help to mitigate the environmental effects of a crude oil release.

During the spring (high river flow) season, many migratory birds would be returning to riverine and lacustrine habitats in Minnesota or migrating through these areas on their way to breeding habitats farther north. With cold water temperatures prevailing, aquatic and semi-aquatic birds contacted by crude oil in the spring would be likely to succumb to hypothermia. Waterfowl and other semi-aquatic birds present in the affected river reaches would be most affected. Animals upstream of the oil release, farther downstream, or occupying other nearby habitats, would be less affected or unaffected, as it is assumed that emergency response measures to prevent or reduce further possible downstream transport of oil would be in place within 24 hours of the release.

The aquatic and riparian areas associated with Little Otter Creek and Otter Creek provide excellent habitat for a variety of waterfowl species (including wood ducks, dabbling ducks, mergansers, and geese), as well as fish-eating raptors, and other species such as kingfisher, herons and shorebirds. The environmental effects of a crude oil release in the spring and the summer-fall period are likely to be of similar magnitude. With rising water temperatures in summer, rapid mortality of lightly oiled adult birds due to hypothermia becomes less likely than in the spring or fall. The creeks are also unlikely to attract large numbers of migrating birds. However, in the early summer, environmental effects could include egg mortality due to transfer of oil from the feathers of lightly oiled adult birds in the nest, or mortality of young birds due to direct oil exposure or the loss of a parent bird. Chronic adverse effects on the health of birds that survive their initial exposure to crude oil are also possible as a result of ingesting crude oil residues while preening, or while consuming food items. However, as in the spring, effects are expected to be limited to areas of oil exposure. Potential effects on aquatic and semi-aquatic birds in the fall would be similar to those in spring.

The St. Louis River between the Thomson Reservoir and the Fond du Lac Headpond represents a markedly different habitat type than the creeks. With the river flowing in a steep and rocky channel, there is little truly riparian habitat present. Some vegetated islands are found in the river channel, but these can be over-washed by water during periods of high river flow. Aquatic and semi-aquatic bird species more typical of the fast-moving reaches of the St. Louis River would include mergansers, kingfisher, raptors such as osprey and bald eagle, and some shorebirds in spring, summer and fall. Few aquatic and semi-aquatic birds would remain in this habitat during the winter.

The Fond du Lac Headpond is expected to provide habitat to a wide range of nesting and migratory birds during the spring, summer and fall. Ice cover during the winter would preclude use by aquatic birds during the winter, except in areas where open water is maintained by fast river flows such as the tailrace of the Thomson Powerhouse; below the Fond du Lac Dam; and at the tailrace of the Fond du Lac Powerhouse. Small numbers of waterfowl or raptors such as bald eagle might be present in and around these open water areas.

Habitat for aquatic and semi-aquatic birds, including both nesting and migrating individuals, would be abundant in the upper St. Louis River Estuary. The wide range of habitat conditions present here, in addition to the richness of the marsh habitats, would support a wide variety of waterfowl species (including wood ducks, dabbling ducks, mergansers, and geese), as well as fish-eating raptors, and other species such as kingfisher, herons, bitterns, and shorebirds. The lower estuary also supports large numbers of gulls and some terns. In winter, ice cover would strongly limit the availability of habitat to aquatic and semi-aquatic birds, and only those areas that remain ice-free would provide habitat to a limited range of species.

Figures 5-5 and 5-5 show the extent of surface oil movement down the affected watercourses in the 24-hour period following oil release. For the high river flow (spring freshet) scenario, floating oil is predicted to approach Oliver, WI, and would affect the entire waterway between the release site at Little Otter Creek, and the upper St. Louis River Estuary. For the average river flow scenario, both crude oil types were predicted to remain above the Fond du Lac Dam after 24 hours. The spring freshet period, when the water is cold and crude oil (CLB or Bakken) has the potential to be rapidly transported into the upper St. Louis River Estuary, is the season when risk to birds would be greatest. At this time of year, early seasonal migrants would be present, and early nesting could be underway. Total numbers of affected birds would likely be modest in Little Otter Creek, Otter Creek, and the St. Louis River upstream from the Fond du Lac Headpond. The number and variety of affected birds would be expected to increase in the Fond du Lac Headpond, and to increase substantially below the Fond du Lac Dam. Risk to birds would be lower during the average river flow season, when predominantly resident and nesting birds would be present, and when it is less likely that floating oil would be transported into the St. Louis River Estuary.

In the winter months, very few aquatic and semi-aquatic birds would be directly affected by a crude oil release. The most likely areas where interactions could occur would be areas of open water frequented by over-wintering waterfowl, as well as raptors such as bald eagle feeding on ducks or fish. These birds would be susceptible to hypothermia if contacted by significant amounts of crude oil.

5.2.3.3 Semi-Aquatic Mammals

While the semi-aquatic mammal species found in Minnesota include terrestrial species such as moose and raccoon, this assessment focuses particularly on species that have a primary association with the aquatic environment such as muskrat and beaver (herbivores), American mink (carnivore-piscivore), and river otter (piscivore). These species are at greater risk of exposure to an oil release in water than more fully terrestrial mammals.

Effects to semi-aquatic mammals are typically described in terms of direct physical effects (e.g., hypothermia due to loss of insulation), direct toxicological effects (e.g., gastro-enteropathy caused by ingestion of crude oil residues while grooming oiled fur or ingesting food), and indirect effects caused by changes to habitat (e.g., land cover and food availability). The spatial extent along affected watercourses of Little Otter Creek, Otter Creek, the St. Louis River, and the St. Louis River Estuary where effects may occur, and the magnitude of such effects, is related primarily to the season and river flow rate, and to a lesser extent the type of oil released. Effects to semi-aquatic mammals relate more to the amount of time spent in the water and oil-contaminated riparian habitat (and consequent exposure to physical oiling) than to dietary preferences. Timely capture and rehabilitation of oiled mammals may help to mitigate the environmental effects of a crude oil release.

During the spring freshet (high river flow) season, with cold water temperatures prevailing, semi-aquatic mammals contacted by crude oil are likely to die as a result of hypothermia. Animals upstream from the oil release site, farther downstream where there is no exposure, or occupying other nearby habitats, would likely be unaffected. Therefore, although exposure and potential mortality of semi-aquatic mammals would be expected at a local scale, large-scale (i.e., regional) population-level effects are unlikely. Environmental effects of a crude oil release in the summer or fall periods are likely to be of a lesser magnitude than those associated with a release during spring. This is due to the combination of the spatial extent of oil exposure (greatest during periods of high river flow), as well as the effects of water temperature on the survival of oil-exposed animals.

With warmer water temperatures in the summer, rapid mortality of lightly oiled semi-aquatic mammals due to hypothermia is less likely than in the spring. Chronic adverse effects on the health of semi-aquatic mammals that survive their initial exposure to crude oil are also likely as a result of ingesting crude oil residues while grooming, or while consuming food. However, as in the spring, effects during average river flows would be limited to areas of oil exposure, which would be smaller under the lower flow scenarios. While the death of animals would be a serious environmental effect locally, longer-term population-level effects on semi-aquatic mammals are not likely to be observed given the abundance of other wetland, lake, river and riparian habitat in the affected counties of Carlton and St. Louis, the Lake Superior watershed, and the state of Minnesota more generally.

In the winter months, muskrat and beaver are likely to reduce their activity levels, although American mink and river otter would remain active. Animals in Little Otter Creek, Otter Creek, or the St. Louis River between the Thomson Reservoir and the Fond du Lac Headpond that became oiled in the winter would be likely to die as a result of hypothermia or ingestion of fresh crude oil as they attempted to clean themselves.

5.2.4 Human and Socio-Economic Receptors

Crude oils are complex mixtures of hydrocarbon compounds. Light crude oils typically contain more volatile organic compounds (VOCs) than heavier crude oils, although diluted bitumen may contain similar amounts of VOCs to light crude oils, depending upon the type and amount of diluent they contain. Air quality in the vicinity of a crude oil release, and along the downstream corridor, would be affected by the release of VOCs (such as benzene, which is often used as an indicator substance for VOCs) primarily within the first 24 hours of an oil release.

Based on OILMAPLand and SIMAP simulations, CLB and Bakken crude oil were predicted to follow similar downstream transport patterns, with each predicted to reach approximately 20 miles downstream 24 hours after a release under the high river flow scenario, and approximately 14 miles downstream under the average river flow scenario. The local area is not highly populated, however, the flow path passes close to the Minnesota communities of Carlton (population <1,000 in the 2010 census), Thomson (population <200 in the 2010 census), and the Duluth neighborhoods of Fond du Lac and Gary – New Duluth, as well as the Wisconsin community of Oliver (population <400 in the 2010 census).

Typical human health effects associated with short-term (acute) inhalation of volatiles from crude oil include headache, dizziness, nausea, vomiting, cough, respiratory distress, and chest pain. Short-term or repeated skin contact with crude oil may result in dermatitis (i.e. irritated skin or rash). The case studies (Stantec et al. 2017, Section 7.1) do not reveal any instances of human fatality as a result of inhalation of crude oil vapor. Similarly, ATSDR (1995) report that there are no known instances of human fatality as a result of inhalation of vapor from fuel oils, which would be comparable to light crude oils.

If a crude oil release was to occur in winter, and to be largely confined below ice on the river, very little of the volatile hydrocarbon present in the oil would be released to the atmosphere as VOCs. The potential for VOC inhalation exposures to the public would be greatest in the spring and summer-fall seasons, near and downwind from the release site, while the released oil is on the water surface. However, in winter, the volatiles would be released over a longer period of time due to ice cover, and exposure concentrations in air would likely be considerably lower than during the ice-free months.

In the unlikely event of a crude oil release, nearby residents would become aware of a strong hydrocarbon odor that would alert them to the presence of a hazard. Most of the volatile hydrocarbons would be lost within the first 24 hours following a release of crude oil. It is also expected that emergency response personnel would contact such residents and advise them to evacuate. Actual or potential exposure to crude oil vapor may result in residents leaving or being advised to leave their homes for a period of time while the emergency response takes place.

Direct contact with fresh or moderately weathered petroleum hydrocarbon residues can cause skin irritation or dermatitis. However, the odor associated with fresh crude oil would normally be sufficient to indicate to members of the public the presence of released crude oil. Therefore, recreational users of the natural environment (e.g., swimmers, boaters, anglers and hunters) are not likely to come into direct contact with the released oil.

Drinking water for the communities of Carlton and Thomson are drawn from groundwater sources by city owned and operated wells. These wells were identified as drinking water HCAs (Figure 5-2). Therefore, the water supplies for residents of Carlton are not likely to be affected by a release. Drinking water supplies for the communities of Fond du Lac, Gary – New Duluth, and Oliver are understood to be municipally operated and drawn from water intakes in Lake Superior that would not be affected by a crude oil release to Little Otter Creek. It is possible that some rural dwellings close to the affected watercourse might be supplied with water from private wells. However, in the event of a crude oil release, it is expected that people would be notified and testing would be completed to confirm the safety of the water supply. Based upon case studies involving crude oil releases elsewhere, this process could take a few days to two weeks, but reports of crude oil releases affecting private wells are rare, making this an unlikely effect.

Relatively little has been published regarding the long-term effects of human exposure to a crude oil release. Health effects observed in residents and clean-up workers in the months following such releases generally do not persist over the long term (Eykelbosh 2014). The International Agency for Research on Cancer (IARC 1989) has determined there is "limited evidence of carcinogenicity" of crude oil in experimental animals and "inadequate evidence of carcinogenicity" of crude oil in humans. Although toxicological effects from short-term exposure to volatile hydrocarbons are reversible when exposure is reduced, other health effects such as anxiety and depression may occur, and may persist, regardless of whether the individual was physically exposed to hydrocarbons.

No overland transport of released crude oil was modeled for the Little Otter Creek hypothetical release site; the release was assumed to occur directly into the watercourse. Infiltration of crude oil into soil and subsequently into groundwater is assumed to be negligible.

Downstream of the hypothetical release site, the St. Louis River flows through Jay Cooke State Park and other reserved lands (e.g., the Fond du Lac Park, St. Louis River Streambank Protection Area, Pokegama-Nemedji Wetlands, and Bureau of Land Management lands associated with the St. Louis River Estuary; see Figure 5-3). These locations provide a variety of recreational opportunities. Effects on air and water quality, or the presence of crude oil residues in the sediment or habitat, could potentially disrupt public use of natural resources (e.g., drinking water supplies, hunting, fishing, recreation). Emergency response workers, in cooperation with public health and safety officials, would be active in isolating, containing and recovering released crude oil, as well as notifying the public about the release. Recreational activities would be disrupted following a release of crude oil along the predicted downstream trajectory of the release. Fisheries regulators and public health officials typically close fisheries until it is confirmed through monitoring that fish consumption is not a threat to public health. This standard approach is an effective mitigation strategy to protect human receptors from contact with constituents in the oil.

