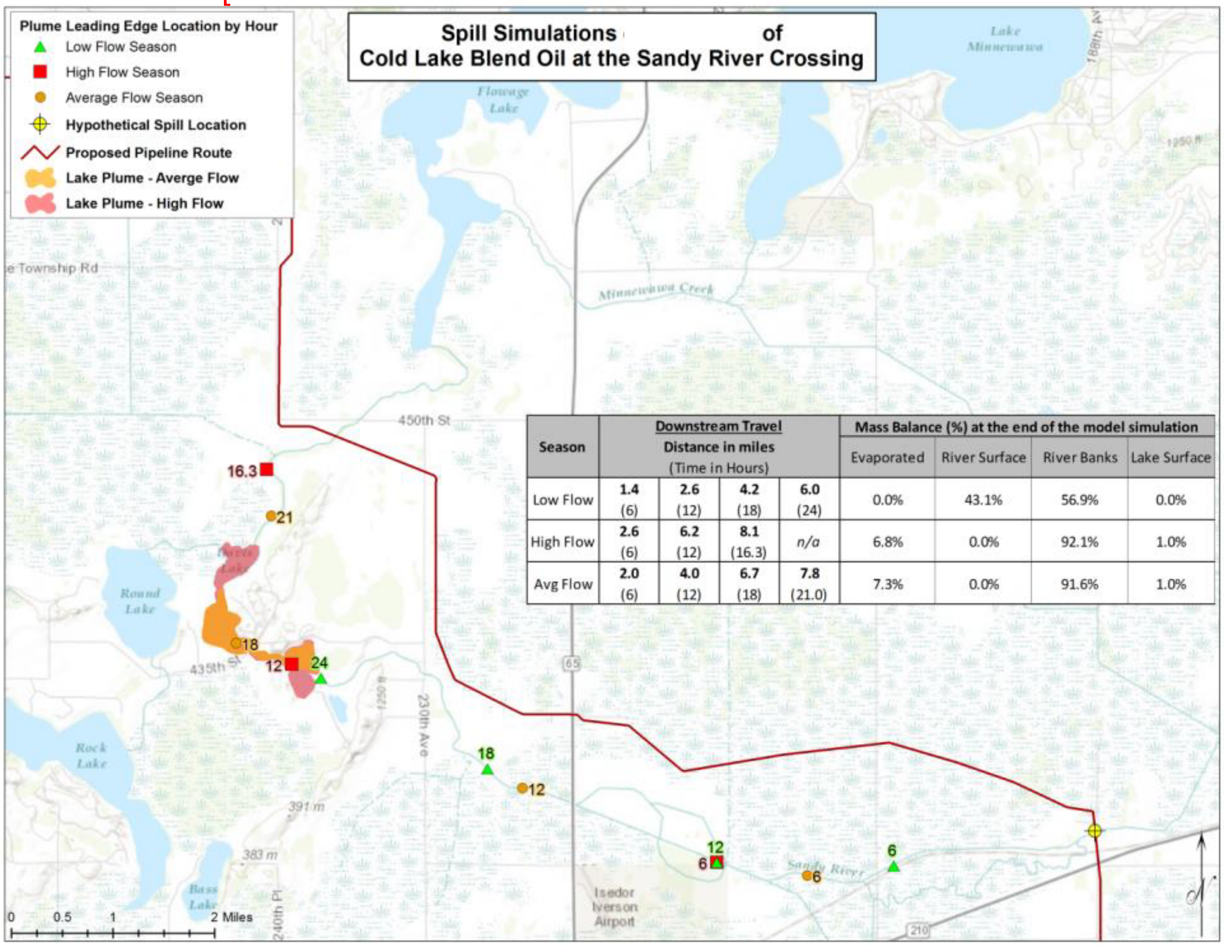
detection. This includes the combination of identification of the rupture, analysis of the pipeline condition, pipeline shutdown and full valve closure in the affected pipeline section. While 13 minutes is the maximum time for valve closure, this is a conservative assumption, since a response through to valve closure is expected to occur in less than 13 minutes in a full bore rupture leak scenario. Based on these assumptions, the site-specific hypothetical release volume was estimated [NONPUBLIC DATA HAS BEEN EXCISED] of Bakken, CLB, or CLWB crude oil.

7.4.5 Summary of Predicted Downstream Transport of Bakken and Cold Lake Crude Oils

A summary of the predicted downstream trajectory and mass balance of Cold Lake and Bakken crude oils, under the three seasonal scenarios, is illustrated in Figure 7-23 and Figure 7-24, respectively. These simulations are assumed to provide bounding conditions for a release of heavy or light crude oil types. The fate of most types of crude oil, if released, would lie within the envelope of predictions for the Cold Lake and Bakken crude oil types. The Cold Lake crude oil was assumed to be CLB for the high flow and average flow scenarios, and to be CLWB for the low flow scenario. Details about the predicted downstream transport are provided in the following sections.

As noted in Section 7.5.3, the maximum simulation duration using OILMAP Land was 24 hours, as it was assumed that emergency response measures to prevent continued downstream transport of released oil would be in place within that length of time. Symbols on the drawings indicate the river seasonal flow condition (high corresponding to spring freshet, medium corresponding to summer-fall conditions, and low corresponding to winter flow under ice). 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. Numbers other than these (e.g., 16.3) indicate the time in hours of the predicted termination of downstream transport of the released oil due to adhesion or holdup of the oil along the river banks. Tables inserted within the Figures also provide information on the mass balance (i.e., oil remaining on the surface of the river, adhering to river banks, or evaporated to the atmosphere) of the released oil at relevant points in time after the start of the release.

[NONPUBLIC DATA HAS BEEN EXCISED...

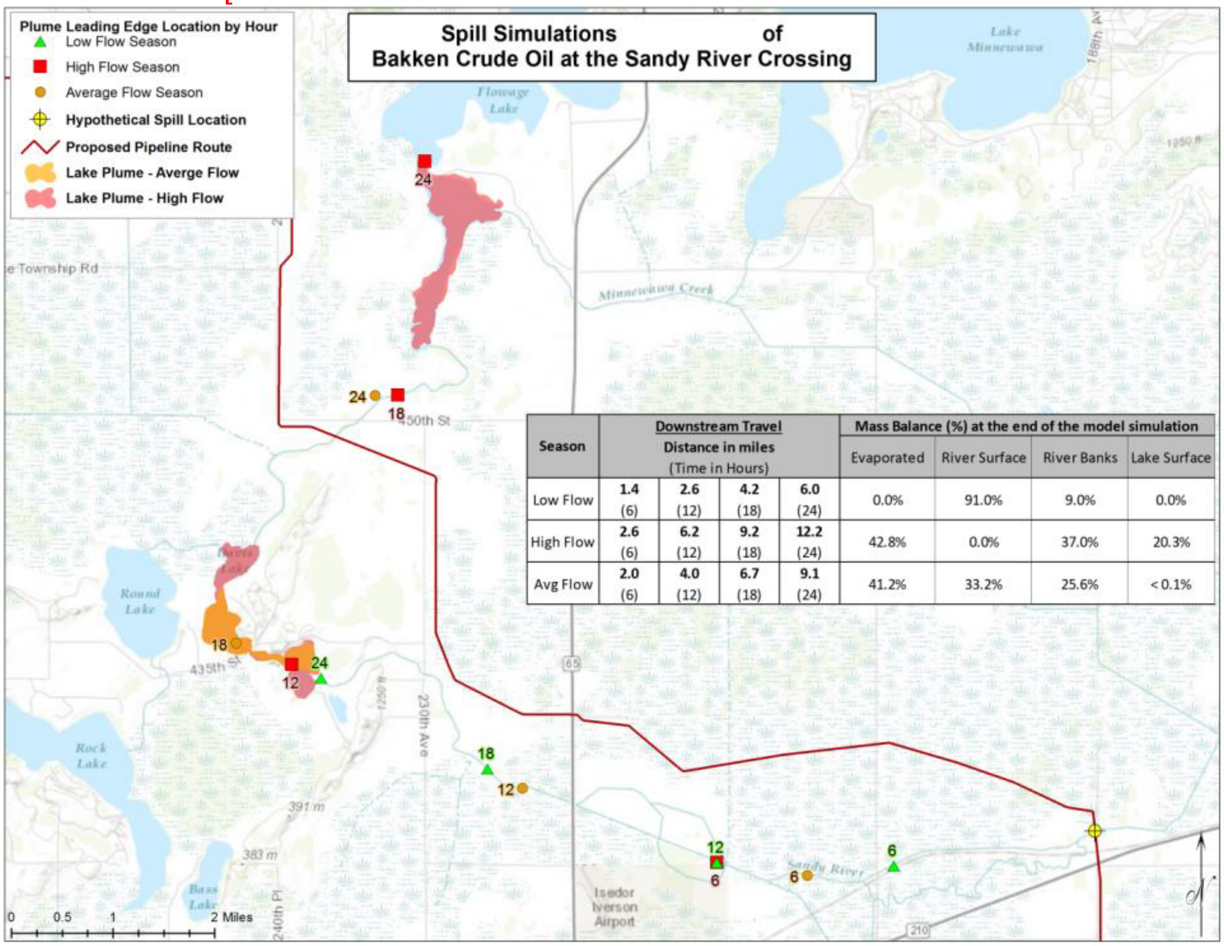


Season	Downstream Travel Distance in miles (Time in Hours)				Mass Balance (%) at the end of the model simulation			
					Evaporated	River Surface	River Banks	Lake Surface
Low Flow	1.4 (6)	2.6 (12)	4.2 (18)	6.0 (24)	0.0%	43.1%	56.9%	0.0%
High Flow	2.6 (6)	6.2 (12)	8.1 (16.3)	n/a	6.8%	0.0%	92.1%	1.0%
Avg Flow	2.0 (6)	4.0 (12)	6.7 (18)	7.8 (21.0)	7.3%	0.0%	91.6%	1.0%

...NONPUBLIC DATA HAS BEEN EXCISED]

Figure 7-23 Predicted Downstream Transport of CLB Oil at the Sandy River Crossing Location

[NONPUBLIC DATA HAS BEEN EXCISED...



Season	Downstream Travel Distance in miles (Time in Hours)				Mass Balance (%) at the end of the model simulation			
					Evaporated	River Surface	River Banks	Lake Surface
Low Flow	1.4 (6)	2.6 (12)	4.2 (18)	6.0 (24)	0.0%	91.0%	9.0%	0.0%
High Flow	2.6 (6)	6.2 (12)	9.2 (18)	12.2 (24)	42.8%	0.0%	37.0%	20.3%
Avg Flow	2.0 (6)	4.0 (12)	6.7 (18)	9.1 (24)	41.2%	33.2%	25.6%	< 0.1%

...NONPUBLIC DATA HAS BEEN EXCISED]

Figure 7-24 Predicted Downstream Transport of Bakken Crude at the Sandy River Crossing Location

7.4.5.1 Sandy River Release During High Flow (Spring) Period

The OILMAP Land model transported oil downstream with these velocities to a point where all oil had evaporated and/or adhered to the shoreline. Under this high river flow scenario, CLB crude oil was predicted to travel a total of approximately 8.1 miles downstream, within 16.3 hours of the release. The CLB crude oil was predicted to be transported along the Sandy River, to then spread over the surfaces of both Steamboat Lake and Davis Lake (for a total area of 0.182 square miles and at a thickness of 0.004 inches [0.1 mm]), and then continue another 0.7 miles down Sandy River. Approximately 92.1% of the CLB crude oil was predicted to oil the shorelines of Sandy River, 1.0% to have spread over the surface of Steamboat and Davis lakes, and 6.8% to have evaporated into the atmosphere.

Bakken crude oil was predicted to be transported approximately 12.2 miles downstream, over the full 24-hour modeled period. The Bakken crude oil was predicted to be transported down the Sandy River, to then spread over the surfaces of both Steamboat Lake and Davis Lake (for total area of 0.182 square miles at a thickness of 0.00004 inches), and then continue another 3.5 miles in Sandy River before reaching Flowage Lake. Oil was predicted to spread very thinly (less than 0.00004 inches) over approximately 0.22 square miles of the surface of Flowage Lake. If left unmitigated, it is predicted that this spreading would continue to occur after 24 hours, covering a larger surface area of the lake. Approximately 37.0% of the Bakken crude oil was predicted to oil shorelines of Sandy River, 20.3% would have spread over the surface of Steamboat, Davis, and Flowage lakes, and 42.8% would have evaporated into the atmosphere.

Bakken crude oil was predicted to result in oiling 4.1 miles farther downstream, than the CLB crude oil (8.1 miles) under high flow river conditions. The difference in the extent of downstream transport was primarily the result of the differences in the shoreline and lake surface oil retention between the two oil types. CLB, the more viscous crude oil, would adhere to shorelines and spread as a thicker slick than the less viscous Bakken crude oil. Therefore, the same amount of Bakken would oil a greater length of shoreline and more lake surface, but at a lower slick thickness. While this result is logical, it is based upon the assumption of 100% shoreline oiling coverage (i.e., all shoreline up to that point is oiled to its maximum holding capacity) as oil makes its way downstream, and the assumption that oil would spread evenly within lake. In the event of an actual release, the downstream extents of CLB and Bakken crude oils may be more similar, and the effects of CLB may extend farther downstream than presented, with patchy coverage. Due mostly to the lighter nature and higher volatile content, much more of the Bakken crude oil was predicted to evaporate (42.8%) than was predicted for the CLB crude oil (6.8%).

7.4.5.2 Sandy River Release During Average Flow (Summer-Fall) Period

Under average river flow conditions, CLB crude oil was predicted to travel a total of 7.8 miles downstream within 21 hours of the release. The CLB crude oil was predicted to be transported down the Sandy River, to then spread over the surfaces of both Steamboat Lake and Davis Lake (for total area of 0.106 square miles at a slick thickness of 0.004 inches), and then to continue another 0.7 miles down the Sandy River. Approximately 91.6% of the CLB was predicted to oil shorelines of Sandy River, 1.0% to have spread over the surface of Steamboat and Davis lakes, and 7.3% to have evaporated into the atmosphere.

Relative to the high river flow condition, the CLB crude oil was predicted to be transported a shorter distance downstream (0.3 miles). This was predominantly due to the longer duration of the scenario which allowed for more evaporation. Under both high and average flow conditions, oil was modeled to spread over the entire surface of both Steamboat and Davis lakes. However the area of the lakes was smaller in the average flow condition.

Under average river flow conditions, Bakken crude oil was predicted to be transported approximately 9.1 miles downstream over the 24-hour modeled period (Figure 7-24). The Bakken crude oil was predicted to be transported down the Sandy River, and to then spread over the surfaces of both Steamboat and Davis lakes (for total area of 0.106 square miles and at a thickness of 0.00004 inches). It was then able to continue another 2.05 miles down Sandy River. Approximately 25.6% of the Bakken crude oil was predicted to oil shorelines of Sandy River, less than 0.1% to spread over the surface of Steamboat and Davis lakes, 41.2% to have evaporated into the atmosphere, and 33.2% to remain on the river surface at the end of the 24 hour simulation. If left unmitigated, it is predicted that the remaining Bakken crude oil on the river surface would continue downstream, with weathering and oiling of shorelines continuing until all the oil is removed from the water surface.