Little Otter Creek and Otter Creek flow through wetland and riparian habitats that would potentially support fishing, hunting, trapping, and gathering of plants for food or medicinal purposes. The St. Louis River below the Thomson Reservoir flows through Jay Cooke State Park, a notable area for outdoor recreation. Other protected lands near the Fond du Lac Headpond would also support outdoor recreation including hunting, fishing, gathering of plants, and other traditional activities. In spring, the leading edge of both oil types is predicted to extend into the St. Louis River Estuary within 24 hours of release. The estuary is also an area where public use and traditional use of resources by tribal members are expected to occur at a high level of intensity. Effects on air and water quality, or the presence of crude oil residues in the sediment or habitat, could potentially disrupt such uses of natural resources. Emergency response workers, in cooperation with public health and safety officials, would be active in isolating, containing and recovering released crude oil, as well as notifying the public about the release. Both recreational activities by members of the public, and traditional use of land and resources by tribal members would be disrupted following a release of crude oil along the predicted downstream migration route.

5.3 Summary and Conclusions

The proposed pipeline would carry a variety of crude oil types, ranging from very light (e.g., Bakken crude oil) to heavy (e.g., diluted bitumen such as CLB). The discussion of expected environmental effects on receptors after a hypothetical large crude oil release at the proposed Little Otter Creek crossing site within the Lake Superior watershed is based on these crude oil types as bounding conditions. Potential terrestrial receptors, aquatic receptors, semi-aquatic wildlife receptors and human and socio-economic receptors were screened to identify those with the most likely interactions with released oil. The results of this assessment are summarized in Table 5-6.

Table 5-6 Environmental Effects Summary Table for Pipeline Crude Oil Releases to Little Otter Creek.

Receptor	Expected Environmental Effects of Released Crude Oil to Little Otter Creek	Relative Effect	
		Light Crude Oil	Diluted Bitumen
Terrestrial Receptors			
Soils	It is assumed in the model that crude oil would enter directly into Little Otter Creek with no overland flow of oil. In the event of an actual oil release, any oil on land would undergo prompt and effective remediation. Residual effects on plant communities, soil or groundwater quality are unlikely.	SAME	SAME
Groundwater		SAME	SAME
Terrestrial Vegetation		SAME	SAME
Aquatic Receptors			
Rivers (Little Otter Creek, Otter Creek, St. Louis River, Fond du Lac Headpond)	Both light and heavy oil would travel downstream from the hypothetical release site, affecting Little Otter Creek, Otter Creek and the St. Louis River between the Thomson Reservoir and the Fond du Lac Headpond. In spring, both light (Bakken) and heavy (CLB) crude oil types are predicted to display similar downstream transport patterns, moving past the Fond du Lac Dam and into the St. Louis River Estuary. Both are predicted to reach approximately 20 miles downstream within 24 hours after a release, form slicks of heavy black oil on the water surface and cause heavy oiling of shorelines. During spring (high river flow) and summer (average river flow) seasons, similar amounts of Bakken and CLB are predicted to remain on the surface of Little Otter Creek and Otter Creek after 24 hours. However, more of the CLB is predicted to remain on the surface of the St. Louis River and Fond du Lac Headpond after 24 hours, as a greater fraction of the Bakken crude oil would have evaporated by that time. Given the presence of rapids and several dams along the St. Louis River, both types of crude oil would be driven into the water as fine droplets to mix and dissolve into the water column; and both oil types are predicted to cause total dissolved hydrocarbon concentrations in water are predicted to generally exceed 5,000 µg/L.	SAME	SAME

Receptor	Expected Environmental Effects of Released Crude Oil to Little Otter Creek	Relative Effect	
		Light Crude Oil	Diluted Bitumen
Estuary (St. Louis River Estuary)	Crude oil would only reach the St. Louis River Estuary in 24 hours or less during periods of high river flow (e.g., spring freshet). In other seasons, it is likely that both types of crude oil would remain above the Fond du Lac Dam after 24 hours. In the estuary, both CLB and Bakken crude oil types would exhibit similar transport patterns, although slick thickness would be slightly less for the Bakken than for the CLB. Both crude oil types could cause heavy oiling (>500 g/m^2) of shorelines.	SAME	SAME
Lakes (Lake Superior)	Crude oil was not predicted to reach Lake Superior within the first 24 hours following release in any season. It is unlikely that any substantial quantity of released oil would be transported from the St. Louis River Estuary into Lake Superior once emergency response activities are taken into consideration. Therefore, there would be no consequential environmental effects on Lake Superior as a result of a crude oil release at the Little Otter Creek crossing site.	SAME	SAME
Sediment	Crude oil is predicted to be retained in the sediments of Little Otter Creek and Otter Creek, and preferentially be deposited to the sediments near the head of the Fond du Lac Headpond, and in the St. Louis River Estuary where river flow slows, and the habitat becomes more lake-like. The Bakken crude oil was less likely than the CLB to be retained by stream-bank sediments in Little Otter Creek and Otter Creek, and very little (<1%) of either the Bakken or CLB crude oil types was predicted to be deposited to sediment in the St. Louis River or Estuary within the first 24 hours after release. However, in the longer term, considerably more of the Bakken crude oil was expected to evaporate, and much of the residual CLB crude oil would be expected to accumulate in sediments at the above-noted locations.	LESS	MORE

Receptor	Expected Environmental Effects of Released Crude Oil to Little Otter Creek	Relative Effect	
		Light Crude Oil	Diluted Bitumen
Shoreline and Riparian Areas	Both light and heavy oil would travel downstream from the release site, affecting Little Otter Creek, Otter Creek, the St. Louis River and Fond du Lac Headpond and, under high river flow conditions, the St. Louis River Estuary. Both Bakken and CLB crude oil types are predicted to exhibit similar downstream transport patterns (each predicted to move up to 20 miles downstream within 24 hours after a release. During spring (high river flow) and summer (average river flow) seasons, similar amounts of CLB and Bakken crude oil are predicted to adhere to shorelines in Little Otter Creek and Otter Creek. Slightly more of the CLB (18.2%) than the Bakken crude oil (13.3%) is predicted to strand on shorelines after 24 hours in the spring season. Flooding of riparian habitats in spring could lead to stranding of crude oils in these habitats, with heavy crude oil likely to be deposited as patties or tar balls, which would be persistent, in contrast to light crude oil which would be deposited as a thin layer or sheen which would weather more quickly.	LESS	MORE
Wetlands	The main areas of wetland habitat are located along the banks of Little Otter Creek and Otter Creek, and in the St. Louis River Estuary. Both crude oil types would have similar potential to enter wetland areas near Little Otter Creek and Otter Creek during the spring (high river flow) season. Crude oil would only reach the St. Louis River Estuary within 24 hours of release in the spring season. Both crude oil types would have similar potential to enter and cause damage to wetlands.	SAME	SAME
Aquatic Plants	The main areas of aquatic plant habitat are located in Little Otter Creek and Otter Creek, and in the St. Louis River Estuary. Aquatic plants would be relatively unaffected by a release of crude oil in the winter or spring seasons. Actively growing plants contacted by crude oil in the summer would potentially be killed. The physical transport patterns of Bakken and CLB crude oil are very similar. Therefore, risks to aquatic plants would be similar regardless of the crude oil type.	SAME	SAME

Receptor	Expected Environmental Effects of Released Crude Oil to Little Otter Creek	Relative Effect	
		Light Crude Oil	Diluted Bitumen
Benthic Invertebrates	In all three seasons, very little of either the CLB or the Bakken crude oil is predicted to deposit to sediment within the first 24 hours following release. Longer-term, more of the Bakken crude oil is expected to evaporate, while more of the CLB would remain in the river, with the potential to accumulate in depositional areas at the head of the Fond du Lac Headpond and in the upper St. Louis River Estuary. Crude oil deposition to sediment of >50 g/m^2 would be expected to cause reduced community diversity, biomass and productivity. As a result, based on the SIMAP model results and professional judgement, the potential for crude oil deposition to sediments that would be toxic to benthic invertebrates is expected to be somewhat greater for the CLB crude oil than for the Bakken crude oil.	LESS	MORE
Fish	Environmental effects on fish would be limited to areas affected by the released oil. Mortality of fish is expected throughout Little Otter Creek and Otter Creek in all seasons, and for both crude oil types. The turbulent flow of the St. Louis River would effectively mix both types of crude oil into the water as fine droplets, promoting dissolution of low molecular weight and aromatic hydrocarbons at concentrations likely to exceed 5,000 µg/L throughout extensive sections of the watercourse and, in spring, into the St. Louis River Estuary. Although short-lived due to subsequent flushing of the river, these high concentrations are also likely to result in extensive mortality of fish.	SAME	SAME
Semi-Aquatic Wildlife Receptors			
Amphibians and Reptiles	Both light and heavy oil would travel downstream from the release site. Both Bakken and CLB crude oil types are predicted to exhibit similar downstream transport patterns, and form slicks of similar thickness (frequently as heavy black oil). Flooding of riparian habitats in spring could lead to stranding of crude oils in these habitats, with heavy crude oil likely to be deposited as patties or tar balls, which would be persistent, in contrast to light crude oil which would be deposited as a thin layer or sheen. Within these habitats, oiling effects on adults, juveniles, and eggs could potentially be observed. Higher potential would exist for effects on amphibians than for turtles, which appear to be somewhat tolerant of external oiling. Dormancy of	SAME	SAME

Receptor	Expected Environmental Effects of Released Crude Oil to Little Otter Creek	Relative Effect	
		Light Crude Oil	Diluted Bitumen
	amphibians and reptiles in winter and early spring means exposure to oil released at this time of year could be negligible, and adverse environmental effects less likely.		
Birds	Mortality of oiled aquatic and semi-aquatic birds would occur in areas affected by the released oil. Both light and heavy crude oil types are predicted to travel similar distances, and both would form slicks of comparable thickness. During the spring high river flow season, many migratory birds would be returning to riverine and lacustrine habitats in Minnesota or migrating through these areas on their way to breeding habitats farther north. Few birds are present in winter, so effects would be lower in that season.	SAME	SAME
Semi-aquatic Mammals	Mortality of oiled semi-aquatic mammals would be limited to areas affected by the released oil. Both light and heavy crude oil types are predicted to travel similar distances, and both would form slicks of comparable thickness. Adverse effects on mink and otter would be particularly severe in winter, due to the effects of oil in the insulating properties of fur, in combination with cold water temperatures. However, muskrat and beaver might be less vulnerable due to their lower activity levels in winter.	SAME	SAME
Human and Socio-Economic Receptors			
Air Quality	Effects on air quality have the potential to temporarily disrupt human use and occupancy patterns. Light crude oils typically contain more VOCs than heavier crude oils, although the VOC content of diluted bitumen may be similar to that of light crude oil, depending on the type and quantity of diluent used in its manufacture. Air quality in the vicinity of the oil release would be most affected within the first 24 hours of an oil release. CLB crude oil and Bakken crude oil were predicted to exhibit similar downstream transport patterns. However, considerably more of the Bakken crude oil is predicted to evaporate into the atmosphere within 24 hours than is the case for the CLB. Both oil types are predicted to pass the communities of Carlton, and Thomson, MN in all seasons, and to pass Fond du Lac and Gary – New Duluth, MN, and approach Oliver, WI, during the spring (high river flow) season. As a result, environmental effects on air quality are predicted to be spatially similar for both crude oil types, although slightly more severe for the Bakken crude oil due to	MORE	LESS

Receptor	Expected Environmental Effects of Released Crude Oil to Little Otter Creek	Relative Effect	
		Light Crude Oil	Diluted Bitumen
	its higher VOC content. Under winter conditions, cold temperatures, ice cover and absorption of crude oil into snow pack would strongly limit emissions of VOCs, in addition to constraining the area of effects.		
Human Receptors	Typical human health effects associated with short-term inhalation of VOCs from crude oil releases include headache, dizziness, nausea, vomiting, cough, respiratory distress, and chest pain; fatality is unlikely. Skin irritation or contact dermatitis are also possible for individuals who have prolonged contact with fresh or moderately weathered crude oil. Nearby residents would become aware of a strong hydrocarbon odor that would alert them to the presence of a hazard. Most volatile hydrocarbons would be lost within 24 hours following a release. The human receptors most likely to be exposed to VOCs under this hypothetical crude oil release scenario would be located in homes located close to Little Otter Creek or Otter Creek. Humans could also be exposed to VOCs as a result of recreational use of Jay Cooke State Park. Crude oil is only forecast to pass the Fond du Lac Dam in spring (high river flow) conditions, and much of the volatile component of both CLB and Bakken would have been released to air as the oil passed through Jay Cooke State Park, or over the Fond du Lac Dam. Therefore, effects on air quality near Gary – New Duluth, MN, and Oliver, WI, are expected to be minor. Under winter conditions, cold temperatures, ice cover and absorption of crude oil into snow pack would strongly limit emissions of VOCs, in addition to constraining the area of effects.	SAME	SAME