The Bakken crude oil was predicted to be transported 3.1 miles less under summer-fall conditions when compared to the high river flow conditions. The lower river velocities of the average river flow condition prevented the oil from being transported as far downstream within the 24 hour simulation period. The Bakken crude oil evaporated less in the average flow condition (41.2 %) than the high flow condition (42.8%) due to the reduced surface area oiled. This was a result of smaller area of Steamboat and Davis lakes, and the reduced downstream transport. When compared to the CLB crude oil under average river flow conditions Bakken was transported 3 miles farther downstream before reaching the 24 hour model limit. Approximately 33.2% of the Bakken crude oil was predicted to remain on the river surface at the end of the simulation. If left unmitigated, it is predicted that the remaining Bakken crude oil on the river surface would continue downstream, with weathering and oiling of shorelines continuing until all the oil is removed from the water surface. The Bakken crude oil was able to travel farther downstream, under the same river velocities, due to differences in the shoreline and lake surface oil retention between the two oil types.

7.4.5.3 Sandy River Release During Low Flow (Winter) Period

Under winter conditions, it was assumed that the Sandy River and downstream lakes would be frozen (100% coverage of ice). It was assumed that CLWB crude oil would be released directly into the river from the pipeline under the riverbed, and that all oil would remain trapped under the ice. The ice cover would strongly limit or prevent evaporation of crude oil vapors to the atmosphere. Flow velocity for Sandy River during these winter conditions resulted in minimum river velocities during March.

Under low river flow conditions, CLWB crude oil was predicted to be transported a total of 6.0 miles downstream, over the full 24-hour modeled period. The CLWB crude oil was predicted to stop just before reaching Steamboat Lake. Approximately 43.1% of the CLWB crude oil was predicted to remain in the river below the ice, and the remaining 56.9% to have oiled the shorelines of Sandy River. Any CLWB remaining in the river after 24 hours would continue to move downstream, oiling shorelines and Steamboat Lake, if not intercepted by emergency response teams.

Relative to the high and average river flow conditions, the CLWB crude oil was predicted to be transported over a shorter distance during low river flow conditions, stopping before reaching Steamboat Lake. This was due to the reduced river velocities under the low river flow conditions.

Under low river flow conditions, Bakken crude oil was predicted to be transported a total of 6.0 miles downstream, over the full 24-hour modeled period to a point just before Steamboat Lake. Approximately 91.0% of the Bakken crude oil was predicted to remain in the river below the ice, and the remaining 9.0% to oil shorelines of Sandy River. If not intercepted by emergency response teams, the remaining Bakken crude oil in the river after 24 hours would be expected to move downstream, oiling shorelines and Steamboat Lake.

Relative to the high river flow conditions, the Bakken crude oil under low river flow was predicted to be transported 6.2 miles less downstream. Relative to the average river flow condition, the Bakken crude oil was predicted to be transported 3.1 miles less downstream. Under low river flow conditions, the shore types were assumed to be the same as the average flow condition. With the oil being transported at a slower speed, the 24 hour modeled time limit was reached at a distance that was shorter than that of the average river flow condition with oil remaining on the surface. With the Bakken crude oil below the ice of the river, no oil was allowed to evaporate from the surface. When compared to the CLWB oil under low river flow conditions, 47.9% more of the Bakken crude oil remained in the river and under the ice. This would provide only temporary storage of the oil, and oil would be expected to re-mobilize in response to changes in flow velocity, and particularly during the spring breakup of ice. This was due to the lower shoreline oil retention between the two oils. For this reason the Bakken crude oil was predicted to have greater mobility under the ice in winter.

7.4.6 Qualitative EHHRA for the Sandy River

In this section the likely environmental effects of a crude oil release at the pipeline crossing location on the Sandy River are described. A worst case crude oil release from a main-line pipeline, such as described here, would be an unlikely event (Chapter 4.0). The proposed pipeline could 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). Therefore, the following discussion is based on the likely environmental effects of a crude oil release on relevant ecological and human environment receptors (identified in Section 7.5.3), using the predicted geographic extent of effects of released Bakken or CLB crude oil types over the 24 hour simulations as bounding conditions. Effects of season (including temperature, river flow conditions, and receptor presence/absence and sensitivity) as appropriate were also considered in the analysis. The rationale supporting the effects analysis, based on case studies describing the effects of crude oil releases on the various ecological and human environment receptors, was provided in Section 7.1 and Table 7-60.

7.4.6.1 Terrestrial Receptors

For this modeling scenario, the hypothetical release of crude oil is assumed to occur into the Sandy River, so that environmental effects on soils, terrestrial vegetation and groundwater quality are assumed to be localized, limited in spatial extent, and readily remediated using conventional clean-up techniques. The environmental effects of a crude oil release on land cover receptors are not considered further for this release scenario.

7.4.6.2 Aquatic Receptors

The aquatic environmental and ecological receptors that are most closely associated with the Sandy River, and Steamboat, Davis, and Flowage lakes are addressed in this section. These receptors include water and sediment quality in rivers and lakes, shoreline and riparian river bank habitat, wetlands, aquatic plants (including wild rice), benthic invertebrates, and fish.

If crude oil were to enter the Sandy River during the spring (high flow) or summer-fall (average flow) periods, it would be predicted to travel downstream and then enter and partially to fully cover the surfaces of Steamboat, Davis and Flowage lakes. As it traveled, crude oil would interact with vegetation and seasonal shoreline, the amount of which would vary depending upon season and water levels. During high flow conditions, the lakes have approximately one and a half to two times greater surface area than under average or low river flow conditions. Heavier crude oils could result in plumes on Steamboat and Davis Lake with a greater thickness than expected for lighter crude oils, but this would also tend to reduce the extent of overall downstream transport. Lighter oils could also enter Flowage Lake and could be found spread very thinly.

Based on a 24 hour model run, the OILMAP Land simulations suggest that crude oil could be carried between 2.0 and 12.2 miles downstream from the point of release during spring and summer-fall periods. For heavy oil, stranding on river banks would be the primary fate, with only small amounts of evaporative weathering of the oil occurring before the oil becomes stranded. However, for light oil the primary fate is evaporation with a moderate amount expected to remain on river banks or on the surface of Sandy River (under average flow conditions) or downstream lakes (under high flow conditions). Receding waters in the lakes in late summer could lead to further stranding of oil as riparian and wetland habitats drain.

The effects of crude oil release on benthic invertebrates and fish depend on characteristics of the released oil and environmental conditions at the time of the release. Light oils have low viscosity relative to heavier oils and turbulence in the river water could potentially disperse the light oil as small droplets in the water column, meaning potentially toxic fractions of the light oils would more readily dissolve into the water column. As a result, the potential for acute toxicity to fish and invertebrates is often greater for light crude oil than for heavier oils. However, Sandy River is a low-gradient watercourse, and both Steamboat and Davis lakes are small water bodies, with limited fetch (and low potential for the formation of breaking waves on their surfaces). Therefore, both light and heavy oils are likely to float on the water surface, with low potential for turbulence to entrain oil as fine droplets into the water column.

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. Sandy River is a small, shallow watercourse at the hypothetical release location, and even though flow in the river is unlikely to entrain small crude oil droplets into the water column, the very limited dilution provided by this river means that there is high potential for toxicity to fish and other aquatic life. While the large volume of water flow associated with the spring period freshet may dilute and limit the maximum dissolved hydrocarbon concentration in Sandy River as compared to periods of lower water flow in summer, it is unlikely that this would reduce effects to fish within the lake systems given the predicted crude oil coverage on the water surface in both seasons. As a result, narcotic effects on fish and benthic invertebrates are likely in all seasons. There would also be potential for phototoxicity, caused by an interaction of ultraviolet light with PAHs accumulated in fish tissues. This potential would be greatest in summer, due to high light intensity and long day length, and lowest in winter due to ice and snow cover, shorter day length, and lower sun angles. There would also be potential for chronic effects of released crude oil on fish eggs and embryos (i.e., induction of deformities or mortality collectively termed blue sac disease). Many fish species spawn in the spring and early summer. The eggs and embryos of these species could be exposed to total PAH concentrations in the river water that could be sufficiently high to induce deformities or cause mortality.

The non-turbulent flow characteristics of Sandy River suggest that entrainment of crude oil as fine droplets in the water column is unlikely. Therefore, there is low potential crude oil to interact with suspended sediment particles in the water column, resulting in the formation of OPAs. However, the released oils could still contact organic matter and sediment particles along shorelines, and some accumulation of both light and heavy oils in depositional areas is likely as a result of interactions between released oil and shorelines. Neither the light nor the heavy 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.

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. However, the Sandy River to Flowage Lake system supports a wide range of aquatic plants and where they occur, floating aquatic plants would be expected to be killed if contacted by an oil slick. 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 most sensitive groups of aquatic biota to such exposure. Emergent aquatic plants are generally quite tolerant of moderate exposure to floating oil (such that a portion of the stem could be oiled). However, flooded riparian areas and wetland habitats (especially during spring periods when the lakes are at their maximum surface area) would also be exposed to the released oil, and if not properly remediated, crude oil residues could kill 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.

Wild rice is an emergent aquatic plant of biological and cultural importance in Minnesota and occurs in many areas between the predicted point of release and Flowage Lake. Wild rice provides a food source and nesting cover for many birds, and is also harvested as a food source by people in the area. Given the extent of predicted oiling in spring and summer seasons, loss of emergent plants from contact with crude oil could be expected.

Under low flow conditions, it was assumed that Sandy River and its associated lakes would be frozen (100% coverage of ice). Based on the 24 hour simulations, both bounding oil types were predicted to be transported a total of 6.0 miles downstream. More of the light oil (91%) is predicted to remain potentially mobile under the ice after 24 hours than for the heavy oil (43%), with the balance of the oils assumed to be trapped in hollows under the ice, or close to the river margins, between the ice and the river sediment. For both oil types, the winter ice would effectively inhibit evaporation, while providing greater potential for dissolution into the water column during the period of lowest dilution flow. Therefore, a release in winter could cause mortality to fish due to narcosis. This result would be more likely for the light crude oil, which remain at the ice-water interface, than for the heavy crude oil, which would tend to remain in thicker localized accumulations along the banks. Fish eggs and larvae would generally not be present during the winter. Both crude oil types could accumulate in sediment, and both would be subject to re-mobilization with spring breakup of the ice, and increasing water flow rates.

7.4.6.3 Semi-Aquatic Wildlife Receptors

Habitats along Sandy River, Steamboat Lake, Davis Lake and Flowage Lake support semi-aquatic wildlife receptors including amphibians (e.g., frogs, salamander), reptiles (e.g., turtles, snakes), semi-aquatic birds (e.g., ducks, geese, cranes) and semi-aquatic mammals (e.g., muskrat, otter). While individual animals may be affected by exposure to released oil in the immediate area of the river, regional populations of these animals will be robustly supported by extensive wetland and aquatic habitats within the region. Details on predicted environmental effects for amphibians and reptiles, birds and mammals are provided below.

7.4.6.3.1 Amphibians and Reptiles

Crude oil released to the Sandy River during the spring (high flow) and summer-fall (average flow) periods is predicted to travel downstream as it then enters and covers or partially covers the surfaces Steamboat, Davis and Flowage lakes. Within these habitats, oiling effects on amphibians (adults, juveniles, and eggs) and reptiles would be observed. Higher potential would exist for effects on amphibians (i.e., physical effects of oiling, as well as narcotic effects similar to fish and benthic invertebrates) than for adult turtles, which appear to be somewhat tolerant of external oiling. A release of light crude oil during the spring would likely have a greater effect than in summer due to the greater predicted transport distance, and interaction with more riparian and wetland habitats than under average flow conditions. Reptiles like lizards and snakes are primarily terrestrial species and are less intimately associated with aquatic environments. As a result, exposure of these animals to released crude oils would be limited.

Amphibians and reptiles undergo a winter dormancy period when temperatures drop below approximately 41 to 45°F. At this time, amphibians and turtles typically bury themselves in river bottom substrates. Therefore, during the winter (and likely up until April or May when winter ice is gone), these organisms would have very little exposure to released oil moving on the water surface or within the water column.

7.4.6.3.2 Birds

Aquatic and semi-aquatic birds are those that use rivers, lakes, wetlands, and riparian areas as components of their habitats, 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. 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 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 are likely to die as a result of hypothermia. Animals in the affected river reach and lakes would be most affected. Animals upstream, farther downstream, or occupying other nearby habitats, would likely be less affected since emergency response measures to prevent or reduce farther possible downstream transport of oil would be in place within 24 hours of the release. Therefore, although mortality of some semi-aquatic birds is expected, large-scale population level effects are unlikely.

Environmental effects of a crude oil release in the summer period are likely to be of similar or lesser magnitude. Due to lower river flow rates, the size of the potentially affected river reach is smaller. With rising water temperatures, mortality of lightly oiled adult birds due to hypothermia becomes less likely than in the spring. 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. 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.

In the winter months, ice cover on the Sandy River, and Steamboat, Davis and Flowage lakes, would strongly limit the opportunities for aquatic and semi-aquatic birds to occupy this habitat. In addition, released crude is predicted to remain beneath the ice cover of Sandy River and both Steamboat and Davis lakes. Therefore, adverse effects on the health of aquatic and semi-aquatic birds are not likely for a release of crude oil during the winter.

7.4.6.3.3 Semi-aquatic Mammals

While the semi-aquatic mammal species found in Minnesota include terrestrial species such as moose and raccoon, this assessment focuses particularly upon 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 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 the Sandy River and associated lake systems where effects may occur, and the magnitude of effects, is related to the type of oil released and the season in which semi-aquatic mammal could be exposed. Effects to semi-aquatic mammals relate more to the amount of time spent in the water (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 (high flow) season, with cold water temperatures prevailing, semi-aquatic mammals contacted by crude oil are likely to die as a result of hypothermia. Animals in areas where there is predicted to be crude oil on the surface of the Sandy River and associated lakes could be affected. Animals upstream, farther downstream where there is no exposure, or occupying other nearby habitats, would likely be unaffected. Therefore, although mortality of some semi-aquatic mammals could be expected, large-scale population level effects are unlikely. Environmental effects of a crude oil release in the summer-fall period are likely to be of similar or lesser magnitude to those associated with a release during spring freshet. Due to lower river flow rates, the size of the potentially affected river reach is smaller. With rising water temperatures, mortality of lightly oiled semi-aquatic mammals due to hypothermia is expected to be 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 possible as a result of ingesting crude oil residues while grooming, or while consuming food items. However, as in the spring, effects are expected to be limited to areas of oil exposure based on the 24 hour model run.

In the winter months, muskrat and beaver are likely to reduce their activity levels, although American mink and river otter would remain active. Animals that became oiled in the winter would be likely to rapidly die as a result of hypothermia

7.4.6.4 Human and Socio-Economic Receptors

Crude oils are complex mixtures of hydrocarbon compounds. Light crude oils typically contain more VOCs than heavier crude oils, although diluted bitumens 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) primarily within the first 24 hours of an oil release. When crude oil is spread out as a thin layer, the rate at which the VOCs evaporate does not vary greatly with oil type. Therefore, air quality would be most affected by the initial concentration of benzene and other VOCs in the crude oil, the size of the area affected by the release, and weather conditions such as winds and atmospheric stability that will determine how quickly the VOCs disperse in air.

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. The case studies (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.

The community of McGregor, Minnesota was identified through the HCA analysis as an "other populated area". The OILMAP Land modeling indicated that the leading edge of released crude oil would pass approximately one mile north of McGregor, although individual farms and homes are located within 100 ft of the Sandy River, Steamboat and Davis lakes. While no drinking water HCAs were identified along the path of the release, the homes located along the trajectories of predicted releases are likely to rely on groundwater as a drinking water source. 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. 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.

The potential for VOC inhalation exposures to the public would be greatest near and downwind from the release site and near to the Sandy River, Steamboat, Davis and Flowage lakes while the released oil is on the water surface. In the unlikely event of a crude oil release, residents in close proximity would become aware of a strong hydrocarbon odor. 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 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.

Relatively little has been published regarding the long-term effects of exposure by humans to an oil release. Health effects observed in residents and clean-up workers in the months following an oil release generally do not persist over the long term (Eykelbosh 2014). The International Agency for Research on Cancer (IARC 1989) 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.

Effects of a crude oil release on human receptors would be generally similar for the spring (high flow) and summer-fall (average flow) seasons. In summer, the warmer temperatures and slower river flow velocities in the summer would promote more rapid evaporation of volatile hydrocarbons in a smaller area. In the spring freshet period, higher river flow velocity would transport the released oil farther downstream within the first 24 hours, potentially resulting in lesser exposures, but to a larger number of people. The flow modeling suggests that the light crude oil (i.e., Bakken crude oil) is likely to be transported farther downstream within 24 hours than the heavy crude oil (Cold Lake diluted bitumen). As a result, a release of the light crude oil may affect a larger number of individuals than a release of the heavy crude oil type. Both Bakken crude oil and Cold Lake diluted bitumen are expected to contain similar overall amounts of volatile hydrocarbons, so differences related to the chemical characteristics of the released oil are likely to be minor.

No overland transport of released crude oil was modeled for this hypothetical release location. Infiltration of crude oil into soil and subsequently into groundwater would be limited. During the spring freshet period, the Sandy River could be susceptible to flooding and could overtop its banks and spread into the surrounding wetlands or farmland. A release of light and medium crude oils during this period would provide a potential pathway for oil deposition to soil in low-lying areas. Light and medium crude oils would be expected to become dispersed over a large area, and are readily biodegraded, so that persistent accumulation of these oil types in riparian areas or temporarily flooded farmland is unlikely. Heavy crude oils and diluted bitumen are more likely to be deposited as thicker layers of more persistent oil, and could require more active remediation of affected areas.

The Sandy River, as well as Steamboat, Davis and Flowage lakes provide recreational opportunities (e.g., fishing, hunting, boating, swimming, bird watching) downstream of the release location. 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 migration route. 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 for contact with constituents in the oil.

7.4.6.5 Summary and Conclusions

Expected environmental effects to key ecological and human environment receptors after a hypothetical large crude oil release to the Sandy River area have been assessed. The proposed pipeline could 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 is based on these crude oil types as bounding conditions. Potential terrestrial and aquatic habitats, aquatic receptors, semi-aquatic wildlife receptors, human and socio-economic receptors were screened to identify those most likely to have interactions with released oil. Potential environmental effects to these receptor groups are summarized in Table 7-62.

Table 7-62 Environmental Effects Summary Table for Pipeline Crude Oil Releases to Sandy River

Receptor	Expected Environmental Effects of Released Crude Oil to the Sandy River	Relative Effect	
		Light Crude Oil	Diluted Bitumen
Terrestrial Receptors			
Soils	It is assumed in the model that crude oil would enter directly into the Sandy River with no holdup of oil on land. 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 (Sandy River)	Both light and heavy oil would travel downstream from the release location, entering the Sandy River. Lighter crude oils are predicted to travel farther downstream than heavier crude oils in spring and summer-fall conditions, but would be thinner and less persistent on the water. Both light and heavy crude oils are predicted to travel similar travel distances under winter conditions, although the heavy oil would be more likely to remain trapped along the edges of the rivers and lakes. The Sandy River is small, with a low gradient. Therefore, turbulent conditions that could entrain low-viscosity oil into the water column as fine droplets are unlikely to occur.	MORE	LESS
Lakes (Steamboat, Davis and Flowage Lake)	Both light and heavy oil would travel downstream from the release location, enter, and spread over the surfaces of Steamboat and Davis lakes, with the light crude oil also entering Flowage Lake under high flow conditions. Heavier crude oils would result in lake plumes with a greater thickness than expected for lighter crude. The lakes are small, with low fetch. Therefore, breaking waves that could entrain low-viscosity oil into the water column as fine droplets are unlikely to occur. In low flow winter conditions, neither type of crude oil was predicted to reach a lake within the 24 hour model simulation.	MORE	LESS

Table 7-62 Environmental Effects Summary Table for Pipeline Crude Oil Releases to Sandy River

Receptor	Expected Environmental Effects of Released Crude Oil to the Sandy River	Relative Effect	
		Light Crude Oil	Diluted Bitumen
Sediment	Lighter crude oils are predicted to travel farther downstream than heavier crude oils in spring and summer conditions, with equal travel in winter months. The low mixing energy prevailing in the Sandy River system suggests that neither type of oil is likely to be entrained into the water column as fine droplets that could form OPAs. However, both oil types would interact with shoreline sediments, and the potential for oil to become absorbed into these sediments, or to sink in combination with adhering sand or silt particles, would remain. In this case, the light crude oil would be spatially more extensive, but also less persistent than the heavy crude oil. Under winter conditions, more of the heavy crude oil is predicted to become trapped along the margins of the rivers and lakes, and this oil is also likely to interact with sediment, resulting in mixing of oil and sediment. Neither the light nor the heavy 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.	LESS	MORE
Shoreline and Riparian Areas	Both light and heavy oil would travel downstream from the release location. Lighter crude oils are predicted to travel farther downstream than heavier crude oils in spring and summer-fall conditions, but would be thinner and less persistent on the water. Crude oil released under ice during the winter would not contact shoreline or riparian areas, although crude oil that was not recovered could be dispersed over a large area during the spring freshet. For heavy oil, stranding on shore would be the primary fate. For light oil, stranding would remain the primary fate, but considerably more of the released oil could be lost to evaporation. Flooding of riparian and wetland 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, in contrast to light crude oil which would be deposited as a thin layer or sheen. Receding waters in the lakes in late summer could lead to further stranding of oil as wetland habitat forms.	LESS	MORE
Aquatic Plants	The Sandy River and Steamboat, Davis and Flowage lakes support emergent, floating and submerged aquatic plants. Where they occur, floating aquatic plants would be expected to be killed if contacted by an oil slick. Lighter oils are predicted to spread more thinly and cover a larger are than heavier oils. Submerged aquatic plants would be less vulnerable. Emergent aquatic plants are generally quite tolerant of moderate exposure to floating oil (such that a portion of the stem was oiled). However, given the extent of predicted oiling in Sandy River and associated lakes in spring and summer seasons, loss of emergent plants from contact with crude oil is to be expected.	MORE	LESS

Table 7-62 Environmental Effects Summary Table for Pipeline Crude Oil Releases to Sandy River

Receptor	Expected Environmental Effects of Released Crude Oil to the Sandy River	Relative Effect: Light Crude Oil	Relative Effect: Diluted Bitumen
Benthic Invertebrates	Environmental effects on benthic invertebrates would be limited to areas affected by the released oil. Heavy crude oil would have greater potential than light crude oil for deposition of tar balls and patties as a result of oil interaction with sediment. These could accumulate in depositional areas, resulting in chronic effects on benthic invertebrates.	LESS	MORE
Fish	Environmental effects on fish would be limited to areas affected by the released oil. The slow-moving character of the Sandy River is not likely to promote dissolution of low molecular weight hydrocarbons into the water. However, potential for toxicity to fish due to narcosis would exist for both types of oil, due to the small size of the river. Potential chronic effects on fish eggs and embryos (e.g., blue sac disease) could also occur, but would be most likely to occur in spring, when most species spawn. The potential for phototoxicity, caused by an interaction of ultraviolet light with PAHs accumulated in fish tissues, would be greatest in summer due to high light intensity and long day length.	SAME	SAME
Semi-Aquatic Wildlife Receptors			
Amphibians and Reptiles	Environmental effects on amphibians and reptiles would be limited to areas affected by the released oil. Light crude oil is predicted to travel farther downstream under spring and summer conditions than heavy crude oil, affecting a larger area of habitat. Crude oil released under ice during the winter would not contact shoreline or riparian areas, although crude oil that was not recovered could be dispersed over a large area during the spring freshet. Flooding of riparian habitat in spring could lead to stranding of crude oils in this habitat. 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 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 unlikely.	MORE	LESS

Table 7-62 Environmental Effects Summary Table for Pipeline Crude Oil Releases to Sandy River

Receptor	Expected Environmental Effects of Released Crude Oil to the Sandy River	Relative Effect	
		Light Crude Oil	Diluted Bitumen
Birds	Mortality of oiled aquatic and semi-aquatic birds would be limited to areas affected by the released oil. Released light crude oil is generally transported farther than heavy crude oil, so environmental effects to birds could be more spatially extensive for light crude oil types as it enters lake habitat downstream of the hypothetical release location. Marshy areas along the Sandy River (especially McGregor and Grayling Wildlife WMAs), Steamboat, Davis and Flowage lakes provide the highest quality habitat for nesting birds. Cold water in the spring, in combination with greater downstream movement of released oil, suggests that environmental effects of released oil could be greatest for a light crude oil in spring, and of lesser magnitude for a heavy crude oil release. Few birds are present in winter, so effects would be minimal in that season.	MORE	LESS
Semi-aquatic Mammals	Mortality of oiled semi-aquatic mammals would be limited to areas affected by the released oil. Released light crude oil is generally transported farther than heavy crude oil, so environmental effects could be more spatially extensive for light crude oil types. Cold water in the spring, in combination with greater downstream movement of released oil, suggests that environmental effects of released oil could be greatest for a light crude oil in spring, and of lesser magnitude for a heavy crude oil release. In winter, adverse effects on mink and otter would be particularly severe, due to the effects of oil on the insulating properties of fur, in combination with cold water temperatures. However, muskrat and beaver might be spared due to their lower activity levels in winter.	MORE	LESS
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. Light crude oil is likely to be transported farther downstream within 24 hours than the heavy crude oil. As a result, environmental effects on air quality could be more spatially extensive for light crude oil types. 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.	MORE	LESS

Table 7-62 Environmental Effects Summary Table for Pipeline Crude Oil Releases to Sandy River

Receptor	Expected Environmental Effects of Released Crude Oil to the Sandy River	Relative Effect	
		Light Crude Oil	Diluted Bitumen
Human Receptors	Typical human health effects associated with short-term inhalation of VOC from crude oil releases include headache, dizziness, nausea, vomiting, cough, respiratory distress, and chest pain; fatality is unlikely. Residents in close proximity 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. Light crude oil (Bakken crude oil) is likely to be transported farther downstream within 24 hours than the heavy crude oil (Cold Lake diluted bitumen). However, very few people live between Davis and Flowage lakes, and therefore the effect of this additional downstream movement in human receptors would be minimal. 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
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. Light crude oil is predicted to be transported farther downstream than heavy crude oil following a release, affecting a larger area and potentially interrupting more public use of natural resources. No drinking water HCAs were identified along the path of the release. However, a number of homes are located along the trajectory of a predicted release and could rely on groundwater as a drinking water source. 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 the Sandy River would result in adverse health effects to consumers of drinking water. However, recreational activities would be disrupted following a release of crude oil along the predicted downstream migration route.	MORE	LESS

7.5 EXPECTED ENVIRONMENTAL EFFECTS OF LARGE RELEASES OF CRUDE OIL TO THE SHELL RIVER CROSSING AT TWIN LAKES, MN

The proposed pipeline route crosses the Shell River a number of times, and the hypothetical release location selected for modeling is located approximately 7.3 miles south of Park Rapids, Minnesota. This scenario captures a release of oil directly to a watercourse of medium width (70 to 120 ft) and moderately-flowing character that enters directly into the Twin Lakes. After flowing out of Lower Twin Lake, the Shell River meanders approximately 9.2 miles in a generally eastward direction before meeting the Crow Wing River, after which point the flow is generally to the south. There are 59 groundwater wells reported in the lower Shell River area, most of which are reportedly used for agricultural irrigation (MN PCA 2014). Irrigation circles are conspicuous around Park Rapids, to the east of Hubbard, and both south and east of the Twin Lakes. The presence of groundwater wells and residences with docks makes this site representative of inhabited areas that may be used recreationally, and for agriculture. In addition, this region is known to contain sensitive ecosystems. Therefore, the potential for crude oil from the release area into the Twin Lakes and subsequent transport farther down Shell River (and into Crow Wing River) was investigated. The Shell River is part of the Pine Moraines and Outwash Plains Subsection of the Northern Minnesota Drift and Lake Plains Section situated in the Laurentian Mixed Forest Province (MN DNR 2006).

7.5.1 Description of the Freshwater Environment

Upstream of the pipeline crossing location, the river channel is predominantly natural, with riparian marsh/fen/shrub swamp wetlands. Beginning approximately 2,070 ft upstream of the proposed pipeline crossing, the river enters a large wetland with bog elements. Within this area there is evidence of historical channel alteration (straightening), although below the proposed crossing the river channel appears to have reverted to a more natural channel. Approximately 3,000 ft south of the pipeline crossing, the wetland grades into Upper Twin Lake and has a conspicuous sandy outwash deposit. The open water area of Upper Twin Lake is about 4,150 ft long and 1,690 ft wide. The lake is surrounded by shrub swamp and fen, grading into marsh. Lower Twin Lake is slightly larger, being about 4,870 ft long and 1,830 ft wide, and having similar marginal wetlands. Both lakes have residential or cottage development around them but Lower Twin Lake is more intensively developed in this respect.

The Shell River is approximately 95 ft wide, approximately 1.5 ft deep, and passes through forested areas nestled between agricultural lands via a large marshy channel. The streambed is made up of loose sand and fine gravel. During the growing season much of the Shell River's streambed (33% to 40% coverage) supports macrophytes like cattails (MN PCA 2014). During the summer months, the Shell River can have low levels of dissolved oxygen, which is attributed to high water temperature and agricultural runoff (MN PCA 2014).