Receptor	Expected Environmental Effects of Released Crude Oil to Little Otter Creek	Relative Effect	
		Light Crude Oil	Diluted Bitumen
Public Use of Natural Resources	Both light and heavy crude oil types are predicted to travel similar distances, and both would form slicks of comparable thickness, potentially interrupting public use of natural resources over a similar area. Effects on air and water quality, or the presence of crude oil residues in the sediment or habitat, could potentially disrupt public use of natural resources. Emergency response workers, in cooperation with public health and safety officials, would be active in isolating, containing and recovering released crude oil, as well as notifying the public about the release. Drinking water for the communities of Carlton and Thomson are drawn from groundwater sources by city owned and operated wells. Water intakes for the cities of Duluth and Superior are located in Lake Superior. Therefore, the water supplies for residents of these communities are not likely to be affected by a release. However, there could be some rural residents with private potable water wells located near Little Otter Creek or Otter Creek. In the event of a crude oil release, people would be notified and testing would be completed to confirm the safety of the water supply. It is unlikely that a crude oil release to Little Otter Creek would result in adverse health effects to consumers of drinking water. Both recreational activities by members of the public, and traditional use of land and resources by tribal members would be disrupted following a release of crude oil along the predicted downstream migration route.	SAME	SAME

6 ENVIRONMENTAL RECOVERY FOLLOWING RELEASES OF OIL

6.1 Properties of Crude Oil

Crude oil is a complex mixture of petroleum hydrocarbons and its composition varies widely depending on its origin and processing. Created from organic matter, crude oil is primarily composed of carbon and hydrogen, with smaller amounts of other elements. Hydrocarbons vary in molecular weight and form, and include paraffins, aromatics, cycloalkanes, alkenes, and other compounds. The differences in the structure of these compounds, and the relative proportion of each type within each crude oil, account for the physical and chemical properties of different crude oil types, as well as the inherent toxicity of each component.

Light crude oils are characterized by their high proportion of low molecular weight hydrocarbons, with few heavy constituents. Light crude oils generally have low specific gravity and viscosity, but proportionally higher acute toxicity than heavy crude oils, which tend to be more viscous, and less readily dispersed in water. On the other hand, light crude oils tend to evaporate and break down more rapidly and more completely in the environment, whereas heavy crude oils tend to be more persistent.

Diluted bitumens are a class of blended heavy crude oil, made up of bitumen (a type of heavy crude oil) that has been modified with a diluent (a type of light crude oil) to achieve physical properties suitable for transportation in pipelines. As blends, where the diluent is a condensate, diluted bitumens may undergo a more rapid initial weathering phase, caused largely by the evaporative loss of the light-end hydrocarbons, than would be expected for a conventional medium or heavy crude oil.

6.2 Defining Recovery

Stantec et al. (2017, Section 8) provided a detailed review of the recovery of ecosystems and ecosystem components following crude oil spills. The review was in response to a request from EERA and included a review of existing literature, supported with case studies, to evaluate the process of recovery from a crude oil release in a variety of environments and ecosystems relevant to Minnesota. The following is a high-level summary of information that was previously provided by Stantec et al. (2017).

Ecosystems and human environments experience numerous types of disturbance, including natural phenomena such as fire and flooding, and anthropogenic disturbances such as chemical and crude oil releases, agriculture, forestry, mining, and urban development. The ability of a system to recover from disturbance is a complex phenomenon, dependent upon numerous intrinsic and extrinsic factors including the condition of the initial system, resistance and resiliency of the initial system prior to disturbance, and its inherent variability. The rate of recovery is largely dependent on the severity of the disturbance, its areal extent, and its duration. Most of the available literature on crude oil spills and recovery is based on very large releases, with severe and sometimes widespread effects.

Historically, definitions of recovery include a central concept regarding a return of the ecosystem, resource or human use to some desirable state roughly equivalent to its pre-disturbance state. Since pre-disturbance (baseline) conditions are often poorly documented prior to a release, definitive conclusions are sometimes difficult to achieve. More recently, the definition of recovery has meant a return to conditions that would have prevailed had the crude oil release not occurred. This definition recognizes the need to take into account the spatial and temporal variability in natural ecosystems, as well as the influence of natural and man-made factors other than the release. This perspective focuses less on comparison with baseline conditions, while emphasizing the need to identify measures to assess recovery in terms of desirable ecosystem functioning.

6.3 Surface Waters

Surface waters include freshwater habitats that range from lakes, ponds and some wetlands, to rivers and streams. These habitats play a vital role in sustaining aquatic and terrestrial ecosystems, as well as health, economic, and social values vital to humans. Crude oil releases can affect surface water quality and disrupt the values and services provided by these habitats. For surface water, recovery is typically quantified by measuring concentrations of hydrocarbon residues. Regulators generally consider recovery complete when water quality standards protective of human health and the environment are met.

Surface water quality generally recovers quite quickly following crude oil releases, due to the weathering (evaporation, dissolution and dispersion, flushing, biodegradation, photo-oxidation, etc.) of the more water-soluble fractions of the crude oil. At the same time, more persistent components of the crude oil may be left as residues in other parts of the environment, such as soil or sediment. Factors that influence recovery of surface waters include:

- The volume of crude oil that was released: larger releases have the potential to affect a larger area and recovery may take longer.
- The type of crude oil that was released: there is a continuum of potential effects and persistence within the environment. Lighter oils contain a higher proportion of more mobile compounds (e.g. more rapid and complete dissolution and evaporation), while heavier oils are typically more persistent within the environment.
- Water body characteristics: large water bodies, or watercourses with large volumes of water would be more capable of diluting or assimilating released oil with potential for fewer impacts than smaller water bodies. Small water bodies (such as creeks or ponds) can be overwhelmed by a large crude oil release, necessitating extensive physical remediation or reconstruction to achieve recovery within a reasonable time frame.
- Season and weather conditions: warm temperatures and open-water conditions are more favorable for natural recovery (through weathering processes) than frozen conditions or cold temperature conditions. Similarly, other weather conditions (e.g. larger rainfall event with flooding) can exacerbate the region affected (e.g. floodplain) or the potential movement (e.g., enhanced downstream transport).
- The effectiveness of spill response: an effective spill response can contain and recover crude oil, preventing more widespread impacts.

- Clean-up efforts: physical clean-up efforts following the initial spill response can substantially enhance natural recovery and shorten the time to recovery. However, if poorly implemented, clean-up efforts can also impede or lengthen the time to recovery. Sometimes the best solution is to enable natural recovery to proceed. Net environmental benefit analysis is an important tool in deciding where and when to implement more intensive clean-up efforts.

6.4 Sediment

Aquatic sediments are the mineral substrates (e.g., sand, gravel, cobble, boulder and bedrock), as well as finer materials (e.g., silt and clay) and organic matter deposited to the bottom of water bodies. Sediments provide habitat for aquatic organisms such as benthic invertebrates and rooted aquatic plants, as well as essential spawning habitat for many species of fish.

Crude oil can be deposited to sediment, even if the density of the crude oil is less than that of fresh water, as a result of interactions between the released oil and particulate matter that can result in the formation of an OPA that has an aggregate density greater than that of water. Crude oil slicks can interact with shorelines resulting in adhesion of oil to mineral substrates that can subsequently be re-mobilized into the water and sink. Alternatively, crude oil may be dispersed into the water column as fine droplets under turbulent flow conditions. The fine oil droplets may then interact with suspended sediment (e.g., silt or clay-sized particles) in the water column, with subsequent settling of the OPA in slow-moving areas.

It has been suggested that diluted bitumens are particularly prone to rapid weathering and sinking in fresh water; however, this is an over-simplified narrative. Research has shown that the higher viscosity of diluted bitumen products can make them less susceptible to OPA formation than lighter crude oils, and any crude oil can be deposited to sediment under the right conditions.

Another mechanism for the deposition of crude oil residues to sediment is that of hyporheic flow (i.e., the entrainment of river water into bottom gravels, with subsequent upwelling farther downstream, caused by variations in river bottom topography). Hyporheic flows may operate on scales that range from small (a few feet) to large (hundreds of yards), and extend from a few inches into the bottom substrate, to tens of feet into the substrate. Oil droplets drawn into the hyporheic flow system would be trapped in the “natural filter” created by the riverbed materials.

Depending upon the sedimentary environment, recovery of sediment quality may be rapid, or slow. Rapid recovery (a few months or less) might be expected in coarse-grained substrates (erosional sediments) found in flowing waters. Here, the flushing effect of the moving water would allow more water-soluble (and potentially more toxic) hydrocarbons to diffuse out of the sedimented material and be swept away. Moving water environments also tend to contain oxygen at concentrations near saturation, making conditions favorable for microbial degradation of hydrocarbon residues. Lastly, periodic spate events can re-work coarse sediment deposits, leading to the physical removal of hydrocarbon residues. Slow recovery (1 to 2 years or longer) might be expected in depositional sediments found in slow-moving river reaches, lakes, or wetlands. Here, the flushing effects of water movement are minimal. Crude oil residues that become buried by fresh sediment may be isolated from oxygen, resulting in very slow weathering and long (almost indefinite) persistence. Physical interventions to restore sediment quality may be necessary.

Dredging has been used to accelerate sediment recovery. Regulators and industry have effectively worked together to evaluate site-specific conditions at the release site to determine effective remediation strategies that address the net environmental benefit.

6.5 Wetland and Riparian Habitat

Riparian habitats, being by definition adjacent to water bodies, often have wetland attributes such as swamp or fen. These habitats are subject to periodic inundation and depending on conditions at the time of a crude oil release (e.g., water levels), may or may not be seriously affected. Wetlands are defined and classified based on their vegetation, soils, and hydrology. Both vegetation communities and soil quality are subject to impacts from crude oil releases. Therefore, recovery of wetland and riparian habitat will be discussed in these two contexts.

Vegetation recovery is affected by several factors, including the amount and type of crude oil released; ambient temperature which affects weathering and biodegradation rates; remediation or treatment methods applied (e.g., flushing, excavation, in-situ burning); type of ecosystem; and water depth. Releases that occur in winter when plants are dormant may have little effect on plant communities if clean-up is successful. In-situ burning can reduce the amount of residual oil but may also create hydrophobic and sterilized soils which resist recovery of the vegetation community. Excavation of released crude oil may accelerate recovery but may also cause additional harm to plant communities and soils in sensitive environments. Wetland soils are by definition water-saturated and deficient in oxygen, both of which favor the persistence of crude oil residues, particularly if oil is driven into the soil during remediation activities. Case studies and literature demonstrate that wetland and riparian habitat do recover following crude oil spills; however, recovery can be slow. Appropriate remediation techniques can enhance recovery, but inappropriate techniques can cause additional harm. Selection of remedial techniques should be appropriate to the site-specific circumstances.

6.6 Aquatic Biota

Aquatic biota includes aquatic plants, benthic invertebrates, fish, and some herptiles. The recovery of each of these groups depends on the spatial extent and magnitude of initial impacts, as well as the recovery of water and sediment quality. High-energy habitats (fast-moving rivers and streams, or exposed shorelines of large lakes) tend to recover more quickly than low-energy habitats (small ponds or backwater habitats in rivers) because the movement of water can scour crude oil from sediments, help break up and disperse crude oil, and promote aerobic conditions that help to facilitate the biodegradation of crude oil.

Aquatic plants can be killed (in part or in whole) by contact with fresh crude oil. However, many perennial aquatic plants have submerged rootstocks that survive and can regenerate following the acute phase of exposure. Many annual aquatic plants, like wild rice, have the potential for delayed germination of seeds, so that the loss of a single year-class of seeds does not result in the collapse of a population. Most aquatic plants also have dispersal mechanisms, ranging from aerial dispersal of seeds (as in the case of cattails), dispersal of vegetative plants by birds or animals (as in the case of duckweed that can be transported on the feet of waterfowl, or seeds that pass through the digestive tract of a bird or mammal before germinating), or simple downstream movement of vegetative fragments of plants that are capable of rooting and establishing new colonies.

Emergency response methods can either facilitate or impede recovery of aquatic vegetation, depending on the methods employed and the type of vegetation affected. Rates of aquatic vegetation recovery are improved when techniques selected for crude oil removal take into consideration the sensitivity and reproductive strategies of the affected vegetation (e.g., minimize disturbance to rhizomes).

Benthic macroinvertebrates are widely used for monitoring the health of aquatic ecosystems, including effects and recovery from crude oil releases. Being responsive to petroleum hydrocarbon concentrations in sediment, the recovery of the benthic macroinvertebrate community following a crude oil release depends in large part on the recovery of sediment quality. As a group, benthic macroinvertebrates have a variety of dispersal and colonization strategies, ranging from downstream drift to upstream flights (by insects) during egg-laying behavior. Even taxa that are normally thought of as being quite sessile (like unionid mussels) have a larval development stage that attaches to the gill of a host fish, and can be dispersed some distance before being released.

Like benthic macroinvertebrates, fish communities in rivers and streams generally recover quite quickly following disturbance, including crude oil releases. This recovery is typically led by the upstream and/or downstream movement of fish from areas that were not affected by the release, in addition to subsequent annual population growth. The suspension of fishing in affected areas (due largely to concern about possible human exposure to hydrocarbons and PAHs through fish consumption) can also have a positive effect on fish populations through the suspension of angling mortality and selective removal of larger fish. However, it is recognized that important habitat units (e.g., fish spawning areas) can be affected by released crude oil and the recovery of these habitat values may depend on other factors including the rate of recovery of the water and sediment quality.

6.7 Wildlife

Wildlife includes a range of terrestrial, semi-aquatic, and aquatic species including birds, mammals, and most herptiles (i.e., those species and life stages that are not otherwise treated as aquatic biota). In contrast to some marine crude oil spills, releases of crude oil to inland environments including rivers and streams generally affect relatively small numbers of birds and mammals and are not likely to result in adverse effects at a population level. This is not intended to discount the importance of areas such as the St. Louis River Estuary to wildlife, including resident and migratory birds. However, none of the hypothetical unmitigated release scenarios resulted in floating oil moving past Oliver, Wisconsin, during the first 24 hours.

The recovery of individual birds and animals affected by a crude oil release is well documented. Animals captured quickly following oiling and properly treated can survive and, in many cases, be returned to the wild. The success of wildlife rehabilitation efforts in freshwater environments was demonstrated following the John Heinz Wildlife Refuge, the Exxon Mobil Silvertip, and the Enbridge Line 6B crude oil releases (references in Stantec et al. 2017, Section 8).

6.8 Socio-Economic Receptors

Crude oil releases can affect people from financial, emotional, and potentially health perspectives. Depending on specific circumstances, individuals, groups, and communities can be affected in different ways. While effects to physical and emotional well-being, cultural values, and sense of community can occur, quantifying these effects can be subjective, and difficult to quantify. As a result, literature on recovery of such values is limited.

Socio-economic effects of crude oil releases that affect more than a few individuals would generally be those occurring in populated areas, where the lives and livelihoods of larger numbers of people may be affected (e.g., by evacuation, loss of access to natural resources, disruption of social services, disruption of business activity, influx of clean-up workers, etc.). Many of these issues can be addressed through forms of compensation, including financial compensation. With private land and resource owners and users, compensation agreements are negotiated and implemented cooperatively, and can be processed relatively quickly. The claim system may be administered directly by the company or indirectly through a third-party administrator. The terms of such settlements are typically not made public. However, when those affected cannot reach a financial agreement with the company responsible for the release, final resolution may move into the court system, and this process can be adversarial and lengthy.

Crude oil releases may damage or restrict access to natural resources that community residents, Indian tribes and visitors use for various purposes. Examples of such lost uses include closure of recreation areas or access points, restrictions on hunting, fishing and gathering, reductions in harvestable fish, wildlife and plant populations, and changes in the visible landscape. The parties responsible for a spill are required to compensate individuals and communities experiencing lost use of natural resources in two different ways:

- When a lost resource use is suffered by a single entity such as a landowner, parties responsible for the release presently try to provide compensation directly to those affected using a claims process, or through agents assigned to communicate with property owners and other affected individuals to address their particular situations.
- When a lost resource use is a matter for the general public, compensation is generally provided through the Natural Resource Damage Assessment (NRDA) process for larger releases, and through similar state processes for smaller releases. In accordance with the *Oil Pollution Act* of 1990, when an oil release occurs, designated representatives of federal agencies, state agencies, Indian tribes, and in some rare circumstances foreign governments having affected resources under their jurisdiction, form a “Trustee Council” that is responsible for assessing the damages to resources, developing restoration plans, and calculating damages. At the end of the NRDA, one or more compensatory projects are implemented to address losses incurred.

While recovery time for socio-economic receptors is partly a consequence of release size and complexity, decisions made by parties involved in crude oil spill response can greatly affect the outcomes, and time to recovery. Crude oil releases affect people within communities in a variety of ways and not all individuals or businesses affected may be completely satisfied with how the effects are addressed. However, recent experience demonstrates that socio-economic receptors can and do recover after a crude oil release, and that the current regulatory framework usually results in recovery from major releases within two to five years.

7 SUMMARY AND CONCLUSIONS

RPS and Stantec were retained by Enbridge to prepare a risk assessment for potential large releases of oil from the L3RP. The AAR technical report (Stantec et al. 2017) was submitted to the Minnesota DOC by Enbridge in support of its Applications for a CN and a RP for the proposed L3RP.

Information from this report and other technical reports was used by the Minnesota DOC-EERA Staff to prepare a draft EIS and, after public review and revisions, the FEIS. Following public review, revisions, hearings, and deliberation, the PUC issued an order on May 1, 2018, finding the FEIS adequate.

On June 3, 2019, the State of Minnesota Court of Appeals reversed and remanded the MN PUC's adequacy decision on the grounds that the FEIS did not adequately address the potential impact of an oil spill into the Lake Superior watershed. This addendum is intended to provide the DOC with information to assist them in assessing the potential effects of an oil spill into the Great Lakes Watershed.

A number of factors and aspects are discussed in this report, including:

- How the Little Otter Creek site was chosen from a suite of other sites within the Great Lakes Watershed, for modeling and assessment.
- How Enbridge has developed and will further develop emergency response plans, train response personnel, and provide stores of equipment to respond to an oil spill if it were to occur.
- How spill modeling was undertaken.
- The likely trajectory and fate (i.e., behavior) of unmitigated large releases at Little Otter Creek (assuming no emergency responses within the first 24 hours) of several types of crude oil under different geographic, environmental, and seasonal conditions.
- The range of potential effects that an unmitigated large release of crude oil at Little Otter Creek may have on the natural and human environment.
- Potential for recovery of the natural and human environments following a large release of crude oil, including how clean-up and remediation can influence recovery.

7.1 Selection of the Little Otter Creek Site

Nine potential representative sites within the Great Lakes Watershed were considered as potential sites for modeling of a large oil release. These sites included six watercourse crossings in Minnesota and three in Wisconsin. As before, watercourse crossings were selected to maximize the potential downstream distance that may be affected following a release. Little Otter Creek was chosen as the preferred release site within the Great Lakes Watershed for modeling, as a hypothetical oil release there is more likely than the other options considered in Minnesota to enter the St. Louis River, and ultimately have the potential to reach Lake Superior.

7.2 Emergency Response and Training

Pipeline operators such as Enbridge are required to prepare emergency response plans, demonstrate response preparedness through regular inspections of response equipment, and regularly conduct drill exercises for hypothetical oil releases. In the unlikely event of a release, emergency response actions would be undertaken to contain and collect the release to help reduce the potential immediate and long-term effects on the natural and human environments. Site remediation and restoration methods would help reduce long-term effects on the environment and facilitate recovery of affected receptors.

If an oil release were to occur, Enbridge would respond to the release within a matter of hours. Accordingly, the hypothetical release modeling of unmitigated full-bore ruptures of crude oil constitutes an unlikely and highly conservative scenario for the proposed pipeline. As a result, the predicted trajectories, fates, and effects described here represent unlikely worst case scenarios.

7.3 Modeling of a Large Release of Crude Oil

Large releases of crude oil from the pipeline were simulated at Little Otter Creek using a combination of the OILMAPLand and SIMAP oil spill fate and transport models developed by RPS. Because Little Otter Creek is a small watercourse, the 2-dimensional OILMAPLand model was sufficient to capture the movement, timing, and behavior of oil within the watercourse. However, once Little Otter Creek enters the St. Louis River, the 3-dimensional SIMAP model was used to characterize the movement and behavior of oil in this larger and more dynamic watercourse.

Modeling using OILMAPLand and SIMAP was based on the following key assumptions:

- A direct release of oil into Little Otter Creek where it is crossed by the proposed L3RP pipeline, as opposed to a land-based release of oil. A direct spill into a watercourse assumes all of the estimated volume of released crude oil would enter the aquatic environment, thereby allowing an assessment of worst-case outcomes with respect to the transport, fate, and potential effects of released oil.
- The volume of crude oil released in this hypothetical event was based on a full bore rupture with an initial 10 minute release prior to shutdown (i.e., actively pumping out oil), followed by 3 minutes to valve closure, and a subsequent hydraulic drain-down of the pipeline between the valves within the isolated section. Based on these assumptions, the pipeline specifications, and topographic conditions in proximity the Little Otter Creek site, the maximum volume of oil released was estimated to be 13,007 bbl (2,068 m^3).
- The same release volumes were used for Bakken Crude Oil (a light conventional crude oil with a high aromatic content) and CLB (a diluted bitumen). For the latter, a winter and summer blend were used to reflect seasonal difference in the chemical and physical characteristics of the CLB.
- Modeling assumed that the releases of this volume of oil were unmitigated for the modeled 24 hour period (i.e., no benefits of emergency response operations were incorporated into the

model). In a real-life scenario, emergency response procedures would be expected to be initiated much sooner and would help contain, collect, and mitigate the effects of the modeled incidents.

- Three seasons were modeled to reflect a range of representative stream and river flow rates, as well as other factors (e.g., temperature, wind speed) that could affect the fate and transport of released crude oil.

7.4 Likelihood of a Large Release of crude oil

Stantec et al. (2017, Section 3) examined potential threats to the pipeline, including: external corrosion, internal corrosion, stress corrosion cracking, manufacturing defects, construction defects, equipment failure, third party damage, incorrect operations, weather related and outside force, and other threats.

The annual likelihood of a large crude oil release is proportional to the total length of the pipeline. As described in Stantec et al. (2017), the total length of the pipeline segment that was susceptible to releasing oil into Little Otter Creek was quantified using the OILMAPLand model. High-resolution analysis of outflow and overland spill modeling was conducted at 32.8 ft (10 m) intervals inland from each side of the watercourse crossing for this modeled location. The total length of pipeline that could affect Litter Otter Creek was predicted to be 2,986 ft (910 m). This is slightly higher than the upper end of the range of pipeline segments (207 to 2,543 ft) at each of the previously modeled seven representative sites (Stantec et al. (2017). These previous results compared to a likelihood of 4.388 $x10^{-6}$ to 3.961 x 10^{-7} for the seven representative sites. Together, the failure frequencies for the eight representative sites are equivalent to average annual return periods from 227,894–2,524,615 years. While the annual likelihood of a large crude oil release affecting Little Otter Creek would be slightly greater than the previously modeled seven representative sites, the annual return period would still be approximately 200,000 years. Based on these values, it can be ascertained that large releases of crude oil from the proposed L3RP are considered to be unlikely at these watercourse crossings.

7.5 Trajectories and Fate

Crude oils and refined petroleum products are complex mixtures of many thousands of different hydrocarbon compounds derived from natural geological formations. Each oil has specific physical and chemical properties (e.g., viscosity, density, solubility, volatility) that reflect its composition and will affect its transport and fate, once released into the environment (NRC 2003). These physical and chemical properties affect the natural weathering processes for released oil, as do the characteristics of the receiving environment (e.g., site of the release, season, and weather conditions). To account for the differences in the types of crude oil that could be transported and the range of behaviors these oils could have within the environment (see Lee et al. 2015), a light crude oil (i.e., Bakken Crude) and two different blends of a heavy crude oil (i.e., CLSB and CLWB) were considered in the risk analyses. These are the same types of crude oil that were modeled in Stantec et al. (2017).

The Little Otter Creek scenarios represent a small water body within the Lake Superior watershed that flows into a progressively larger and more high energy environment (i.e., St. Louis River) that contains rapids, waterfalls, and dams. Ultimately, the release could enter the St. Louis River Estuary (including Spirit Lake and St. Louis and Superior bays) and potentially Lake Superior.

The hypothetical downstream transport and fate of released crude oil from the Little Otter Creek site is largely determined by river flow conditions and the type of crude oil. Three seasonal periods were considered in the modeling of an oil spill into the Lake Superior watershed: high river flow, coinciding with the spring freshet; average river flow, during summer or fall; and low river flow in winter, which is typified by freezing conditions and probable ice cover on the water surface.

OILMAPLand was used to simulate the trajectory and fate of oil within Little Otter Creek during ice-free conditions, with approximately 80% of the CLB and 70-80% of the Bakken predicted to be transported downstream to the point where it entered the St. Louis River. Because of its small size, oil is predicted to cover the surface of Little Otter Creek as thick black oil.