At the proposed crossing, the Shell River flows directly south where it reaches the Twin Lakes (Upper Twin Lake and Lower Twin Lake) about 0.6 miles downstream. The watercourse enters the northern end of Upper Twin Lake before draining into a small reach that feeds Lower Twin Lake. The Twin Lakes cover a total area of approximately 0.75 square miles and are bounded by a number of homes with lake access. Both Upper and Lower Twin Lake have a diverse mix of aquatic plants including emergent (e.g., wild rice), floating (e.g., duckweed, waterlily) and submerged (e.g., Canada waterweed, flatstem pondweed, northern watermilfoil, coontail, and muskgrass) communities (Perleberg 2005; MN PCA 2014). Both lakes also provide habitat for numerous fish, including northern pike, walleye (a stocked species), perch, bass, and white sucker (MN PCA 2014). In addition to the recreational fishery, the bait fish industry is also well represented in the area (MN DNR 2006). The Shell River flows out of the northeastern edge of Lower Twin Lake and continues east through Huntersville State Forest, and south of Duck Lake. Here the river is wider (up to approximately 225 ft) than at the predicted release location. East of Duck Lake (which is surrounded by homes) and within the boundaries of the Huntersville State Forest and the Crow Wing Chain WMA, the Shell River merges with the Crow Wing River and flows south (MN DNR 2016g). The Shell and Crow Wing rivers provide opportunities for canoeing and fishing, with access along the river through the Huntersville State Forest (MN DNR 2016h). The average velocity of the Shell River changes with season, with slowest velocities (e.g., about 0.56 mph) expected during low flow periods in the winter, and greater velocities (e.g., about 1.2 mph) during the spring high flow period. Flow in the Shell River often exceeds the flow of the Crow Wing River (MN DNR 2016g).

The Pine Moraines and Outwash Plains is known to be home to 89 SGCN; these include birds (61 species), fish (4 species), insects (12 species), mammals (5 species), mollusks (2 species), and reptiles (4 species) (MN DNR 2006). Of these, 29 are afforded federal or state endangered, threatened, or of special concern status (MN DNR 2006; MN DNR 2016d). It is foreseeable that some of these SGCN could utilize aquatic habitats along the Shell River, Twin Lakes, and Crow Wing River.

Several access points downstream from the proposed pipeline crossing location were visited in May, 2016, to provide additional insight into baseline environmental conditions for the Shell River. Representative site photographs are provided in Figure 7-25 through Figure 7-28. Field observations are summarized in Table 7-63.

Figure 7-25 Shell River and Riparian Habitat Between Upper and Lower Twin Lakes Approximately 2 Miles Downstream of Pipeline Crossing

Figure 7-26 Shell River and Riparian Habitat Between Upper and Lower Twin Lakes Approximately 2 Miles Downstream of Pipeline Crossing

Figure 7-27 Crow Wing River and Riparian Habitat Approximately 25 Miles Downstream of Pipeline Crossing

Figure 7-28 Crow Wing River and Riparian Habitat Approximately 47 Miles Downstream of Pipeline Crossing

Table 7-63 Environmental Characteristics Observed at Selected Access Points on the Shell River near Twin Lakes, MN, May 2016

Access Point	Latitude Longitude	Notes
South Twin Lake Water Access approximately two miles downstream of pipeline crossing	46.803341 -95.034157	Habitat Description: broad open water/floodplain area. Fringe of open water dominated by cattail marsh with floodplain meadow (dominated by nonnative reed canary grass) and shrub swamp fringe on the outside of emergent marsh. Black willow and green ash trees, as well as red osier dogwood are common on the floodplain fringe. Wildlife observed: yellow-headed blackbird, Baltimore oriole, osprey, red-wing blackbird, American robin, yellow throat
Mary Brown Water site access, #5 State Water Access approximately 25 miles downstream of pipeline crossing	46.7177 -94.9293	Habitat Description: broad, flat floodplain in this area with good quality emergent marsh and wet/sedge meadow dominant. Shrub swamp and terrace forest occur in lesser amounts. Water clarity is good with the submergent plant wild celery common. Wildlife observed: mallard, veery
Crow Wing River, Cottingham Co. Park, #11 State Water Access Site; approximately 47 miles downstream of pipeline crossing	46.5055 -94.8074	Habitat Description: river banks are somewhat steep and transition into forest with a blend of floodplain forest and terrace forest. Areas farther upslope include red maple, bur oak basswood, quaking aspen and others, with a diverse shrub and ground layer. Wildlife observed: eastern Kingbird, yellow warbler, fly catcher

7.5.2 High Consequence Area Assessment for the Shell River at Twin Lakes, MN

As defined in Section 7.0, HCAs include populated areas, drinking water source areas, ecologically sensitive areas, and commercially navigable waterways. Sensitive AOIs include Minnesota drinking water management areas, native plant communities, sensitive lake shores, recreational areas, tribal lands, and protected areas of several types (e.g., national forests, military lands, state parks).

The locations of the various HCA (none of which are commercially navigable) and AOI near the hypothetical release location and the predicted trajectory of the floating oil are illustrated in Figure 7-29. Table 7-64 and Table 7-65 provide brief descriptions of the HCA and AOI for the Shell River hypothetical crude oil release location.

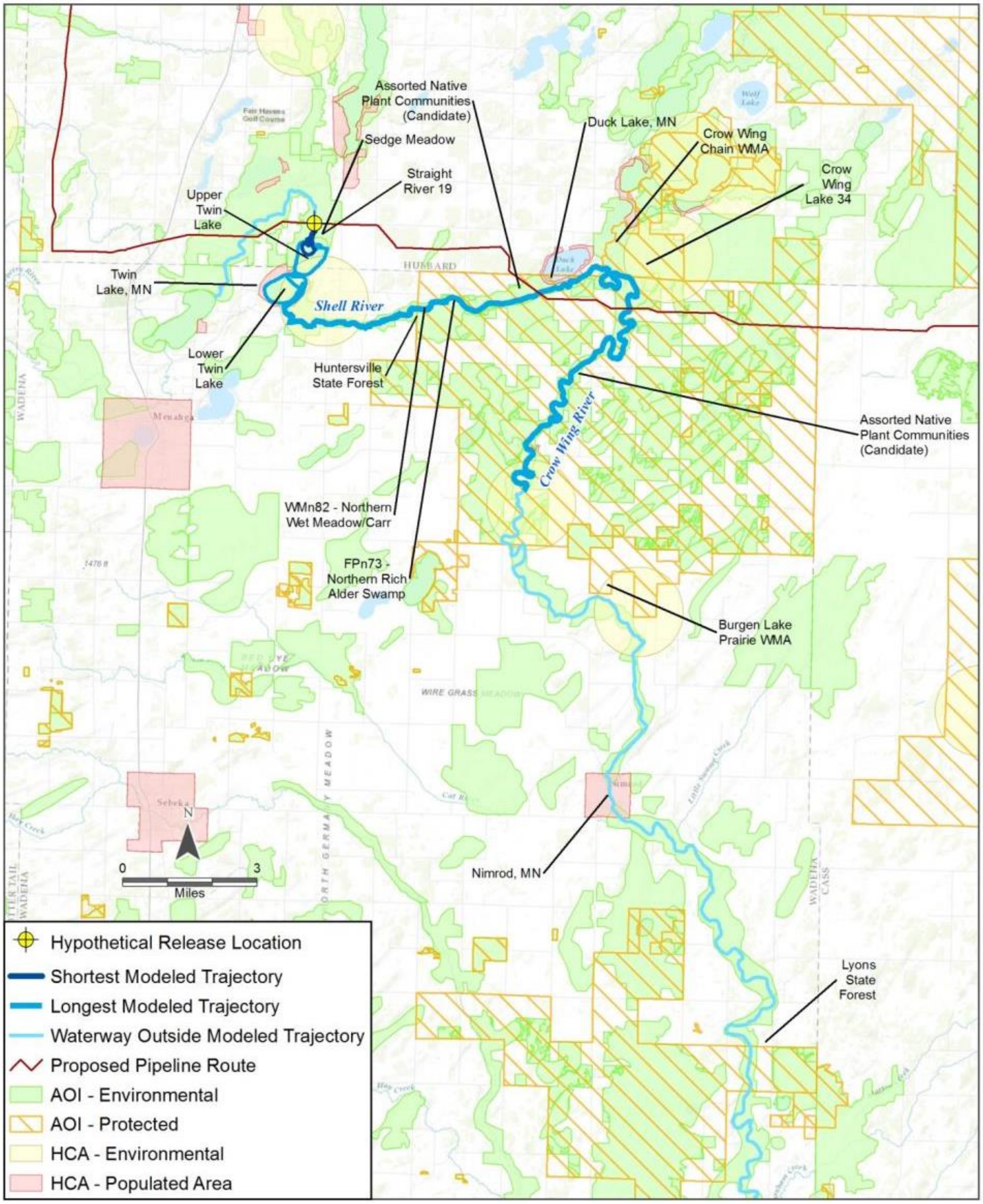


Figure 7-29 HCAs and AOIs Potentially Affected by a Crude Oil Release at the Shell River Crossing Location

Table 7-64 HCAs Potentially Affected by a Release of CLB and Bakken Crude Oil at the Shell River Crossing Location

HCA Type	HCA Subtype	Description / Locations
Environmentally Sensitive Area	N/A	N/A
Population Area	Other	Twin Lake, MN (i.e., Lower Twin Lake) Duck Lake, MN
NOTE: Data for the HCA analysis were obtained from the United States Department of Transportation: Pipeline and Hazardous Materials Safety Administration (USDOT PHMSA) HCA datasets plus additional HCAs compiled by Enbridge during 2010 and 2013.		

Table 7-65 AOIs Potentially Affected by a Release of CLB and Bakken Crude Oil at the Shell River Crossing Location

AOI Type	AOI Subtype	Description / Locations
Environmental	Lake of Biological Significance	Upper Twin Lake
	Wild Rice Lake	Lower Twin Lake Upper Twin Lake
	Native Plant Community (Candidate)	Sedge Meadow. Forests along Crow Wing River, Lowlands/forest along the Shell River, Northern Rich Alder Swamp, Northern Terrace Forest, Northern Wet Meadow/Carr, Upland aspen, wet meadow along river, Wet meadow along river; upland aspen/conifers
	Site of Biodiversity Significance	Crow Wing Lake 34, Straight River 19
Protected Area	State Forest	Huntersville State Forest
	Wildlife Management Area	Crow Wing Chain WMA
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 and the Minnesota Department of Transportation.		

7.5.3 Selection of Key Ecological and Human Environment Receptors for Shell River at Twin Lakes

Taking into account environmental characteristics of the Shell River at Twin Lakes, 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 7-66.

Table 7-66 Key Ecological and Human Environment Receptors for Shell River at Twin Lakes

Receptor	Relevance for Inclusion as an Environmental Receptor for the Shell River at Twin Lakes 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 the Shell River upstream of Upper Twin Lake with no holdup of oil on land. Any oil that contacted 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 the Shell River upstream of Upper Twin Lake 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 the Shell River upstream of Upper Twin Lake 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 (Shell River and Crow Wing River)	High. An assumption made in the fate modeling for this scenario is that released oil would enter directly into the Shell River with subsequent physical transport downriver of floating oil.	Y
Lakes (Upper and Lower Twin Lake)	High. An assumption made in the fate modeling for this scenario is that released oil would enter directly into the Shell River with subsequent physical transport into the Twin Lakes system.	Y
Sediment	High. An assumption made in the fate modeling for this scenario is that released oil would enter directly into the Shell River upstream of Upper Twin Lake with subsequent physical transport downriver. This allows potential 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 the Shell River upstream of Upper Twin Lake with subsequent physical transport downriver. This allows potential interaction with shoreline and riparian habitat.	Y
Wetlands	High. An assumption made in the fate modeling for this scenario is that released oil would enter directly into the Shell River upstream of Upper Twin Lake with subsequent physical transport downriver and potential interaction with wetlands along the river and lakes.	Y
Aquatic Plants	High. An assumption made in the fate modeling for this scenario is that released oil would enter directly into the Shell River upstream of Upper Twin Lake with subsequent physical transport downriver and potential interaction with plants. Aquatic plants are present in Shell River, the Twin Lakes and Crow Wing River as well as associated riparian and wetland habitats.	Y

Table 7-66 Key Ecological and Human Environment Receptors for Shell River at Twin Lakes

Receptor	Relevance for Inclusion as an Environmental Receptor for the Shell River at Twin Lakes Scenario	Selected (Y/N)
Benthic Invertebrates	High. The Shell River and Twin Lake system supports benthic invertebrate communities.	Y
Fish	High. The Shell River and Twin Lake system support fish communities.	Y
Semi-Aquatic Wildlife Receptors		
Amphibians and Reptiles	High. The Shell River and Twin Lake system supports aquatic and semi-aquatic amphibians and reptiles.	Y
Birds	High. The Shell River and Twin Lake system supports waterfowl and other semi-aquatic birds.	Y
Semi-aquatic Mammals	High. The Shell River and Twin Lake system supports semi-aquatic mammals.	Y
Human and Socio-Economic Receptors		
Air Quality	High. The community of Hubbard is located approximately 1.4 miles northeast of the hypothetical release location. The Twin Lakes and Duck Lake are ringed with homes and cottages, and are located along the downstream flow path for released crude oil. Effects on air quality have the potential to temporarily disrupt human use and occupancy patterns.	Y
Human Receptors	High. The Twin Lakes are bordered by homes and used for boating, fishing, and potentially harvesting of wild rice. The Shell and Crow Wing rivers are used recreationally (e.g., hunting, fishing, and canoeing). Effects on air quality or the presence of crude oil residues in aquatic and riparian habitat have the potential to temporarily affect human health.	Y
Public Use of Natural Resources	High. The Shell River, Twin Lakes and Crow River are bordered by homes and used for many recreational activities (e.g., hunting, fishing, boating, canoeing). Effects on air quality, water quality, or the presence of crude oil residues in rivers, lakes and riparian habitat could potentially disrupt public use of natural resources (e.g., drinking water supplies).	Y

7.5.4 Modeled Conditions at the Release Location

A description of key modeling assumptions for the environmental effects analysis for the Shell River at Twin Lakes is provided in this section. The OILMAP Land software was used by RPS ASA to simulate hypothetical releases of CLB and Bakken crude oils into the Shell River for a 24 hour period (Chapter 5). A longer time period was not modeled as it was assumed that emergency response measures to prevent further downstream transport of released oil would be in place within the 24 hour period. While OILMAP Land does provide an indication of the downstream extent of oiling and mass balance of oil within the modeled period, it does not quantify the amounts of oil components dissolved into the water column (Chapter 5.0). No overland transport of released CLB or Bakken crude oil was modelled for this hypothetical release location, as it was assumed that released oil would directly enter the watercourse (Chapter 3.0). This is a worst-case assumption for a release of crude oil near the watercourse.

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 (CLB/CLWB, heavy diluted bitumen crude oil types having higher viscosity and density). The environmental fate of most light, medium or heavy crude oil types that might be transported by the proposed pipeline would lie within the envelope represented by these simulations. Seasonal variations in river flow velocity, temperature, wind speed, and snow and ice cover were all considered at the release location. A summary of key variables is provided in Table 7-67.

In the event of an actual release, the downstream extents of CLB and Bakken crude oil may be more similar, and the effects of CLB may extend farther downstream than predicted, with patchy coverage.

Table 7-67 Environmental and Hydrodynamic Conditions for the Three Modeled Periods at the Shell River Crossing

Season	Month	Air Temperature (°C)	Wind Speed (m/s)	Average River Velocity (m/s)
Low Flow (Winter)	March	-4.65	4.58	0.25
Average Flow (Summer/Fall)	August	18.61	3.52	0.35
High Flow (Spring)	April	4.04	5.05	0.54
NOTE: A velocity of 1 m/s is equivalent to 2.25 miles per hour.				