The smaller amount of Bakken predicted to reach the St. Louis River is the result of enhanced evaporation and lower shoreline retention due to the lower viscosity and higher volatile content of the Bakken crude oil, compared to CLB. This was apparent with the <2% evaporation predicted for CLB versus approximately 20-25% evaporation predicted for Bakken within the OILMAPLand simulations. In addition, approximately 20% of the CLB was predicted to be retained on shorelines within Little Otter Creek, compared with the 3% shoreline retention predicted for Bakken. While the rates for each fate process (i.e., evaporation and shoreline retention) were different between the oils, they countered one another and resulted in similar amounts of either oil (1,500-1,600 m^3) ultimately predicted to reach the St. Louis River, under high and average river flow conditions. Under low river flow wintertime conditions with complete ice cover, more Bakken was predicted to enter the St. Louis River (1,844 m^3) when compared to CLB (820 m^3) due to the thinner equilibrium thickness (and reduced retention) of Bakken under the ice (0.07 in. or 0.18 cm) within Little Otter Creek, when compared to CLB (0.4 in. or 1.02 cm). Under high, average, and low river flow conditions, both CLB and Bakken oil were predicted to reach the St. Louis River at 6.12, 7.93, and 9.92 hours following the release.

SIMAP was used to simulate the trajectory and fate of oil within the St. Louis River down to St. Louis River Estuary (including Spirit Lake, St. Louis and Superior bays) and ultimately Lake Superior. During ice-free conditions, approximately 60-80% of the CLB release was predicted to be on the water surface after 24 hours, versus only 40-50% of the Bakken release. This was due to the enhanced evaporation of Bakken Crude oil, compared to CLB.

The presence of rapids, waterfalls, and dams within the St. Louis River influenced the fate of the released oil within each simulation. Enhanced turbulence and mixing within these high energy environments resulted in the entrainment of surface oil into the water column. Large amounts of oil were predicted to entrain into the water column (>80% of the simulated release) throughout the roughly 4 miles of rapids below the Thomson Dam through Jay Cooke State Park. While oil was predicted to re-surface in the quiescent waters above the Fond du Lac Dam, large amounts of oil were predicted to re-entrain into the water column as the oil and water passed over the Fond du Lac Dam.

The maximum downstream transport of released crude oil for the Little Otter Creek release site was predicted to be approximately 20 miles within 24 hours under high river flow conditions (e.g., spring freshet). However, in the event of an actual release, it is expected that the downstream extents of both crude oils may be more similar, although the distribution of diluted bitumen may be patchier than light crude oils. Light oils such as Bakken crude oil are predicted to spread more thinly on the water surface with less adhering to riverbanks than heavy oils.

Both types of crude oil are predicted to travel a shorter distance downstream from the Little Otter Creek release site during average river flow conditions (e.g., summer) with maximal extents of 13.7 miles within 24 hours. Evaporative losses would typically be greater for light crude oils such as Bakken, when compared to heavier crude oils such as CLB.

Under low river flow conditions (e.g., winter), the predicted downstream extents of Bakken crude oil and CLB from the Little Otter Creek release site were much less than during either the high or average river flow periods. The shorter downstream travel distances during the low flow period (i.e., winter) reflect the lower velocity of water in streams during the winter period, as well as adhesion of the oil to the undersurface of the ice. For Bakken, the equilibrium thickness of oil under the ice was predicted to be 0.07 in. (1.9 mm). For CLB, the thickness was predicted to be over five times thicker at 0.4 in. (10.6 mm). Ice cover during the winter also strongly limits or prevents evaporation to the atmosphere regardless of the crude oil type.

In smaller riverine environments, light crude oils such as Bakken would be expected to travel further downstream than the CLB due primarily to differences in shoreline oil retention. Larger amounts of CLB are predicted to strand as a thicker layer of oil on a given length of shoreline than for the Bakken crude oil. Conversely, the same amount of Bakken crude oil could affect a greater length of shoreline, with a lesser thickness of oil. However, in turbulent waterways (enhanced volatilization) and large waterways (larger surface area where a slick may not extend bank to bank), enhanced evaporation of light ends within crude oils may result in similar or reduced downstream transport for light oils.

None of the simulations for either type of oil under any of the three seasonal conditions resulted in oil reaching Spirit Lake or entering Lake Superior after 24 hours. Bakken Crude was predicted to reach maximum downstream distances of 12.0, 13.7 and 19.7 miles under low, average, and high water conditions. CLB was predicted to reach a maximum distance of 8.2, 13.7, and 20.0 miles downstream during the same seasonal periods with identical geographic and environmental conditions. The differences in the downstream extent between the CLB and the Bakken under ice free conditions are the result of the enhanced evaporation of the Bakken crude oil, due to its increased volatility. The large difference under wintertime ice-covered conditions is the result of the different equilibrium thickness of oil (CLB is over five times thicker than Bakken) under the ice.

For the low river flow scenarios, with an assumed 100% ice cover, all the oil was predicted to remain trapped beneath the ice. Oil was predicted to either be in the water column or on the “surface”, where it was trapped at the water-ice interface. Evaporation was assumed to be negligible (due to ice cover), which enhanced the dissolution of the soluble portion of the volatile fraction and resulted in elevated concentrations of dissolved hydrocarbons within the water column. Maximum concentrations of dissolved hydrocarbons within the water column were predicted to range from

7.6 Potential Effects of Exposure to Oil

As described in Stantec et al. (2017, Sections 7 and 8), scientific studies and monitoring have documented that the effects of exposure to large releases of crude oil on freshwater and terrestrial ecosystems are adverse, and that human uses in the areas of a release can be negatively affected. However, the extent and significance of these effects will depend on many factors, including the type and amount of crude oil released, the sensitivity of the receptor to crude oil exposure, seasonal and environmental conditions, physical conditions such as river flow rates and shoreline types, and biological conditions such as shoreline or wetland vegetation cover.

While effects of exposure to crude oil can be adverse, incident records from past pipeline operations, as well as analyses of failure frequencies demonstrate that a large release from a new and modern pipeline such as L3RP would be unlikely (Stantec et al. 2017). Modern pipeline design includes a wide range of measures to reduce the likelihood of an oil release, including pipeline design, to directly address higher risk segments of the ROW; technical specifications for pipeline materials; construction techniques such as deeper burial in higher risk segments or horizontal directional drilling under watercourses; operational and emergency protocols for pipelines and pump stations; ongoing monitoring and inspection of pipelines; and preventive maintenance.

Overall, the effects of a release of light crude oil are expected to be similar to the effects of a heavy crude oil release, although at the level of the various ecological and human environment receptors, either type of crude oil may be predicted to have more or less spatially extensive or severe effects. For example, for sediment, shoreline, and riparian areas, lighter crude oil is often predicted to have less severe but more spatially extensive effects than heavier crude oil, due to its lower viscosity and adherence to shoreline substrates and riparian vegetation. For the other receptors (e.g., river and lake habitat, aquatic plants, benthic invertebrates, fish, amphibians and reptiles, birds and semi-aquatic mammals, air quality, human receptors, and public use of natural resources), the relative magnitude of effects of lighter and heavier crude oils are variable, depending upon site-specific conditions, and also depending upon whether acute or chronic effects are being considered.

7.6.1 Aquatic Receptors

For both crude oil types, it was predicted that there would be extensive mortality of fish in Little Otter Creek and Otter Creek under all seasonal scenarios, owing to the small dimensions of the creek sections, and the large amount of oil that could enter Little Otter Creek.

The St. Louis River is fast flowing and turbulent, which would entrain crude oil into the water column as small droplets, enhancing the dissolution of low molecular weight and aromatic hydrocarbons into the river water. This would result in a high potential for mortality of fish and other aquatic life throughout the reach leading to the Fond du Lac Headpond, and to some extent within the Headpond. For the high flow scenarios, where floating oil was predicted to be carried over the crest of the Fond du Lac Dam, additional mortality of fish and other aquatic life would be expected in the St. Louis River and Estuary below the dam, as far downstream as Oliver, Wisconsin.

In addition to direct effects on fish and other aquatic life, damage to spawning habitats would be expected, with the potential for mortality of fish eggs and embryos in the event of a crude oil release in the spring or fall. A release in the spring would be of particular concern, as it could affect habitat below the Fond du Lac Dam that has been restored to support the recovery of Lake Sturgeon, as well as other important spawning habitats throughout the system. Deposition of crude oil to bottom substrates in fast-flowing areas would be expected to have short-term effects on the habitat, due to rapid weathering of the oil, and periodic flushing of the substrates. However, deposition of crude oil to soft sediments in Little Otter Creek, Otter Creek, the Fond du Lac Headpond, or the St. Louis River Estuary, could result in medium to long-term effects depending on the oil type, and the nature of the substrates.

Aquatic plant communities in Little Otter Creek and Otter Creek would be adversely affected by a crude oil release. In spring, high water levels would allow crude oil to enter and be deposited in the riparian wetland areas, where it could persist and be damaging to plants. In summer, plants actively growing in the creeks and on active shorelines would be killed, although the potential for oil to enter the riparian wetland zones would be much lower. In winter, plants would be dormant, but residual oil could enter the riparian areas during the spring melt period.

Aquatic plant communities are sparse in the St. Louis River between the Thomson and Fond du Lac dams, and effects would be minor regardless of season. A crude oil release in the spring could result in oil passing over the Fond du Lac Dam, and being transported into the upper St. Louis River Estuary, where aquatic plant communities and wetlands are well developed. High water conditions would promote entry of crude oil into the wetlands, where it would be retained and cause damage to aquatic plant communities and wetland function.

7.6.2 Semi-Aquatic Wildlife Receptors

7.6.2.1 Amphibians and Reptiles

Flooding of riparian habitats in spring could lead to stranding of crude oils in these habitats, with heavy crude oil likely to be deposited as patties or tar balls, which would be persistent, in contrast to light crude oil which would be deposited as a thin layer or sheen. Within these habitats, oiling effects on adults, juveniles, and eggs of amphibians and reptiles could occur. Higher potential would exist for effects on amphibians than for turtles. Dormancy of amphibians and reptiles in winter and early spring means exposure to oil released at this time of year could be lower, and adverse environmental effects less likely.

7.6.2.2 Birds

Mortality of oiled aquatic and semi-aquatic birds would occur in areas affected by the released oil. During the spring high flow season, many migratory birds would be returning to riverine and lacustrine habitats in Minnesota or migrating through these areas on their way to breeding habitats farther north. Few birds are present in winter, so effects would be lower in that season.

7.6.2.3 Semi-Aquatic Mammals

Mortality of oiled semi-aquatic mammals would be limited to areas affected by the released oil. Adverse effects on mink and otter would be particularly severe in winter, due to the effects of oil in the insulating properties of fur, in combination with cold water temperatures. However, muskrat and beaver might be less vulnerable due to their lower activity levels in winter.

7.6.3 Human and Socio-Economic Receptors

Effects on human and socio-economic receptors relate primarily to changes in air quality and associated effects on human health, as well as physical and visual effects on human uses.

Effects on air quality have the potential to temporarily disrupt human use and occupancy patterns. Air quality in the vicinity of the oil release would be most affected within the first 24 hours of an oil release. While CLB crude oil and Bakken crude oil are predicted to exhibit similar downstream transport patterns, considerably more of the Bakken crude oil is predicted to evaporate into the atmosphere within 24 hours than is the case for the CLB. Both oil types are predicted to pass the communities of Carlton, and Thomson, Minnesota in all seasons, and to pass Fond du Lac and Gary – New Duluth, Minnesota, and approach Oliver, Wisconsin, during the spring (high flow) season. Under winter conditions, cold temperatures, ice cover and absorption of crude oil into snowpack would strongly limit emissions of VOCs, in addition to constraining the area of effects.

Typical human health effects associated with short-term inhalation of VOCs from crude oil releases include headache, dizziness, nausea, vomiting, cough, respiratory distress, and chest pain; fatality is unlikely. Nearby residents would become aware of a strong hydrocarbon odor that would alert them to the presence of a hazard. The human receptors most likely to be exposed to VOCs under this hypothetical crude oil release scenario would be those occupying homes located close to Little Otter Creek or Otter Creek. Humans could also be exposed to VOCs as a result of recreational use of Jay Cooke State Park. Under winter conditions, cold temperatures, ice cover, and absorption of crude oil into snowpack would strongly limit emissions of VOCs, in addition to constraining the area of effects.

Little Otter Creek and Otter Creek flow through wetland and riparian habitats that would potentially support fishing, hunting, trapping, and gathering of plants for food or medicinal purposes. The St. Louis River below the Thomson Reservoir flows through Jay Cooke State Park is a notable area for outdoor recreation. Other protected lands near the Fond du Lac Headpond support outdoor recreation including hunting, fishing, gathering of plants, and other traditional activities. Effects on air and water quality, or the presence of crude oil residues in the sediment or habitat, could potentially disrupt such uses of natural resources.

Drinking water for the communities of Carlton and Thomson are drawn from groundwater sources by city owned and operated wells. Water intakes for the cities of Duluth and Superior are located in Lake Superior. Water supplies for residents of these communities are not likely to be affected by a release. However, there could be some rural residents with private potable water wells located near Little Otter Creek or Otter Creek.

In the event of a crude oil release, people would be notified, and testing would be completed to confirm the safety of the water supply. It is unlikely that a crude oil release to Little Otter Creek would result in adverse health effects to consumers of drinking water. Both recreational activities by members of the public, and traditional use of land and resources by tribal members would be disrupted following a release of crude oil along the predicted downstream migration route.

7.7 Recovery

As described in Stantec et al. (2017) and Section 6, evidence from actual oil releases demonstrates that biophysical and human receptors are likely to recover following exposure to released crude oil, although the timeframes for recovery can vary (weeks to years). Effective clean-up of a release, combined with appropriate remediation and restoration methods, will enhance recovery.

Importantly, the specifics of any given incident will drive the fate and effects of released crude oil and refined petroleum products. Swift and effective containment of released crude oil, as well as clean-up, remediation, and restoration, will help to reduce the scale and magnitude of adverse effects (Lee et al. 2015).

7.8 Conclusions

The proposed L3RP will be built and operated to the standards for new and modern pipelines. The design, material specifications, construction methods, and operational protocols, including inspection and preventative maintenance, will help to reduce the likelihood of a crude oil release. Based on the failure frequency analyses for the L3RP (Stantec et al. 2017), a large release of crude oil from the pipeline is considered unlikely. However, should there be a release, emergency responders would be prepared, and response actions would be undertaken to contain and collect the release to help reduce immediate and long-term effects on the natural and human environment.

While a large release of crude oil is unlikely at Little Otter Creek or the other seven representative sites, when freshwater or terrestrial ecosystems and human uses are exposed to a release of crude oil, effects are adverse. The significance of these effects can range from minor on local and regional receptor populations or uses, to substantial on a major portion of the exposed receptor population or uses. The significance of the effects of a crude oil release on a receptor will depend strongly on:

- the receptor itself in terms of its vulnerability to exposure to crude oil, and its sensitivity, if it is exposed to crude oil;
- the type and volume of crude oil released;
- the timing and location of the release relative to seasonal occurrences and locations of sensitive receptors and uses;
- the climatic and site conditions at the time of the release;
- the ability of responders to contain the release; and
- the speed, type and extent of cleanup, remediation, and restoration activities.

This report assessed potential effects of an unmitigated large release of crude oil into Little Otter Creek, located within Minnesota in the Great Lakes watershed. In the unlikely event of an actual release of crude oil, swift and effective emergency response and clean-up measures would help reduce the extent of effects and help promote recovery of the affected receptors. Similarly, remedial actions and habitat restoration measures, as appropriate, would help further reduce many of the expected effects, while also aiding in recovery of freshwater and terrestrial environments, as well as human uses.

NON-PUBLIC DOCUMENT – CONTAINS TRADE SECRET DATA

8.0 REFERENCES

Audubon. 2019. Website accessed 7 August, 2019. https://www.audubon.org/important-bird-areas/st-louis-river-estuary

Barnes, P.W., D.M. Schell and E. Reimnitz, (Editors). 2013. The Alaskan Beaufort Sea: Ecosystems and Environments. Elsevier Publishers - Science.

Cox, J.C., L.A. Schultz. 1981. In "Proceedings of the Fourth Arctic Marine Oilspill Program Technical Seminar," p. 3. Environmental Protection Service, Ottawa.

Cox, J.C., L.A. Schultz, R.P. Johnson and R.A. Shelsby. 1981. The Transport and Behavior of Oil Spilled in and under Sea Ice. *In* Environmental Assessment of the Alaskan Continental Shelf. Final Reports of the Principal Investigators. Volume 3. Physical Science Studies. Boulder, CO.: National Oceanic and Atmospheric Administration and Bureau of Land Management. 427.

Di Toro, D.M., J.A. McGrath and D.J. Hansen. 2000. Technical Basis for Narcotic Chemicals and Polycyclic Aromatic Hydrocarbon Criteria. I. Water and Tissue. Environmental Toxicology And Chemistry 19: 1951–1970.

Dickins, D.F., J. Bradford and L. Steinbronn. 2008. Detection of Oil on and Under Ice: Phase III Evaluation of Airborne Radar System Capabilities in Selected Arctic Spill Scenarios. Report submitted to US Department of Interior, Minerals Management Service. July 2008. 68 pp.

Drozdowski, A., S. Nudds, C.G. Hannah, H. Niu, I.K. Peterson and W.A. Perrie. 2011. Review of Oil Spill Trajectory Modelling in the Presence of Ice. Canadian Technical Report of Hydrography and Ocean Sciences 274. Fisheries and Oceans Canada and Bedford Institute of Oceanography. Dartmouth, NS, Canada. 84 pp.

Enbridge, 2014. Enbridge, Inc. Line 3 Replacement Program. Application Submitted to the NEB, Appendix 6: Aquatic Technical Report. Exhibits B6-15 and B6-16.

Homer, C.G.,J.A. Dewitz, L. Yang, S. Jin, P. Danielson, G. Xian, J. Coulston, N.D. Herold, J.D. Wickham, and K. Megown. 2015. Completion of the 2011 National Land Cover Database for the conterminous United States-Representing a decade of land cover change information. Photogrammetric Engineering and Remote Sensing, v. 81, no. 5, p. 345-354. Available: http://www.mrlc.gov/nlcd2011.php.

Horizon Systems. 2012. NHDPlus Verizon 2. Available at: http://www.horizon-systems.com/nhdplus/. Accessed: September 2019.

Jobson, H.E. 1996. Prediction of Traveltime and Longitudinal Dispersion in Rivers and Streams, U.S. Geological Survey Water Resources Investigations Report 96-4013. U.S. Geological Survey.

Lewis, E.L. 1976. Pacific Marine Science Report 76-12. Institute of Ocean Sciences. Victoria, BC.

NOAA. 2016. Environmental Sensitivity Index (ESI) Maps. Available: https://response.restoration.noaa.gov/resources/environmental-sensitivity-index-esi-maps. Accessed: July 2019.

NOAA. 2016a. National Centers for Environmental Information – Land-Based Station Data.https://www.ncdc.noaa.gov/data-access/land-based-station-data. Available at: https://www.ncdc.noaa.gov/data-access/land-based-station-data. Accessed: March 2016.

Sørstrøm, S.E., P.J. Brandvik, I. Buist, P. Daling, D. Dickins, L-G. Faksness, S. Potter, J. Fritt-Rasmussen and I. Singsaas. 2010. Joint Industry Program on Oil Contingency for Arctic and Ice-Covered Waters. Summary Report. Report No. 32. SINTEF A14181, ISBN-no. 978-82-14-04759-2.

Spaulding, M.L. 1988. A State-of-the-Art Review of Oil Spill Trajectory and Fate Modeling. Oil and Chemical Pollution 4(1):39-55.

St. Louis River Estuary Project. 2019. Website accessed 7 August, 2019. http://stlouisriverestuary.org/map/map.php#12/46.7342/-92.1018

Stantec et al. 2017. Line 3 Replacement Project. Assessment of Accidental Releases: Technical Report

Thomas, D.R. Interaction of Oil and Arctic Sea Ice. Edited by Peter W. Barnes, Donald M. Schell, Erik Reimnitz. Reference to equation which is in: The Alaskan Beaufort Sea: Ecosystems and Environments. https://books.google.com/books?id=GvQgBQAAQBAJ&pg=PA446&lpg=PA446&dq=thickness+of+oil+under+ice&source=bl&ots=NYXQwrvXnx&sig=AhPJsi5xOG-R10pWBW0lCjGkl7M&hl=en&sa=X&ved=0ahUKEwjSw9SC3e_JAhUT52MKHclVAaoQ6AEISjAJ#v=onepage&q=thickness%20of%20oil%20under%20ice&f=false

U.S. Environmental Protection Agency. 2003. Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms (PDF). PAH Mixtures. EPA-600-R-02-013. . Washington, DC.

U.S. Geological Survey. 2015. The National Map - Elevation. Available at: http://nationalmap.gov/elevation.html. Accessed: March 2016.

U.S. Geological Survey. 2014. The National Map – National Hydrography Dataset. Available at: http://nhd.usgs.gov/. Accessed: March 2016.

Zhou, J., H. Dettman and M. Bundred. 2015. A Comparative Analysis of Environmental Behaviour of Diluted Bitumen and Conventional Crudes., Proceedings of the Thirty-eighth AMOP Technical Seminar on Environmental Contamination and Response. (pp. 495-516). Vancouver, British Columbia, Canada. Environment Canada, Ottawa, ON.

Inland Spill Response Tactics Guide

Contributions in the creation of this tactics guide were made by the staff of:

ENBRIDGE

ELASTEC

Riverspill Response Canada Ltd.

QualiTech
Together, we make ideas that work.™

LAMOR

© 2018 Enbridge Pipelines Inc.
This material is protected by copyright and is the exclusive property of Enbridge Pipelines Inc. and its affiliates. No external distribution or transmission of this material is permitted without the prior written consent of Enbridge Pipelines Inc. Applications for the copyright holder's written permission to reproduce any part of this publication should be addressed to the Law Department of Enbridge Pipelines Inc. at Edmonton Center, 10175 – 101 St, Edmonton, Alberta T5J 0H3. Enbridge Pipelines Inc. assumes no responsibility for errors or omissions in this document or for direct, incidental or consequential losses or damages that may result from the external use or duplication of this material.

Contents

Contents

Contents

Line 3 Replacement Project: Addendum to Assessment of Accidental Releases: Technical Report
Attachment 1

Introduction

1

Inland Spill Response Tactics Guide

The Inland Spill Response Tactics Guide is an internal Enbridge document that can be used as a quick reference by Enbridge first-on-scene responders to select and implement containment and recovery tactics with Enbridge-owned oil spill response equipment during the first 72 hours of the response. It illustrates a collection of inland spill tactics that can be applied using obtainable resources to a liquid products release until additional resources and personnel arrive on site. This document is also placed on the **emergencyresponderinfo.com** site for use by first responders.

This guide is not intended to replace Enbridge's regulated and approved emergency response plans and in every instance, verification with these plans is required. The guide is a reference tool and supplement to prior training, field experience, technical instruction and equipment operation knowledge. The guide is not an all-inclusive manual and is a work in progress. Enbridge Pipelines Inc. retains the right to modify the guide as it deems necessary to update tactics and/or equipment improvements.

Enbridge's first responder's primary responsibility is to ensure personal safety and the safety of the public. The safety of our responders is paramount – no response tactic shall be employed if it threatens human health or safety. The company will rely on the training and judgment of its first-on-scene responders to select only those tactics that can be accomplished safely. Enbridge is on a path to zero injuries, incidents and occupational illnesses. On the following pages you will find our Health and Safety Principles, which guide our actions, policies, procedures and culture with regard to safety, as well as our 6 Lifesaving Rules, which are founded on real-life incidents at Enbridge and focus on areas of high risk and high consequence.

Inland Spill Response Tactics Guide

Safety

2

2.1 | Safety Message

Rule 1:
HAZARD MANAGEMENT

Rule 2:
DRIVING SAFETY

Rule 3:
CONFINED SPACE ENTRY

Rule 4:
GROUND DISTURBANCE

Rule 5:
ISOLATION OF ENERGIZED SYSTEMS

Rule 6:
REPORTING SAFETY INCIDENTS

Lifesaving Rules

Lifesaving Rules

Working for Enbridge means working safely. At Enbridge we value the safety of our communities, customers, contractors and employees.

The Lifesaving Rules are founded on real incidents at Enbridge at the heart of our commitment to safety.

For more information visit **ELink** and search **'Lifesaving Rules'**

2.1 | Safety Message

1. All injuries, incidents, and occupational illnesses can be prevented.
2. All operating exposures can be controlled.
3. Leaders are accountable for safety performance.
4. All employees/contractors are responsible for safety.
5. Assessment and improvement are a must.
6. We promote off-the-job health and safety for our employees 24/7.

Health and Safety Principles

Enbridge is committed to ensuring everyone returns home safely at the end of each and every day, and that our assets are operated in a safe and reliable manner. We base our commitment to safety on our care for employees, contractors, the communities in which we operate and the environment.

Our values of Integrity, Safety and Respect guide our decisions, actions and interactions individually and as a company. Our Safety Principles support our values and highlight the fundamental beliefs we share on our path to a zero-incident workplace.

Safety. It's a core value that makes us Enbridge. It's our way of life.

Our Path to Zero

For more information visit **ELink** and search **'Safety Principles'**

2.2 | Responder's Duty

The first duty of first responders to a spill or suspected spill incident is to ensure the safety of the public and the response personnel. Under no circumstance should personnel place themselves in harm's way or be directed to do so by others when performing response activities.