The highest average flow velocity of the Shell River coincides with the spring freshet (i.e., April-June), a result of rising temperatures and snowmelt. Average flow would typically occur in summer and fall seasons. August, the month with the warmest temperature was selected to represent the maximum amount of evaporation. The lowest flow velocity occurs in winter (i.e., January–March), and was typified by freezing conditions and probable ice cover on water.

The crude oil release volume was calculated as a full bore rupture, with a maximum time to response in the pipeline Control Center of 10 minutes, followed by a 3-minute period to allow for valve closure. Therefore, the release volume represents the volume of oil actively discharged in the period of time required to detect and respond to the event (taking into consideration the pipeline diameter, pipeline shutdown time, pipeline design flow velocity), followed by the volume of oil lost due to drain-down of the elevated segments of pipeline. The maximum 13-minute response time to valve closure is an Enbridge standard for safe operations and leak detection. This includes the combination of identification of the rupture, analysis of the pipeline condition, pipeline shutdown and full valve closure in the affected pipeline section. While

13 minutes is the maximum time for valve closure, this is a conservative assumption, since a response through to valve closure is expected to occur in less than 13 minutes in a full bore rupture leak scenario. Based on these assumptions, the site-specific hypothetical release volume was estimated [NONPUBLIC DATA HAS BEEN EXCISED] of Bakken, CLB or CLWB crude oil.

7.5.5 Summary of Predicted Downstream Transport of Bakken and Cold Lake Crude Oils

A summary of the predicted downstream trajectories and mass balance for Cold Lake and Bakken crude oils, under the three seasonal scenarios, is provided in Figure 7-30 and Figure 7-31, respectively. These simulations are assumed to provide bounding conditions for a release of heavy or light crude oil types. The fate of most types of crude oil, if released, would lie within the envelope of predictions for the Cold Lake and Bakken crude oil types. The Cold Lake crude oil was assumed to be CLB for the high flow and average flow scenarios, and to be CLWB for the low flow (winter) scenario. As noted in Chapter 5.0, while OILMAP Land does provide an indication of the downstream extent of oiling and mass balance of oil within the modeled period, it does not quantify the amounts of oil components dissolved into the water column.

The maximum simulation duration using OILMAP Land was 24 hours, as it was assumed that emergency response measures to prevent or reduce further downstream transport of released oil would be in place within that length of time. Symbols on the drawings indicate the predicted trajectory during river seasonal flow condition (high corresponding to spring freshet, average corresponding to summer-fall conditions, and low corresponding to winter flow under ice). 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. Numbers other than these (e.g., 5.5) indicate the time in hours of the predicted termination of downstream transport of the released oil due to adhesion or holdup of the oil along the river banks. Tables inserted within the Figures also provide information on the mass balance (i.e., oil remaining on the surface of the river, adhering to river banks, or evaporated to the atmosphere) of the released oil at relevant points in time after the start of the release.

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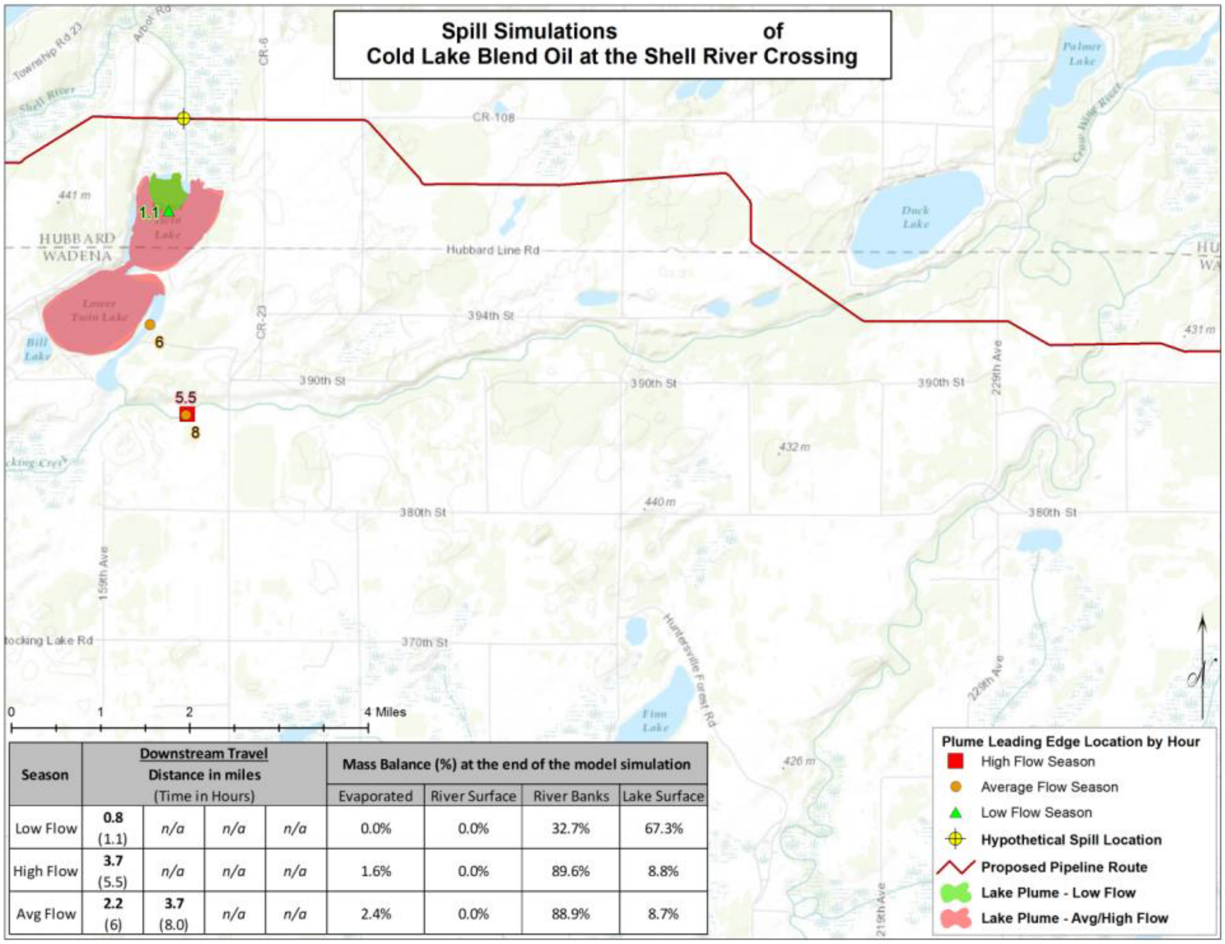

Season	Downstream Travel Distance in miles (Time in Hours)				Mass Balance (%) at the end of the model simulation			
					Evaporated	River Surface	River Banks	Lake Surface
Low Flow	0.8 (1.1)	n/a	n/a	n/a	0.0%	0.0%	32.7%	67.3%
High Flow	3.7 (5.5)	n/a	n/a	n/a	1.6%	0.0%	89.6%	8.8%
Avg Flow	2.2 (6)	3.7 (8.0)	n/a	n/a	2.4%	0.0%	88.9%	8.7%

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Figure 7-30 Predicted Downstream Transport of CLB Oil at the Shell River Crossing Location

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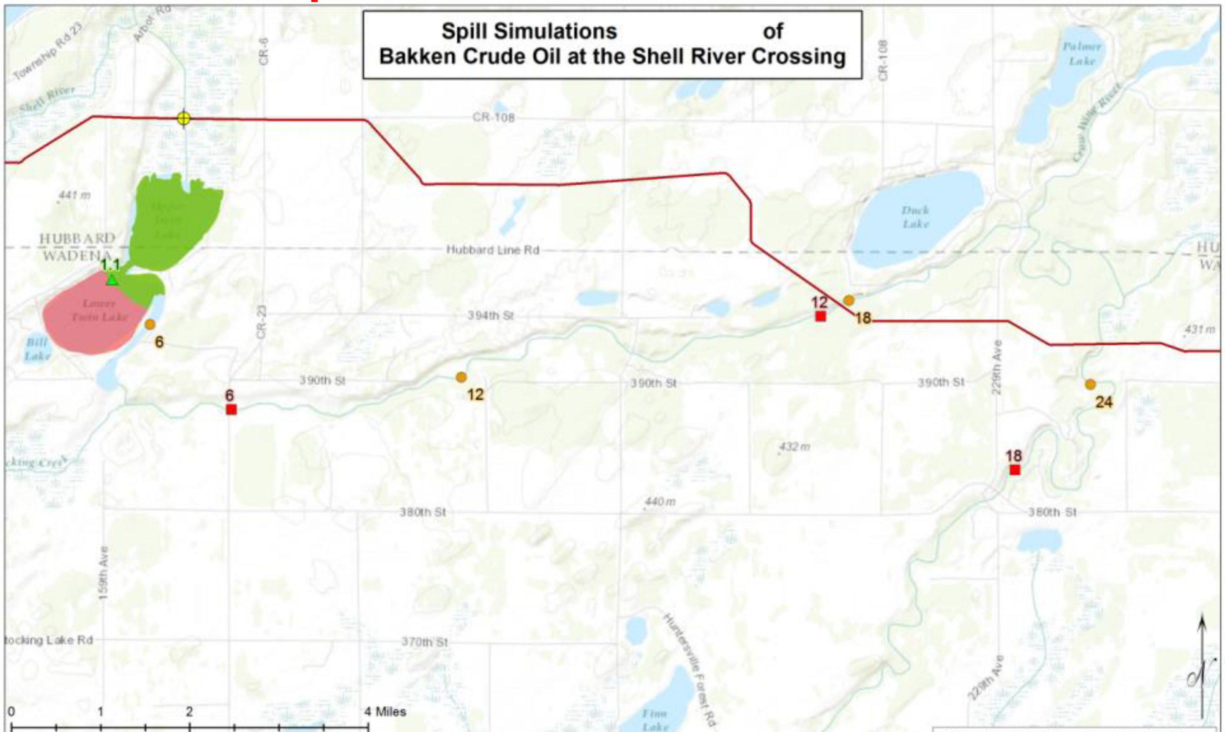

Season	Downstream Travel Distance in miles (Time in Hours)				Mass Balance (%) at the end of the model simulation			
					Evaporated	River Surface	River Banks	Lake Surface
Low Flow	**1.5** (1.1)	*n/a*	*n/a*	*n/a*	0.0%	0.0%	30.9%	69.1%
High Flow	**4.1** (6)	**9.0** (12)	**16.3** (18)	**21.9** (24)	39.4%	14.1%	46.5%	<0.1%
Avg Flow	**2.2** (6)	**5.9** (12)	**9.2** (18)	**13.9** (24)	42.9%	22.4%	34.7%	<0.1%

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Figure 7-31 Predicted Downstream Transport of Bakken Crude Oil at the Shell River Crossing Location

7.5.5.1 Shell River at Twin Lakes Release During High Flow (Spring) Period

Under the high flow scenario, CLB was predicted to travel approximately 3.7 miles downstream within 5.5 hours of the release (Figure 7-23). Under this scenario, CLB was predicted to be transported down the Shell River to the Twin Lakes, and then spread, covering the surfaces of both Upper and Lower Twin Lakes, a total of 0.75 square miles to a thickness of 0.004 inches. In addition, the release is predicted to continue another 1.8 miles down the Shell River below Lower Twin Lake. Approximately 89.6% of the CLB was predicted to oil shorelines, 8.8% to spread over the surface of Upper and Lower Twin Lakes, and 1.6% to have evaporated into the atmosphere.

Bakken crude oil was predicted to be transported approximately 21.9 miles downstream, over the 24-hour modeled period. The Bakken crude oil was predicted to be transported down the

Shell River, and then spread, covering the surfaces of both Upper and Lower Twin Lakes to a thickness of 0.00004 inches. The released oil was then predicted to continue another 20 miles down the Shell River and enter the Crow Wing River. Approximately 46.5% of the Bakken crude oil was predicted to oil shorelines, less than 0.1% to have spread over the surface of Upper and Lower Twin Lakes, 39.4% to have evaporated into the atmosphere, and 14.1% to remain on the river surface at the end of the 24 hour simulation. If left unmitigated, the remaining Bakken crude oil on the river surface would continue downstream, weathering and oiling shorelines until all the oil was removed from the water surface.

The release of Bakken crude oil under high flow conditions was predicted to result in oiling farther downstream than the CLB. The difference in the extent of downstream transport was primarily the result of differences in the shoreline and lake surface oil retention, and evaporation, between the two oil types. Both oil types were predicted to cover the surface of the Twin Lakes with a crude oil slick, but the Bakken would result in a thinner slick. The Bakken crude oil would also be deposited onto shoreline and riparian areas as a thinner layer of oil than the more viscous CLB crude oil. This result is based upon the assumption of 100% shoreline oiling coverage (i.e., all shoreline up to that point was oiled to its maximum holding capacity for that oil type) as oil made its way downstream, and the assumption that oil would spread evenly within lake.

A larger proportion of the Bakken crude oil was predicted to evaporate to the atmosphere than was predicted for the CLB. This was due in part to the lighter and more volatile character of the Bakken crude oil. In addition, the greater downstream transport of the Bakken crude oil took more time, and resulted in more water surface area with oil, both of which could allow more of the released oil to evaporate. Volatile components of the CLB would continue to evaporate after becoming stranded on shoreline, but this process was not included within the OILMAP Land model for stranded oil.

7.5.5.2 Shell River at Twin Lakes Release During Average Flow (Summer-Fall) Period

Under average river flow conditions, the CLB crude oil was predicted to travel approximately 3.7 miles downstream within 8 hours of release (Figure 7-30). The CLB crude oil was predicted to be transported down the Shell River and then spread over the surfaces of both Upper and Lower Twin Lakes, a total area of 0.75 square miles to a thickness of 0.004 inches. From here the released oil is predicted to continue another 1.8 miles down the Shell River. Approximately 88.9% of the CLB crude oil was predicted to adhere to shorelines of Shell River, 8.7% to have spread over the surface of Upper and Lower Twin Lake, and 2.4% to have evaporated into the atmosphere.

Relative to the high flow condition, slightly more of the CLB crude oil was predicted to evaporate. This was mainly due to the longer time required for the CLB crude oil to move downstream due to the lower stream velocities. As a result, modeling predicted that slightly less oil might remain on the river shoreline and lake surface under the average river flow condition, as compared to the high flow condition.

Under the average flow condition, Bakken crude oil was predicted to be transported approximately 13.9 miles downstream, over the 24-hour modeled period (Figure 7-24). The Bakken crude was predicted to be transported down the Shell River and then to spread over the surfaces of both Upper and Lower Twin Lakes to a thickness of 0.00004 inches. The released oil was then predicted to continue another 12.0 miles down the Shell and Crow Wing rivers. Approximately 34.7% of the Bakken crude oil was predicted to adhere to shorelines, less than 0.1% to spread over the surface of Upper and Lower Twin Lakes, 42.9% to evaporate to the atmosphere, and 22.4% to remain on the river surface at the end of the 24 hour simulation. It was assumed that emergency response measures to prevent further possible downstream transport of surface oil would be in place within 24 hours of the release.