Source control – Notify the Control Centre, who will isolate the pipeline or give instructions to responders on how to isolate the pipeline.

In Case of Emergency – 24 Hour Contact

US Regions	**1-800-858-5253**
North Dakota Region	**1-888-838-4534**
CND Region	**1-877-420-8800**
Athabasca Region	**1-888-813-6844**
In Quebec	**1-780-420-8899**
Enbridge Media Hotline Canada/US	**1-888-992-0997**

2.2 | Responder's Duty

Control and containment of the released material – Focus on limiting the spread of the released material, especially where watercourses and sensitive areas are vulnerable.

Recovery or alternative removal – Once preparations for controlling the source and the spread are underway, responders can begin to focus on ways to remove the spilled product.

Safety – Responsibility to ensure all operations are conducted in accordance with Enbridge safety standards to include the wearing of PFD's near water and procedures for ground disturbance.

2.3 | Initial Discovery/Response Actions

Purpose: When exploring a suspected or reported emergency incident, safe work practices will be followed per the following guidelines. The order of these actions will depend upon the situation:

Explore

- ☐ Ensure safety of personnel in the area.
- ☐ Determine the wind direction and approach cautiously from upwind.
- ☐ Explore the suspected release area only when wearing appropriate PPE, using the buddy system if possible.
- ☐ Conduct a hazard assessment to determine the potential for fire, explosion and hazardous toxic vapors.
- ☐ Eliminate or shut off all potential ignition sources in the immediate area.
- ☐ Use intrinsically safe equipment (e.g., flashlights, two-way radios, gas detectors with audible alarms).
- ☐ Maintain regular/scheduled communication with the Control Centre and Regional Management/on-call person.

Approach

- ☐ Verify wind direction and stay upwind.
- ☐ Are people injured or trapped?
- ☐ Are there external people involved in rescue or evacuation?

Are there immediate signs of potential hazards such as:

- ☐ Electrical lines down or overhead?
- ☐ Unidentified liquid or solid products visible?
- ☐ Vapors visible?
- ☐ Smells or breathing hazards evident?
- ☐ Fires, sparks or ignition sources visible?
- ☐ Holes, caverns, deep ditches, fast water or cliffs near?
- ☐ Is local traffic a potential problem?
- ☐ Ground conditions - ☐ Dry ☐ Wet ☐ Icy

Considerations

- ☐ If possible, photograph the area for situational awareness.
- ☐ Once support has arrived, conduct transfer of command and start preparing for tactical and planning meetings.
- ☐ If appropriate, request surveillance fly-over to determine:
  - Size and description of oil slick
  - Direction of movement
  - Coordinates of leading and trailing edge of oil slick
  - Sensitivities endangered
  - Areas of population that are threatened

2.3 Initial Discovery/Response Actions

Confirm and Control

- [ ] Confirm identification of spilled material and check the SDS/MSDS sheets.
- [ ] Assess the spill threat, site safety and parameters such as spill volume, extent and direction of movement.
- [ ] Has pipeline(s) been shut down?
- [ ] If on water, consult Control Point and High Consequence Area (HCA) maps for appropriate response strategies for incoming resources.
- [ ] Has wind direction been confirmed and windsock erected?
- [ ] Has the public been protected or evacuation considered if necessary?
- [ ] Have all ignition sources been identified and eliminated?
- [ ] Establish exclusion zone and safe work areas (hot, warm and cold).
- [ ] Have personal protection and safety requirements been established and communicated?
- [ ] Is adequate fire protection equipment available and in place?
- [ ] Have valves been locked out if necessary?
- [ ] Are tank and VAC-truck electrical equipment properly grounded?
- [ ] Have decontamination sites and procedures been established?
- [ ] Are activities and events being logged/documented?

Communication

- [ ] Initiate actions to notify government agencies including local authorities of area affected or at risk areas via the Control Centre, Regional Management or designate.
- [ ] Complete notifications for emergency call-out, including regulatory agencies. This will be done by the Regional Management or designate.
- [ ] If excavating, has One-Call agency been notified?
- [ ] Has a Preliminary Incident Report been issued?
- [ ] Has a radio channel been established for communication between the site and other personnel in field?

2.4 Decontamination

During investigation and mitigation operations, it is critical to ensure that secondary contamination is NOT inadvertently introduced into the surrounding area by adhering to strict decontamination procedures for both personnel and tools. A representative decontamination corridor for personnel is depicted in Diagram 2.4a REPRESENTATIVE DECONTAMINATION CORRIDOR. For boats, heavy or vehicular equipment, a formal decontamination cell is usually constructed in the Warm Zone, separate from the personnel decontamination area. Depending on the scope of the emergency incident, a Decontamination Plan may be developed and approved by Incident Command.

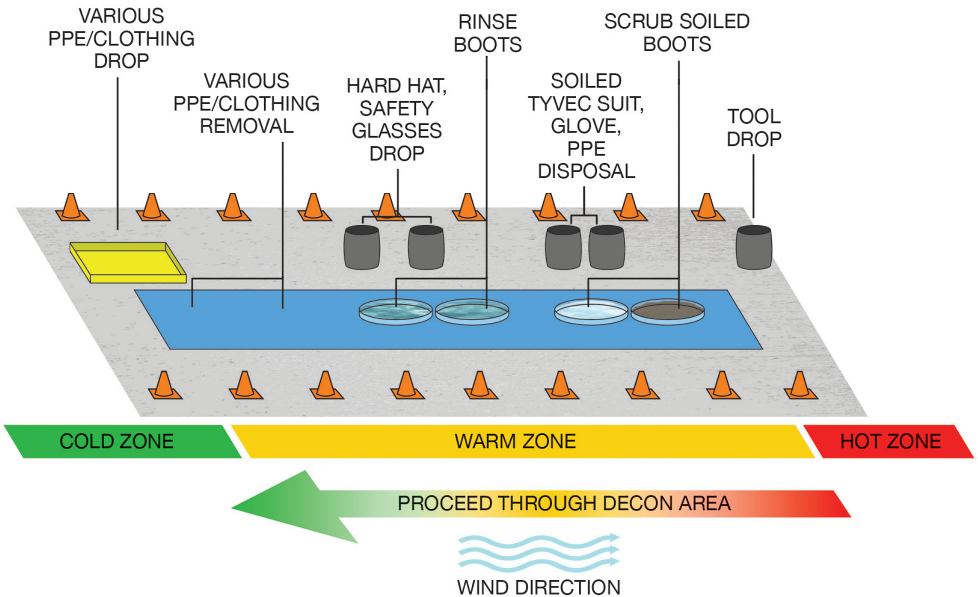


Diagram 2.4a Representative Decontamination Corridor

Inland Spill Response Tactics Guide

Inland Spill Control Tactics

3

Characterize breathing hazards and combustible vapors before starting site mitigation activities. Initial air testing provides information for establishing engineering, administrative and PPE control and establishing protective zones.

Do not enter areas where gas detector readings indicate breathing hazards without appropriate respiratory protection.

Each oil spill is unique, so techniques, strategies and methods to control, contain and recover spilled oil vary depending on safety, practicality, and seasonal and local conditions. Early assessment of some basic parameters—even very rough estimates—can guide decision-making and the selection of strategies and tactics.

Identifying the Extent of the Problem

1. Can the source of the release be found?
2. Can the extent of the impact be estimated?
3. Can it be contained?
4. Does the release threaten a stream or river? If so, how fast is the water flowing? How much time would it take to set up response equipment at some point downstream? How far downstream would Control Points have to be to allow time to mobilize and travel to the Control Point?
5. Is sufficient temporary liquid storage available or en route?

After isolating the source of spilled oil, preventing or at least influencing how it may spread is a response priority. Preventing the spread of spilled material is called "direct containment".

If the situation does not lend itself to containment, then tactics called "reverse containment" can be deployed. Reverse containment seeks to exclude oil from identified resources.

3.1 | Land

While spills on land may not spread as quickly as those on water, quick response remains important to minimize contamination of soils and vegetation and any impact to wildlife. Oil will spread downhill or percolate vertically into the soil. While the latter mechanism is usually gradual and difficult to control, horizontal spreading by gravity can frequently be contained using local materials. This section provides some useful tactics for containing spills by creating barriers. Please note that particular attention is paid to intercepting spills before they reach surface water, where containment becomes even more difficult.

3.1.1 | Land | Berms

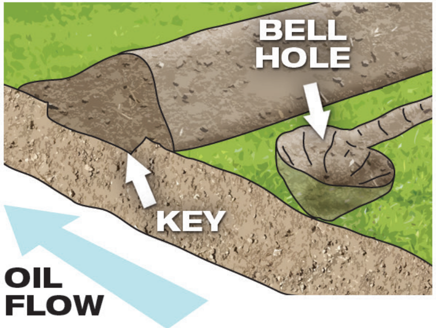


Diagram 3.1.1a
Clay Berm with Key

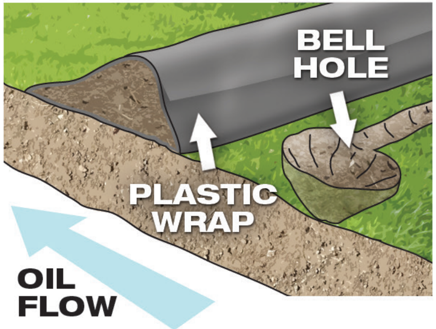


Diagram 3.1.1b
Clay Berm with Plastic Wrap

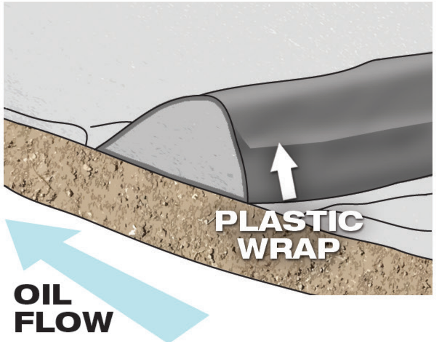


Diagram 3.1.1c
Snow Berm with Plastic Wrap
(or lightly sprayed with water)

Note: Pack snow tightly with shovel or board before spraying with water.

3.1.1 | Land | Berms

Watch Your Step

Call Before You Dig

Tip: Hand-dig small bell hole upstream of berm for recovery.

Purpose: Berms act like curbs to halt the advance and allow for recovery of the spill while reducing the potential for environmental damage. Berms may also be used to channel the spill in a particular direction.

Application: Berms can be constructed immediately, with local material. Berms are typically used on flat terrain.

Environmental Considerations: Consider environmental sensitivities such as essential vegetation, rare plants, sensitive soil types or critical habitat before constructing a berm. Where possible, remove topsoil prior to berm construction and avoid constructing berms with topsoil material.

Equipment Required: Shovel(s) or earth-moving equipment, rolls of plastic sheeting

Recovery Equipment Options: Sorbents, skimmer, pump, hoses, hose strainer, temporary liquid storage capacity, vacuum truck

Waste disposal bags and tags if sorbents are to be used

For snow berms, water spraying equipment is optional. If snow is to be used for berm without plastic cover and water spray equipment is available, compact the face of the berm with shovels and spray water to form an ice crust on the berm. This will reduce spill penetration.

Operation:

1. Lay down plastic, if available, across expected route of spill travel.
2. Pile soils/snow on downstream side of plastic (away from approaching oil).
3. Flip upstream side of plastic over berm to prevent contamination of berm contents.

3.1.2 | Land | Interceptor Trench

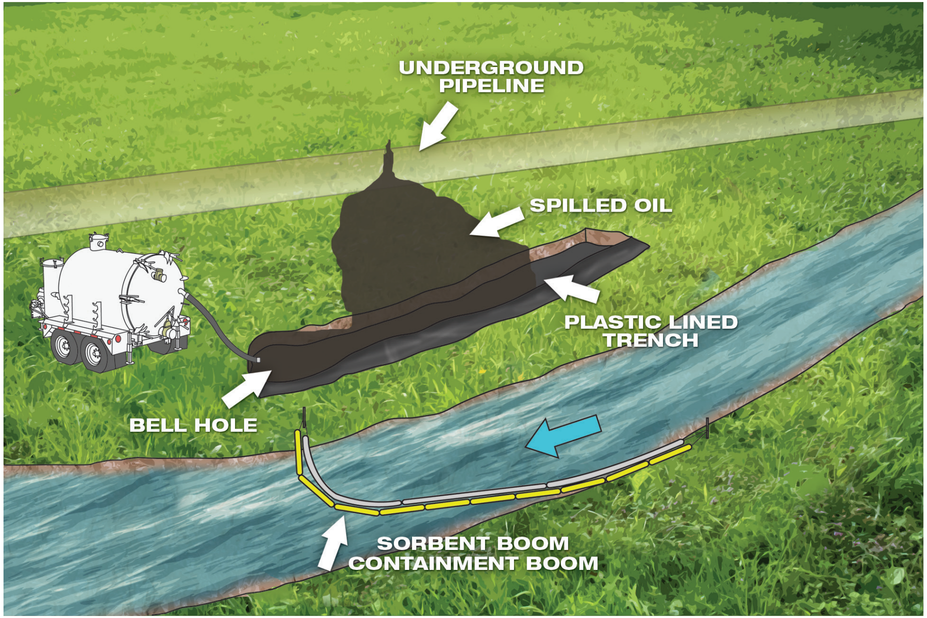


Diagram 3.1.2a Interceptor Trench

3.1.2 | Land | Interceptor Trench

An interceptor trench can be used to prevent a spill from spreading on land. When lined with plastic, it can form a temporary receptacle for oil until the oil can be recovered.

Call Before You Dig

Tip: Installing sorbent boom in the creek serves two purposes: to act as an indicator if the spill is somehow breaching the trench and to collect that seepage.

Purpose: To provide a catchment basin for a spill. The spoil may be used as a berm downstream of the trench to provide further protection.

Application: Where a significant containment capacity is required on a slope.

Environmental Considerations: Consider environmental sensitivities such as essential vegetation, rare plants, sensitive soil types or critical habitat before constructing a berm. Where possible, the maximum trench depth should be above the water table and the trench lined with poly material to prevent groundwater contamination.

Equipment Required: Shovel(s) or earth-moving equipment, rolls of plastic

Recovery Equipment Options: Sorbents, skimmer, pump, hoses, hose strainer, temporary liquid storage capacity, vacuum truck

Waste disposal bags and tags if sorbents are to be used

Operation:

1. Dig trench downstream of the anticipated path of the spill. The spoil taken from the trench may be used to construct a berm on the downstream side as secondary containment.
2. Line bottom and downstream side of trench with plastic sheeting to reduce soil contamination.

3.1.3 | Land | Trench and Berm

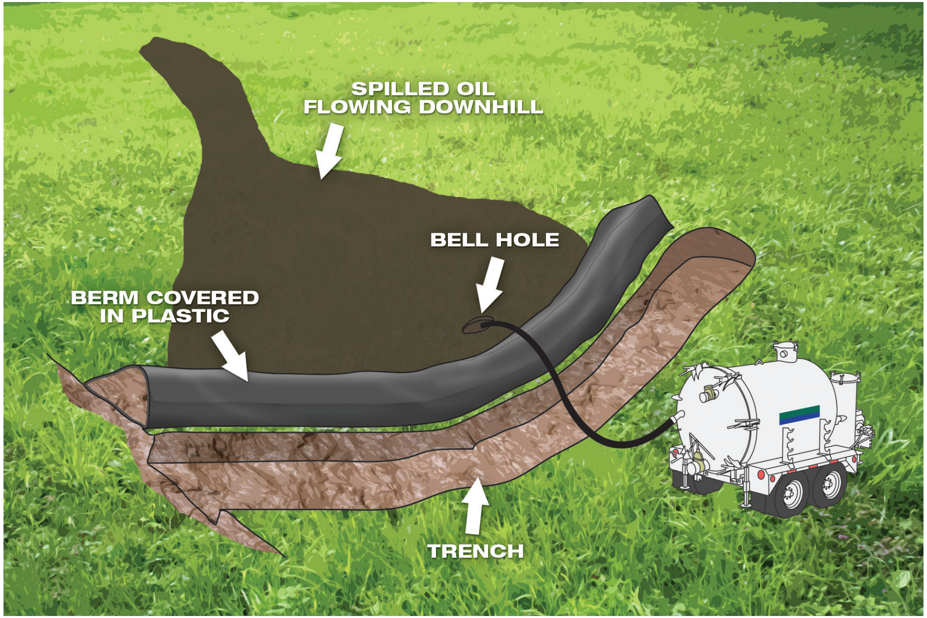


Diagram 3.1.3a Trench and Berm

3.1.3 | Land | Trench and Berm

Call Before You Dig

Tips: - Hand-dig small bell hole upstream of berm for recovery.

- Constructing berm upstream of trench allows berm to be raised in height with clean soil/snow even after spill starts to arrive. It also provides secondary containment (trench) if berm fails.

- This can be used in snow

Purpose: To halt the advance and allow for recovery of a spill while reducing the potential for environmental damage. This tactic takes the soil from the trench to create the berm and act as a secondary defense mechanism, if necessary.

Application: Where a significant containment capacity is required on a slope.

Environmental Considerations: Consider environmental sensitivities such as essential vegetation, rare plants, sensitive soil types or critical habitat before constructing a berm. Where possible, the maximum trench depth should be above the water table and the trench lined with poly material to prevent groundwater contamination.

Equipment Required: Shovel(s) or earth-moving equipment, rolls of plastic

Recovery Equipment Options: Sorbents, skimmer, pump, hoses, hose strainer, temporary liquid storage capacity, vacuum truck.

Waste disposal bags and tags if sorbents are to be used

For snow berms, water spraying equipment is optional. If snow is to be used for berm without plastic cover and water spray equipment is available, compact the face of the berm with shovels and spray water to form an ice crust on the berm. This will reduce spill penetration.

Operation:

1. Lay down plastic, if available, across expected route of spill travel.
2. Dig trench on downstream end of plastic (away from approaching spill). Pile soil/snow on downstream side of plastic (away from approaching oil).
3. When berm is completed, flip the upstream side of plastic over berm to prevent contamination of berm contents while retaining the spill.

3.2 | Small Watercourses

Small watercourses are usually characterized by any combination of shallow depth, narrow width and low current velocity. Watercourses that are less than 10 metres (33 feet) wide, a half metre deep (1.6 feet), flowing at less than a knot are candidates for small watercourse containment response tactics. The tactics that follow rely on man-made fixtures that halt the flow of surface water, or, in the extreme case, halt all flow. Fixtures may be bottom-founded, such as earth dams that are supported by subsoil or stream bed, or rigid structures such as culvert blocks.

3.2.1a | Small Watercourses | Stream Dams | Water Bag

The simplest form of stream dam can be made from a fabric bladder. Filled with water and held in place across a stream or drainage ditch, it can be an effective dam. **Caution:** Single-chamber bladders are susceptible to shifting by rolling as water depth (and hydrostatic pressure) increases on the upstream side. The simple pin anchors driven upstream of the dam in Diagram 3.2.1a are used to secure the dam in place.

Tips: - Tactic can cause possible upstream flooding in areas with flat topography.

- Pin anchors driven upstream and underflow pipe installed to pass water beneath.

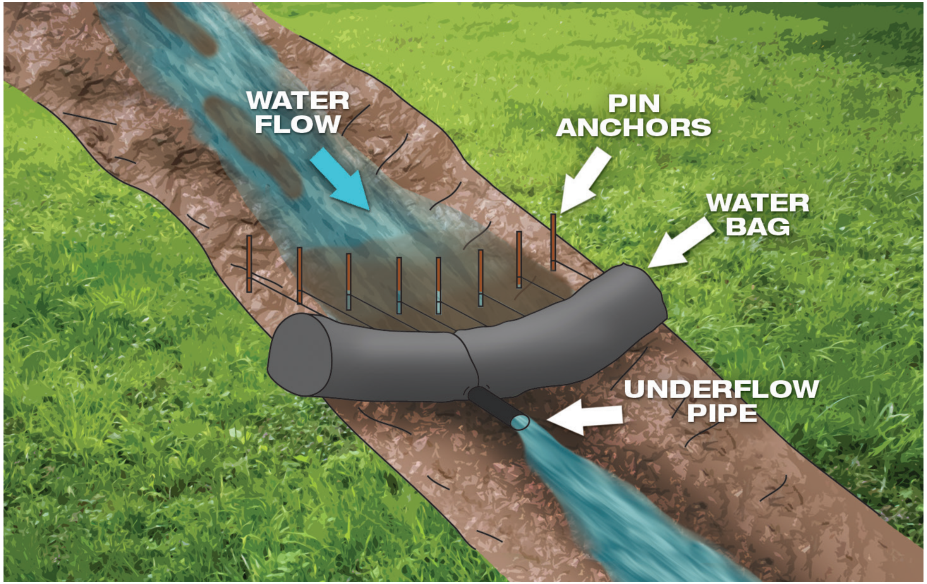


Diagram 3.2.1a Water Bag

3.2.1b | Small Watercourses | Stream Dams | Aquadam™

AquaDams™ are made up of multiple parallel chambers called fill tubes which give it a level of stability against shifting. While slightly more complicated to place and fill than a simple bladder, in many cases it does not require external anchors.

Tip: Tactic can cause possible upstream flooding in areas with flat topography.

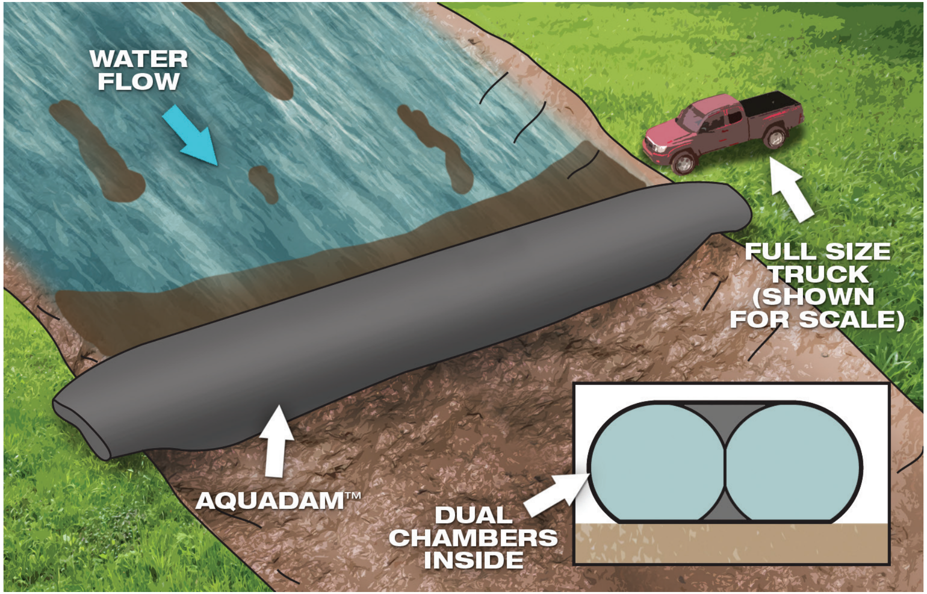


Diagram 3.2.1b Aquadam™

AquaDams™ is a registered trademark of Layfield

3.2.1c | Small Watercourses | Stream Dams | Tiger Dam®

Similar to the AquaDam™, the Tiger Dam® utilizes multiple water tubes for increased freeboard and resistance to sliding. Unlike the AquaDam™, a Tiger Dam's® tubes may be individual units which are strapped together after placement.

Tips: - Tactic can cause possible upstream flooding in areas with flat topography.

- Multiple water tubes for increased freeboard and dead weight to hold dam in place.

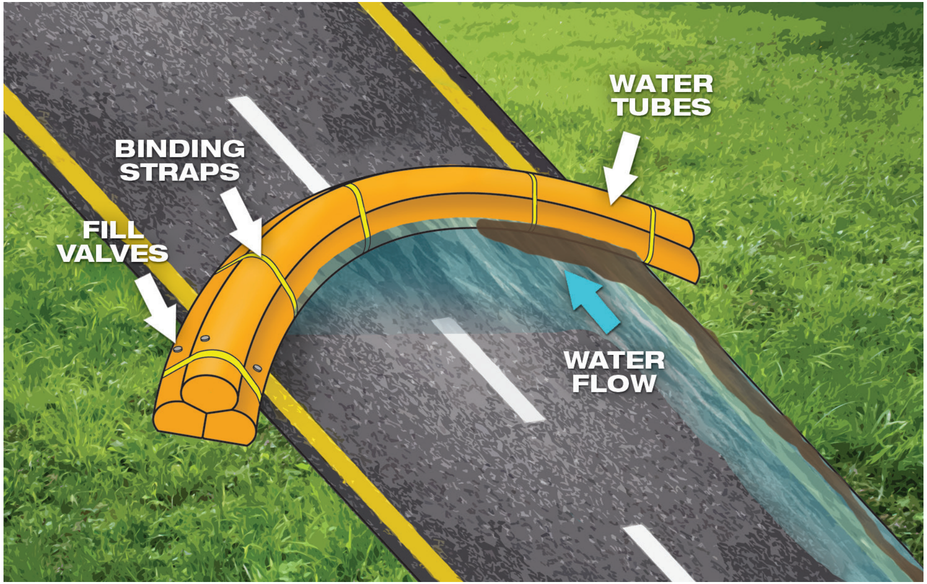


Diagram 3.2.1c Tiger Dam®

Tiger Dam® is a registered trademark of PV Flood Control Corp.