When compared to the CLB crude oil under average river flow conditions, Bakken crude oil was predicted to be transported farther downstream within 24 hours. It was also predicted that 22.4% of the Bakken crude oil could remain on the river surface at the end of the simulation. The Bakken crude oil was predicted to travel farther downstream than the more viscous and adhesive CLB. Although not modeled here, it is expected that a medium crude oil would exhibit fate and transport properties intermediate between those of the Bakken and CLB crude oil types, with a tendency to behave more like the Bakken crude oil. This is because the viscosity and adhesiveness properties of a medium crude oil would typically be higher and, therefore, more similar to those of the Bakken crude oil, than to the CLB.

7.5.5.3 Shell River at Twin Lakes Release During Low Flow (Winter) Period

Under low flow winter conditions, it was assumed that Shell River and Twin Lakes would be completely frozen over. It was also assumed that CLWB would be released directly into the river from the pipeline under the river bottom, and remained trapped under the ice. The ice cover would limit evaporation of crude oil vapors to the atmosphere.

Under low river flow conditions, CLWB was predicted to be transported a total of 0.8 miles downstream, within 1.1 hours of the release. The CLWB crude oil was predicted to be transported down the Shell River for 0.6 miles, and then spread under the ice of Upper Twin Lake to a thickness of 0.42 inches. The oil was predicted to spread under the ice covering an area of 0.054 square miles of Upper Twin Lake. Approximately 32.7% of the CLWB crude oil was predicted to oil shorelines of Shell River, with the remaining 67.3% spreading under the ice within the lake.

Bakken crude oil was predicted to be transported a total of 1.5 miles downstream within 1.1 hours of the release. The Bakken crude oil was predicted to be transported down the Shell River, and then spread under the ice of Upper Twin Lake to a thickness of 0.075 in. The oil was predicted to spread under the ice covering an area of 0.42 square miles including all of Upper Twin Lake and a portion of Lower Twin Lake. Approximately 30.9% of the CLWB was predicted to oil the shorelines of Shell River, and the remaining 69.1% to spread under the ice within the lake. This would provide only temporary storage of the oil, and oil would be predicted to re-mobilize in response to changes in flow velocity, and particularly during the spring breakup of ice. With the

CLWB below the ice of the river, evaporation of oil to the atmosphere would be negligible in the short-term.

When compared to the CLWB crude oil under low river flow conditions, less of the Bakken crude oil was predicted to accumulate at the river margins under the ice. This was due to the differences in shoreline oil retention between the two oils (i.e., lower viscosity and adhesion of the Bakken crude oil). For this reason the Bakken crude oil was also predicted to have greater mobility under the ice in winter.

7.5.6 Qualitative EHHRA for the Shell River at Twin Lakes

In this section the likely environmental effects of a crude oil release at the pipeline crossing location on the Shell River are described. A worst case crude oil release from a main-line pipeline, such as described here, would be an unlikely event (Chapter 4.0). 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). Therefore, the following discussion describes the likely environmental effects of a crude oil release on relevant ecological and human environment receptors (identified in Section 7.4.3), using the predicted geographic extent of effects of released Bakken or CLB crude oil types over the 24 hour simulations as bounding conditions. Effects of season (including temperature, river flow conditions, and receptor presence/absence and sensitivity) were also considered in the analysis, as appropriate. The rationale supporting the effects analysis, based on case studies describing the effects of crude oil releases on the various ecological and human environment receptors, was provided in Section 7.1 and Table 7-66.

7.5.6.1 Terrestrial Receptors

For this modeling scenario, the hypothetical release of crude oil is assumed to enter the Shell River with no overland flow. Therefore, environmental effects on soils, terrestrial vegetation and groundwater quality, if any, are assumed to be localized, limited in spatial extent, and readily remediated using conventional clean-up techniques. The environmental effects of a crude oil release on land cover receptors is not considered further for the Shell River at Twin Lakes scenario.

7.5.6.2 Aquatic Receptors

The aquatic environmental and ecological receptors that are most closely associated with the Shell River at Twin Lakes scenario, namely the Shell River, Upper and Lower Twin lakes, and the Crow Wing River, are addressed in this section. These receptors include water and sediment quality in rivers and lakes, shoreline and riparian habitat, wetlands, aquatic plants, benthic invertebrates, and fish.

Crude oil released into the Shell River during the spring (high flow) or summer-fall (average flow) seasons is predicted to travel downstream, interacting with vegetation and seasonal shoreline areas upstream of the Twin Lakes. Regardless of crude oil type, the OILMAP Land simulations indicate that crude oil would enter and spread to covers the surface of both Upper and Lower Twin lakes. Heavier crude oils would result in thicker oil slicks on the lakes than lighter crude oils. The OILMAP Land simulations (based on a 24 hour model run) indicate that the heavy crude oil could be carried approximately 1.75 miles downstream from the outlet of Lower Twin Lake (Figure 7-4-6). Much greater transport distances are possible for the light crude oil (Figure 7-24). For heavy oil, stranding on shore would be the primary fate, with only small amounts of evaporative weathering of the oil occurring within the first 24 hour period. For light oil, stranding would remain the primary fate, but considerably more of the released oil would be lost to evaporation, and the residual oil would have greater potential mobility of not contained by emergency response measures.

The effects of a crude oil release 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. The large volume of water flow associated with the spring freshet may dilute and limit the maximum dissolved hydrocarbon concentration in the Shell River, as compared to periods of lower water flow in summer or winter. Under spring and summer-fall conditions, the spreading of the released oil onto the surface of the Twin Lakes would also provide a large surface area, which would promote the rapid evaporation of volatile (and potentially water soluble) hydrocarbon constituents from the crude oil. It is likely that this would limit effects to fish within the Twin Lakes. As a result, narcotic effects on fish and benthic invertebrates are likely to occur in the Shell River upstream of the Twin Lakes during the spring and summer-fall season, but unlikely to occur in the Twin Lakes as a result of dilution, generally low water turbulence, and rapid evaporation of volatile hydrocarbons from the lake surfaces. As a result, the potential for acute toxicity to fish and benthic invertebrates could be greater for the light oil than for heavier oils.

There would also be high potential for chronic effects of released crude oil on fish eggs and embryos (i.e., induction of deformities or mortality collectively termed blue sac disease). Many of the fish species present in the Shell River and Twin Lakes, including northern pike (for which spawning habitat is abundant in Lower Twin Lake; MN PCA 2014), spawn in the spring and early summer. The eggs and embryos of these species could be exposed to total PAH concentrations in the river and lake water that could be sufficiently high to induce deformities or cause mortality. In addition 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. Small fish that are lightly pigmented or transparent (i.e., embryos, larval and juvenile fish) are most susceptible to phototoxicity. The risk of phototoxicity would be partially mitigated by high concentrations of dissolved organic carbon present in the water of the Shell River and Twin Lakes, which would strongly absorb and limit the penetration of UV light into the water column.

Entrainment of small crude oil droplets in the water column during the spring freshet also enhances the potential for light crude oils to interact with suspended sediment particles in the water column resulting in the formation of OPAs. Such aggregates may subsequently be preferentially deposited in areas of still or slowly moving water such as sediments near the inflows to Upper and Lower Twin lakes, as well as slowly moving areas and backwaters within the Shell River and Crow Wing River system. Formation of true oil-particle aggregates is less likely to occur with heavy crude oils such as diluted bitumen, as the higher viscosity of the oil precludes the ready formation of fine droplets in the water column (Zhou et al. 2015). However, heavy oils can still contact sediment particles along the shoreline, and some accumulation of both light and heavy oils in depositional areas 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. During the spring, while heavy crude oil is not predicted on the water surface beyond 3.7 miles downstream of the release within the first 24 hours of the predicted release, it is possible that oil accumulated in depositional areas could mobilize over time and move farther downstream in the Shell River.

The Shell River and Upper and Lower Twin lakes support a wide range of emergent, floating and submerged aquatic plants (Perleberg 2005). Where they occur, floating aquatic plants would be expected to be killed if contacted by an oil slick. 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 most sensitive groups of aquatic biota to such exposure. Emergent aquatic plants are generally quite tolerant of moderate exposure to floating oil (such that a portion of the stem could be oiled). Wild rice is an emergent aquatic plant of biological and cultural importance in Minnesota and is abundant within the Twin Lakes. Perleberg reported in 2005 that wild rice was the most common emergent plant species in the Twin Lakes, being more abundant in Lower Twin Lake than Upper Twin Lake, and found from the shoreline to water depths of between 6 and 9 ft. Wild rice provides a food source and nesting cover for many birds, and is also harvested as a food source by people in the area. 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. However, flooded riparian areas and wetland habitats would also be exposed to the released oil, and if not properly remediated, crude oil residues could kill 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. In the early summer, oiling of emerging wild rice plants could lead to growth inhibition or death. Later in the summer, oiling at water level of the stems of emerged plants is unlikely to affect the plants. A release of crude oil in winter would have little direct effect on aquatic plants, as they would be in a dormant state.

Crude oil released during the winter (low flow) period could potentially pool on the frozen river surface. If the release was to occur directly to the river below the ice (as is assumed in the OILMAP Land model), or if there were openings in the ice that the released oil could penetrate, the oil could travel downstream under the ice, accumulating in the narrow gap between the ice and the river sediment, or accumulating in hollows under the ice as it moved. Results provided in Section 7.4.5.3 provide bounding cases for the products likely to be carried in the pipeline. The OILMAP Land simulations indicate that light and heavy crude oil would be transported downstream from the release location, entering and spreading under the ice of the Twin Lakes over the 24 hour model run. Heavy crude oil was predicted to spread under 0.054 square miles of ice in Upper Twin Lake, to a thickness of 0.42 in. Light crude was predicted to spread under the ice of all of Upper Twin Lake and a portion of Lower Twin Lake, covering an area of 0.42 square miles to an average thickness of 0.075 in. For both oil types, the winter ice would effectively inhibit evaporation. This would provide greater potential for dissolution of relatively water soluble crude oil constituents into the water column during the period of lowest dilution flow. Also, both oil types would be predominantly trapped under the ice, remaining mobile at the interface between the lake water and the underside of the ice. Therefore, a release in winter could cause mortality to fish, due to narcosis. This result would be more likely for the light crude oil, which would spread out over a larger area, facilitating release of more water soluble constituents. The heavy crude oil would tend to remain in thicker localized accumulations, and rapid release of more water soluble constituents from a thick layer of crude oil is unlikely. Fish eggs and larvae would generally not be present during the winter, so effects on these life stages due to blue sac disease are not likely, although crude oil residues in water and sediment could, if not adequately remediated, affect fish eggs and larvae in the following spawning season. Phototoxicity is not likely to occur following a release of crude oil in winter due to short day length and lower light intensity in winter, reflection and absorbance of light by snow and ice cover on the lake, and absorbance of UV light by DOC in the water beneath the ice.

Both crude oil types could be accumulated in sediment after a release in winter, and both crude oil types would be subject to re-mobilization with spring breakup of the ice, and increasing water flow rates.

7.5.6.3 Semi-Aquatic Wildlife Receptors

Habitat of the Shell River and Upper and Lower Twin Lake area 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 amphibians and reptiles, birds and mammals are provided below.

7.5.6.3.1 Amphibians and Reptiles

Crude oil released to the Shell River during the spring (high flow) and summer-fall (average flow) periods is predicted to travel downstream, interacting with vegetation and seasonal shoreline areas as it then enters and covers the surfaces of both Upper and Lower Twin Lakes. Heavier crude oils could result in lake plumes with a greater thickness than predicted for lighter crude oils (i.e., 0.004 in. vs 0.00004 in.). The OILMAP Land simulations indicate that crude oil could be carried between 3.7 and 21.9 miles downstream from the point of release, with the extent of downstream transport being in large measure a function of seasonal water flow rate as well as oil viscosity, adhesiveness, and its interactions with shoreline or riparian habitat.

Within the oil-exposed habitats along the lakes and rivers that support amphibians (adults, juveniles, and eggs), oiling effects including mortality would be observed. 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 less likely. Reptiles like lizards and snakes are primarily terrestrial species and have little or no association with aquatic environments. As a result, exposure of these animals to released crude oils would be limited, albeit likely greater during possible flooding of riparian areas. After the Kalamazoo River oil release in 2010 snakes did not appear to be highly exposed to released oil. A release of light crude oil during the spring would likely have a greater effect than in summer due to the greater predicted downstream transport distance and interaction with more riparian and wetland habitats than later in the year, with the river at lower flow stages.

Amphibians and reptiles undergo a winter dormancy period when temperatures drop below approximately 41 to 45°F. At this time, amphibians and turtles typically bury themselves in river bottom substrates or other similar habitats. Therefore, during the winter (and likely up until April or May when winter ice is gone), these organisms would have very little exposure to released oil moving on the water surface or within the water column.

7.5.6.3.2 Birds

Aquatic and semi-aquatic birds are those that use rivers, lakes, wetlands, and riparian areas as components of their habitats, 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.

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 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 are likely to die as a result of hypothermia. Waterfowl and other semi-aquatic birds present in the affected river and lake reach would be most affected. Animals upstream, farther downstream, or occupying other nearby habitats, would likely be unaffected as it is assumed that emergency response measures to prevent further possible downstream transport of oil would be in place within 24 hours of the release.

In addition to the habitat offered by the Shell and Crow Wing rivers and their riparian habitats, which include extensive wetlands, the Twin Lakes represent ideal habitat for a variety of aquatic and semi-aquatic bird species, including both breeding and migratory individuals. Therefore, potential for mortality of a large number (i.e., several hundred) of aquatic and semi-aquatic birds would exist, depending upon the precise circumstances and timing of an accidental crude oil release. However, owing to the tremendous regional habitat resources for these birds, large-scale population-level effects are unlikely.

The environmental effects of a crude oil release in the summer-fall period are likely to be of similar or lesser magnitude. With rising water temperatures, mortality of lightly oiled adult birds due to hypothermia becomes less likely than in the spring, and the temporary presence of large numbers of migrating individuals is unlikely. 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, although a smaller overall length of river habitat would be affected due to lower river flows. It is assumed that the Twin Lakes would both be covered by a crude oil slick, and migrating birds that became oiled would be likely to die as a result of hypothermia.

In the winter months, ice cover on the Shell River, Twin Lakes, and Crow Wing River would strongly limit the opportunities for aquatic and semi-aquatic birds to occupy this habitat. As such, exposure of birds to released crude oil in winter would be very limited.

7.5.6.3.3 Semi-aquatic Mammals

While the semi-aquatic mammal species found in Minnesota include terrestrial species such as moose and raccoon, this assessment focuses particularly upon 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 terrestrial mammals. The area of the Shell and Crow Wing rivers assessed here, which includes the Twin Lakes and extensive riparian wetland areas, provides high-quality habitat for these animals.

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 the Shell River where effects may occur, and the magnitude of effects, is related to the season and river flow rate, and 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 (high flow) season, with cold water temperatures prevailing, semi-aquatic mammals contacted by crude oil are likely to die as a result of hypothermia. Based on the OILMAP Land simulations, the potentially affected river reach could range from 3.7 to 21.9 miles in extent, and could include the Twin Lakes. Animals upstream, farther downstream where there is no exposure, or occupying other nearby habitats, would likely be unaffected. Therefore, although mortality of a considerable number of semi-aquatic mammals could be expected, large-scale (i.e., regional) population level effects are unlikely. Environmental effects of a crude oil release in the summer-fall period are likely to be of similar or lesser magnitude than those associated with a release during spring. With rising water temperatures, mortality of lightly oiled semi-aquatic mammals due to hypothermia is expected to be 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 possible as a result of ingesting crude oil residues while grooming, or while consuming food items. However, as in the spring, effects are expected to be limited to areas of oil exposure.

In the winter months, muskrat and beaver are likely to reduce their activity levels, although American mink and river otter would remain active. As such, exposure of semi-aquatic mammals like muskrat and beaver in winter would be lower than expected for mammals like mink and otter. Animals that became oiled in the winter would be likely to rapidly die as a result of hypothermia.

7.5.6.4 Human and Socio-Economic Receptors

Crude oils are complex mixtures of hydrocarbon compounds. Light crude oils typically contain more 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) primarily within the first 24 hours of an oil release.

The communities of Twin Lake and Duck Lake, Minnesota were identified through the HCA analysis as population areas. The OILMAP Land modeling indicated that the leading edge of released heavy oil would pass through Twin Lake, but that downstream transport would be limited to a short reach of the Shell River below Lower Twin Lake. In contrast the leading edge of released light oil is predicted to pass through Twin Lake, and to pass by Duck Lake, under spring and summer-fall flow conditions. In winter, both types are predicted to remain under ice in the Twin Lakes. Lower Twin Lake has a greater number of structures than Upper Twin Lake, with the majority located on the northwestern and southwestern banks. Duck Lake, which is north of the Shell River and not expected to receive release crude oil, is surrounded by homes and cottages. In addition a number of structures are located along the banks of the Shell River and Crow Wing River, and in the unincorporated community of Huntersville along the Crow Wing.

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. The case studies (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.

The potential for VOC inhalation exposures by the public would be greatest near and downwind from the release site and near to the Shell River and Twin Lakes, while the released oil is on the water surface. In the unlikely event of a crude oil release, residents in close proximity 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.

No drinking water HCAs were identified along the path of the release. However, a number of homes are located along the trajectories of predicted releases and could rely on groundwater as a drinking water source. There are 59 groundwater wells reported in the lower Shell River (downstream of Lower Twin Lake), most of which are used for agricultural irrigation (MN PCA 2014). 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. 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.

Effects of a crude oil release on human receptors would be generally similar for the spring (high flow) and summer-fall (average flow) seasons. In summer, the warmer temperatures and slower river flow velocities in the summer would promote more rapid evaporation of volatile hydrocarbons in a smaller area. The flow modeling suggests that the light crude oil (i.e., Bakken crude oil) is likely to be transported farther downstream within 24 hours than the heavy crude oil (Cold Lake diluted bitumen). However, for either crude oil type, the Twin Lakes represent an area where released crude oil would be expected to spread, and to affect a local population of individuals, before moving downstream as more weathered oil. As a result, a release of the light crude oil could affect a larger number of individuals than a release of the heavy crude oil type, but the difference between the crude oil types is not likely to be large for this hypothetical release example. The individuals most likely to be exposed would be located in the vicinity of the Twin Lakes. Both Bakken crude oil and Cold Lake diluted bitumen are expected to contain similar overall amounts of volatile hydrocarbons, so differences related to the chemical characteristics of the released oil are also likely to be minor.

No overland transport of released crude oil was modelled for this hypothetical release location. Infiltration of crude oil into soil and subsequently into groundwater would be limited. During the spring freshet period, the Shell River is susceptible to flooding and can overtop its banks and spread into the surrounding farmland. A release of light and medium crude oils during this period would provide a potential pathway for oil deposition to soil in low-lying areas. Light and medium crude oils would be expected to become dispersed over a large area, and are readily biodegraded, so that persistent accumulation of these oil types in riparian areas or temporarily flooded farmland is unlikely. Heavy crude oils and diluted bitumen are more likely to be deposited as thicker layers of more persistent oil, and could likely require more active remediation of affected areas.

The Shell River, Twin Lakes, and Crow Wing River provide recreational opportunities (e.g., fishing, hunting, boating, swimming, camping) at many locations downstream of the hypothetical release location. 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 migration route. 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 for contact with constituents in the oil. Under winter conditions the released crude oil is expected to remain in the Twin Lakes.

7.5.6.5 Summary and Conclusions

Expected environmental effects to key ecological and human environment receptors after a hypothetical large crude oil release to the Shell River at Twin Lakes area have been assessed. The proposed pipeline could 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 considers these crude oil types as bounding conditions.

Ecosystem components, terrestrial receptors, aquatic receptors, semi-aquatic wildlife receptors, and human and socio-economic receptors were screened to identify those most likely to have interaction with released oil. Selected receptors for qualitative assessment are highlighted in Table 7-66, discussed in detail in Sections 7.5.6.1 to 7.5.6.4, and likely environmental effects are summarized in Table 7-68.

Table 7-68 Environmental Effects Summary Table for Pipeline Crude Oil Releases to Shell River

Receptor	Expected Environmental Effects of Released Crude Oil to the Shell River	Relative Effect	
		Light Crude Oil	Diluted Bitumen
Terrestrial Receptors			
Soils	It is assumed in the model that crude oil would enter directly into the Shell River with no holdup of oil on land. 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 (Shell River, Crow Wing River)	Both light and heavy oil would travel downstream from the release location, affecting the Shell River, and in some cases also extending to the Crow Wing River. Lighter crude oils are expected to travel farther downstream than heavier crude oils in spring and summer conditions, but would be thinner on the water, and less persistent where they contact shoreline habitat. Both light and heavy crude oils are predicted to travel similar travel distances under winter conditions, although more of the heavy oil would be likely to remain trapped along the edges of the rivers. Light oils have low viscosity relative to heavier oils and turbulence in the river water could potentially disperse the light oil as small droplets in the water column, meaning that potentially toxic fractions of the light oils would more readily dissolve into the water column.	MORE	LESS
Lakes (Upper and Lower Twin Lake)	Both light and heavy oil would travel downstream from the release location, enter, and spread over the surface of the Twin Lakes. Heavier crude oils would result in surface oil slicks that would be thicker than those expected for lighter crude oils. Under winter conditions, oil could form thicker layers under the ice (0.075 to 0.42 inches for light and heavy oil, respectively) and as a consequence would spread to a lesser extent. In winter the CLWB is predicted to remain confined to the northern part of Upper Twin Lake, whereas lighter oil could flow under ice to affect all of Upper Twin Lake and part of Lower Twin Lake.	MORE	LESS

Table 7-68 Environmental Effects Summary Table for Pipeline Crude Oil Releases to Shell River

Receptor	Expected Environmental Effects of Released Crude Oil to the Shell River	Relative Effect	
		Light Crude Oil	Diluted Bitumen
Sediment	Lighter crude oils are predicted to travel farther downstream than heavier crude oils in spring and summer-fall conditions, with both oil types travelling similar distances under winter conditions. Neither the light nor the heavy 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. The low viscosity of the lighter type crude oils could potentially result in a larger amount of oil entrainment as fine droplets as compared to heavier blends, resulting in the formation of OPAs, which could both sink, and enhance biodegradation. Such aggregates may subsequently be preferentially deposited in areas of still or slowly moving water, particularly the Twin Lakes. Contact between the weathered diluted bitumen and lake shorelines is also likely to result in mixing of mineral particles into the crude oil, which could then be deposited to sediments as aggregates of oil and mineral in larger droplets or globules. If not recovered, these aggregates could move from shoreline areas into deeper water as a result of wave action and resuspension followed by deposition. Low molecular weight aromatic hydrocarbons would also be expected to dissolve into the water column within the Twin Lakes, where they could adsorb onto suspended sediment and organic matter. Under winter conditions, more of the heavy crude oil is predicted to become trapped along the margins of the rivers and lakes, and this oil is also likely to interact with sediment, resulting in mixing of oil and sediment, or formation of oil-particle aggregates. The spring freshet is a major seasonal factor that can flush river sediments leading to restoration of damaged habitat, and dispersal of oil-particle aggregates in a way that enhances natural recovery.	LESS	MORE
Shoreline and Riparian Areas	Both light and heavy oil would travel downstream from the release location. Lighter crude oils are expected to travel farther downstream than heavier crude oils in spring and summer conditions, but would be thinner and less persistent where they contacted shorelines and riparian habitat. Crude oil released under ice during the winter would not contact shoreline or riparian areas, although crude oil that was not recovered could be dispersed over a large area during the spring freshet. For heavy oil, stranding on shore would be the primary fate. For light oil, stranding would remain the primary fate, but considerably more of the released oil could be lost to evaporation. Flooding of riparian and wetland 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, in contrast to light crude oil which would be deposited as a thin layer or sheen.	LESS	MORE

Table 7-68 Environmental Effects Summary Table for Pipeline Crude Oil Releases to Shell River

Receptor	Expected Environmental Effects of Released Crude Oil to the Shell River	Relative Effect	
		Light Crude Oil	Diluted Bitumen
Aquatic Plants	The Shell River and Twin Lakes support a wide range of emergent, floating and submerged aquatic plants. Where they occur, floating aquatic plants would be expected to be killed if contacted by a floating oil slick. Submerged aquatic plants would be less vulnerable. Emergent aquatic plants are generally quite tolerant of moderate exposure to floating oil (such that a portion of the stem was oiled). However, given the extent of predicted oiling in the Twin Lakes in spring and summer-fall seasons, death of emergent plants from contact with crude oil, particularly the lighter crude oil type, is also possible.	MORE	LESS
Benthic Invertebrates	Environmental effects on benthic invertebrates would be limited to areas affected by the released oil. In the short-term, the low viscosity of light crude oil would result in greater potential for oil entrainment as fine droplets, as compared to heavier blends. This would enhance dissolution of low molecular weight aliphatic and aromatic hydrocarbons into water (with resulting acute toxicity), in addition to promoting oil-particle interaction and potential deposition of oil to sediment. For heavy crude oil, there would be less potential for dissolution of hydrocarbons into the water, but greater long-term potential for deposition of tar balls and patties as a result of oil interaction with sediment. These could accumulate in depositional areas, resulting in chronic effects on benthic invertebrates.	SAME	SAME
Fish	Environmental effects on fish would be limited to areas affected by the released oil. Light oils have low viscosity relative to heavier oils and turbulence in the river water could potentially disperse the light oil as small droplets in the water column. This would enhance the dissolution of potentially toxic fractions of the light oil into the water column. As a result, the potential for acute toxicity to fish due to narcosis would be greater for the light oil than for heavy oil. Potential chronic effects on fish eggs and embryos (e.g., blue sac disease) could also occur, but would be most likely to occur in spring and early summer, when most species spawn. The potential for phototoxicity, caused by an interaction of ultraviolet light with PAHs accumulated in fish tissues, would be greatest in summer due to high light intensity and long day length.	MORE	LESS

Table 7-68 Environmental Effects Summary Table for Pipeline Crude Oil Releases to Shell River

Receptor	Expected Environmental Effects of Released Crude Oil to the Shell River	Relative Effect	
		Light Crude Oil	Diluted Bitumen
Semi-Aquatic Wildlife Receptors			
Amphibians and Reptiles	Environmental effects on amphibians and reptiles would be limited to areas affected by the released oil. Light crude oil is expected to travel farther downstream under spring and summer conditions than heavy crude oil, but would be thinner and less persistent on the water. Crude oil released under ice during the winter would not contact shoreline or riparian areas, although crude oil that was not recovered could be dispersed over a large area during the spring freshet. Flooding of riparian habitat in spring could lead to stranding of crude oils in this habitat. 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 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 unlikely.	MORE	LESS
Birds	Mortality of oiled aquatic and semi-aquatic birds would be limited to areas affected by the released oil. Released light crude oil is generally transported farther than heavy crude oil, so environmental effects could be more spatially extensive for light crude oil types. However, the Twin Lakes provide most of the highest quality habitat for aquatic and semi-aquatic birds along the predicted trajectory of a release, and numbers of birds could be high during periods of migration. As such, oiling of birds in the Twin Lakes would be the primary outcome of a release, independent of oil type. This habitat is affected equally by light and heavy crude oils under spring and summer-fall conditions. Few birds are present in winter, so effects would be minimal in that season.	SAME	SAME
Semi-aquatic Mammals	Mortality of oiled semi-aquatic mammals would be limited to areas affected by the released oil. Released light crude oil is generally transported farther than heavy crude oil in all seasons, so environmental effects could be more spatially extensive for light crude oil types. However, the Twin Lakes provide most of the highest quality habitat for semi-aquatic mammals, and this habitat is affected equally by light and heavy crude oils under spring and summer-fall conditions. 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 spared due to their lower activity levels in winter.	MORE	LESS

Table 7-68 Environmental Effects Summary Table for Pipeline Crude Oil Releases to Shell River

Receptor	Expected Environmental Effects of Released Crude Oil to the Shell River	Relative Effect	
		Light Crude Oil	**Diluted Bitumen**
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. Light crude oil is likely to be transported farther downstream within 24 hours than the heavy crude oil. As a result, environmental effects on air quality could be more spatially extensive for light crude oil types. 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.	MORE	LESS
Human Receptors	Typical human health effects associated with short-term inhalation of VOC from crude oil releases include headache, dizziness, nausea, vomiting, cough, respiratory distress, and chest pain; fatality is unlikely. Residents in close proximity 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. Light crude oil (Bakken) is likely to be transported farther downstream within 24 hours than the heavy crude oil (Cold Lake diluted bitumen). As a result, a release of the light crude oil may affect a larger number of individuals than a release of the heavy crude oil type. 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.	MORE	LESS

Table 7-68 Environmental Effects Summary Table for Pipeline Crude Oil Releases to Shell River

Receptor	Expected Environmental Effects of Released Crude Oil to the Shell River	Relative Effect	
		Light Crude Oil	Diluted Bitumen
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. Light crude oil is predicted to be transported farther downstream than heavy crude oil following a release, affecting a larger area and potentially interrupting public use of natural resources over a larger area. No drinking water HCAs were identified along the path of the release. However, a number of homes are located along the trajectory of a predicted release and could rely on groundwater as a drinking water source. 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 the Shell River would result in adverse health effects to consumers of drinking water. Recreational activities would be disrupted following a release of crude oil along the predicted downstream migration route. The Twin Lakes would be the area where public use of natural resources would be most affected by a release of crude oil. While light crudes will spread further over the lakes exposing, disrupting larger areas, the greater persistence of heavy crude oil is likely to affect such use over a longer period of time than would be the case for lighter crude oil types.	MORE	LESS

7.6 EXPECTED ENVIRONMENTAL EFFECTS OF LARGE RELEASES OF CRUDE OIL TO THE RED RIVER

The Red River is located along the border of North Dakota and Minnesota, and flows north into Canada. The pipeline crossing is located approximately 3 miles east of Bowesmont, North Dakota and 9 miles southwest of Hallock, Minnesota. This scenario captures a hypothetical release of crude oil to the Red River with downstream transport to the north. From the hypothetical release point, the Red River flows past the communities of Pembina, North Dakota and St. Vincent, Minnesota, before crossing the border with Canada near the town of Emerson, Manitoba. For the purposes of this assessment, environmental effects outside of the jurisdiction of the United States of America are not considered.

At the proposed pipeline crossing location and downstream, the Red River is approximately 150 to 400 ft wide and drops 6 ft in elevation over 35 river miles of flow. The river occupies a well-defined sinuous channel with grassy, forested, and muddy banks nestled between predominantly agricultural lands, although the shorelines are often lined with trees. Flooding of the Red River is common in spring and can be extensive due to the generally flat topography. As identified in Chapter 3.0, the Red River is found in the Red River Prairie ecological subsection of the Prairie Parkland Province in Minnesota.

7.6.1 Description of the Freshwater Environment

The Red River flows north along a well-defined channel through predominantly agricultural lands. The average velocity of the Red River changes with season, with slowest velocities (e.g., about 1.0 mph) expected during low flow periods in the winter, and greater velocities (e.g., about 2.5 mph) during the spring high flow period. During the spring freshet, the Red River is susceptible to flooding and can overtop its banks and spread into surrounding farmland and communities.

Although the Red River is a muddy river, the water quality is high (MN DNR 2014). This is exemplified in August when millions of mayflies rise up from the water in massive hatches (MN DNR 2014). The habitats of the Red River and its tributaries support more than 70 species of fish (MN DNR 2014). The river offers easily accessible fishing opportunities for channel catfish, walleye, northern pike, smallmouth bass, sauger and lake sturgeon (MN DNR 2014). With the exception of lake sturgeon (*Acipenser fulvescens*), most fish species in the Red River are self-sustaining and do not require stocking to maintain healthy populations. The MN DNR began a stocking program to re-establish sturgeon in 1997. Several thousand lake sturgeon have since been released into the Red River basin in the hope that by the time they become sexually mature (15–20 years), dam removal and other naturalization projects will have reconnected the river to historical spawning tributaries (MN DNR 2014).

In addition to the highly valued fishery of the Red River, many bird species (e.g., wood ducks, hooded mergansers, mallard, northern shoveler, blue-winged teal and Canada goose, FWOR 2000) utilize the river and riparian habitat (e.g., oxbows) for feeding, nesting and resting. The Red River Prairie Subsection is home to 83 Species of Greatest Conservation Need (SGCN). These include amphibians (1 species), birds (54 species), fish (2 species), insects (10 species), mammals (9 species), mollusks (3 species), reptiles (3 species) and spiders (1 species) (MN DNR 2006). Of these species, 36 are afforded federal or state endangered, threatened, or of special concern status (MN DNR 2006; MN DNR 2016). It is foreseeable that some of these SGCN could utilize aquatic habitats along the Mississippi River.

Two access points downstream from the proposed pipeline crossing location were visited in September 2016 to provide additional insight into baseline environmental conditions for the Red River. Representative site photographs are provided in Figure 7-32 through Figure 7-35. Field observations are summarized in Table 7-69.

Figure 7-32 Red River and Riparian Habitat Approximately 8 Miles Downstream of Pipeline Crossing

Figure 7-33 Red River and Riparian Habitat Approximately 8 Miles Downstream of Pipeline Crossing

Figure 7-34 Red River and Riparian Habitat Approximately 30 Miles Downstream of Pipeline Crossing

Figure 7-35 Red River and Riparian Habitat Approximately 30 Miles Downstream of Pipeline Crossing

Table 7-69 Environmental Characteristics Observed at Selected Access Points on the Red River in September, 2016

Access Point	Latitude Longitude	Notes
Highway 5/Joliette Crossing approximately eight miles downstream of pipeline crossing	48.787756 -97.157182	*Habitat Description:* Vegetation is composed of floodplain forest dominated by cottonwood and sedges in the ground layer. Areas somewhat higher in elevation are dominated by terrace forest with bur oak, American elm, green ash and boxelder dominant. The ground layer is dominated by natives, including: false indigo, water pepper, cocklebur, lakebank sedge (dominant), white panicled aster, Virginia wildrye, Pennsylvania smartweed, Indian hemp and others. Nonnative plants are uncommon to rare and include reed canary grass and sow thistle. *Wildlife observed:* Crow, white-tail deer
Pembina, North Dakota Highway 59/171 approximately 30 miles downstream of pipeline crossing	48.973412 -97.238831	*Habitat Description:* Vegetation is composed of floodplain forest dominated by cottonwood trees (some of which form a supercanopy), with lakebank sedge common in the ground layer. Areas slightly higher in elevation also support terrace forest tree species, including green ash. The subcanopy consists of young trees, particularly boxelder. The shrub layer is sparse. The ground layer is dominated by natives, including: lakebank sedge (dominant), white panicled aster, Virginia wildrye, Pennsylvania smartweed, Indian hemp, water smartweed and others. Non-native plants are uncommon and include reed canary grass, burdock, stinging nettle and sow thistle.

Table 7-69 Environmental Characteristics Observed at Selected Access Points on the Red River in September, 2016

Access Point	Latitude Longitude	Notes
		Wildlife observed: American crow

7.6.2 High Consequence Area Assessment for the Red River

As defined in Section 7.0, HCAs include populated areas, drinking water source areas, ecologically sensitive areas, and commercially navigable waterways. Sensitive AOIs include Minnesota drinking water management areas, native plant communities, sensitive lake shores, recreational areas, tribal lands, and protected areas of several types (e.g., national forests, military lands, state parks). The principal HCAs include the population centers of Pembina, ND and St. Vincent, MN (Table 7-70). The Red River also flows past recreational areas, protected areas, and environmental AOIs (Table 7-71). These include water access sites and Bureau of Land Management land. The locations of the HCAs and AOI are shown in Figure 7-36.

Table 7-70 High Consequence Areas Potentially Affected by a Release of Cold Lake Blend or Bakken Crude Oil at the Red River Crossing Location

HCA Type	HCA Subtype	Description / Locations
Environmentally Sensitive Area	N/A	N/A
Population Area	Other Population Area	Pembina, ND
	Other Population Area	St. Vincent, MN
NOTE: Data for the HCA analysis were obtained from the United States Department of Transportation: Pipeline and Hazardous Materials Safety Administration (USDOT PHMSA) HCA datasets plus additional HCAs compiled by Enbridge during 2010 and 2013.		

Table 7-71 Areas of Interest Potentially Affected by a Release of Cold Lake Blend or Bakken Crude Oil at the Red River Crossing Location

AOI Type	AOI Subtype	Description / Locations
Recreational	State Land	Water Access Site
Protected Area	Bureau of Land Management	BLM Land
Environmental	US NRCS Easement	Emergency Watershed Protection Program - Floodplain Easement
	Site of Biodiversity Significance	St. Vincent 11
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 and the Minnesota Department of Transportation.		

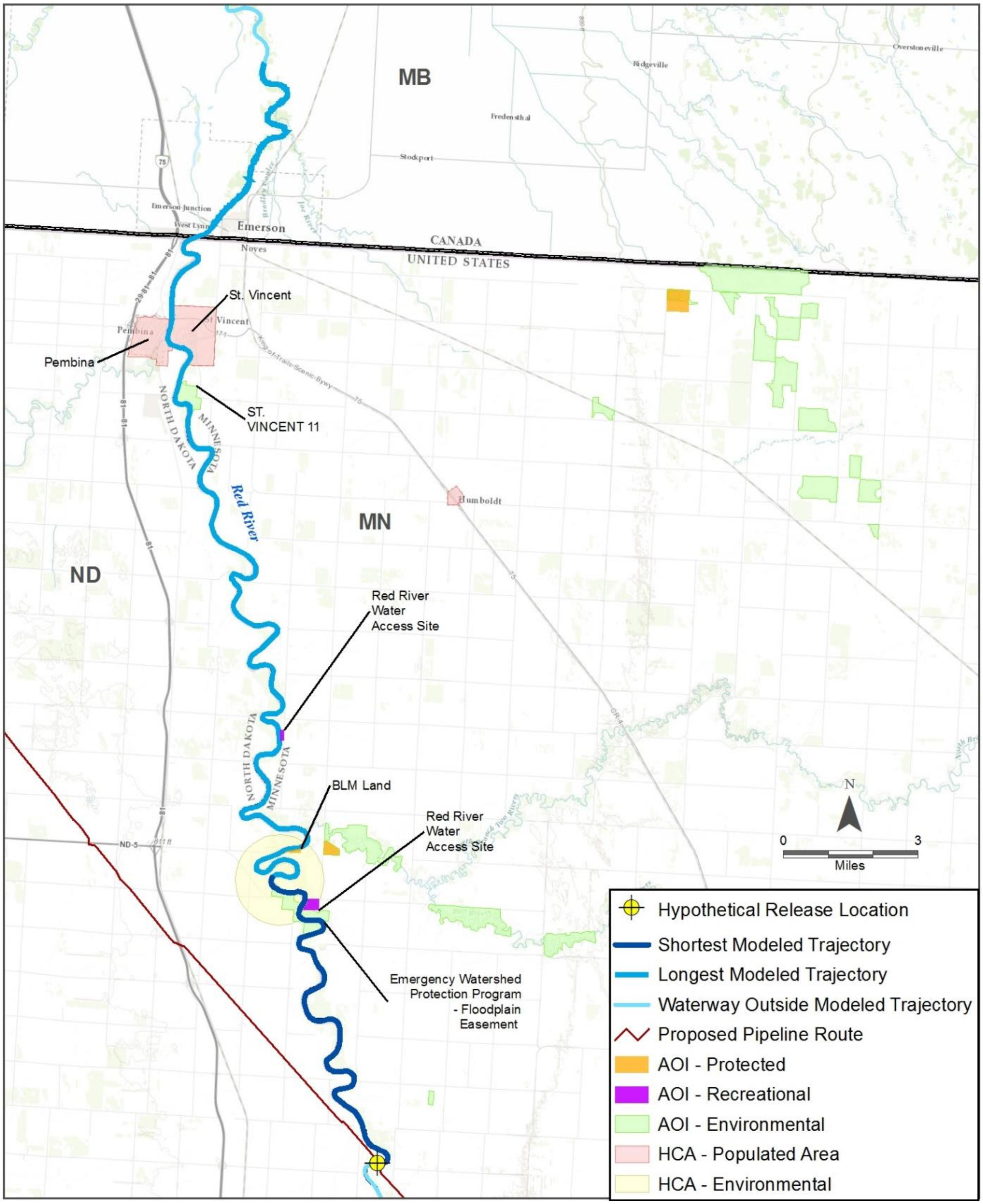

Figure 7-36 High Consequence Areas and Areas of Interest Potentially Affected by a Crude Oil Release at the Red River Crossing Location

7.6.3 Selection of Key Ecological and Human Environment Receptors for Red River

Taking into account environmental characteristics of the Red River, 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 7-72.

Table 7-72 Key Ecological and Human Environment Receptors for the Red River

Receptor	Relevance for Inclusion as an Environmental Receptor for the Red River 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 the Red River with no holdup of oil on land. In the event of an actual oil release, oil remaining on or in the 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 the Red River 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 the Red River 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 cleanup process.	N
Aquatic Receptors		
Rivers (Red River)	High. An assumption made in the fate modeling for this scenario is that released oil would enter directly into the Red River with subsequent physical transport downriver.	Y
Lakes	Low. It is possible that under severe flood conditions the Red River could interact with Lake Stella (a small lake approximately 0.5 miles away from the nearest bank of the Red River). However, an assumption made in the fate modeling for this scenario is that released oil would remain in the Red River after a release.	N
Sediment	High. An assumption made in the fate modeling for this scenario is that released oil would enter directly into the Red River with subsequent physical transport downriver. This allows potential 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 the Red River with subsequent physical transport downriver. This allows potential interaction with shoreline and riparian habitat.	Y

Table 7-72 Key Ecological and Human Environment Receptors for the Red River

Receptor	Relevance for Inclusion as an Environmental Receptor for the Red River Scenario	Selected (Y/N)
Wetlands	Low. An assumption made in the fate modeling for this scenario is that released oil would enter directly into the Red River with subsequent physical transport downriver. There is negligible to no wetland habitat in the vicinity of the predicted release trajectory.	N
Aquatic Plants	Low. The high suspended sediment load of the Red River limits light penetration and opportunities for the development of a substantial aquatic plant community.	N
Benthic Invertebrates	High. The Red River at supports a diverse benthic invertebrate community.	Y
Fish	High. The Red River supports fish.	Y
Semi-Aquatic Wildlife Receptors		
Amphibians and Reptiles	High. The Red River supports amphibians and reptiles.	Y
Birds	High. The Red River supports a diverse bird community.	Y
Semi-aquatic Mammals	High. The Red River supports semi-aquatic mammals.	Y
Human and Socio-Economic Receptors		
Air Quality	High. The communities of Pembina, ND and St. Vincent, MN are located approximately 30 miles north of the hypothetical release location. Effects on air quality have the potential to temporarily disrupt human use and occupancy patterns.	Y
Human Receptors	High. The communities of Pembina, ND and St. Vincent, MN are located approximately 30 miles north of the hypothetical release location. Effects on air quality or the presence of crude oil residues in aquatic and riparian habitat have the potential to temporarily affect human health.	Y
Public Use of Natural Resources	High. The Red River downstream of the crossing is shared by two public water access sites. In addition, Fort Daer Landing and Recreation Area as well as Pembina State Park are also along the trajectory of the modeled release. Effects on air and water quality, or the presence of crude oil residues in the sediment and riparian habitat, could potentially disrupt public use of natural resources (e.g., drinking water, hunting, fishing, recreation).	Y

7.6.4 Modeled Conditions at the Release Location

A description of key modeling assumptions for the environmental effects analysis for the Red River scenario is provided in this section. The OILMAP Land software was used by RPS ASA to simulate hypothetical releases of Cold Lake Blend and Bakken crude oils into the Red River (Chapter 5.0) for a 24 hour period, or until the released crude oil reached the border between the United States and Canada. A longer time period was not modeled as it was assumed that emergency response measures to prevent farther downstream transport of released oil would be in place within the 24 hour period. While OILMAP Land does provide an indication of the downstream extent of oiling and mass balance of oil within the modeled period, it does not quantify the amounts of oil components dissolved into the water column (Chapter 5.0). No overland transport of released Cold Lake Blend or Bakken crude oil was modelled for this hypothetical release location, as it was assumed that released oil would directly enter the watercourse (Chapter 3.0). This is a worst-case assumption for a release of crude oil near the watercourse.

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 (Cold Lake Blend/Winter Blend, heavy diluted bitumen crude oil types having higher viscosity and density). Seasonal variations in river flow, temperature, wind speed, and snow and ice cover were all considered at the release location. A summary of key variables is provided in Table 7-73.

In the event of an actual release, the downstream extents of CLB and Bakken crude oil may be more similar, and the effects of CLB may extend farther downstream than predicted, with patchy coverage.

Table 7-73 Environmental and Hydrodynamic Conditions for the Three Modeled Periods for the Red River Crossing

Season	Month	Air Temperature (°C)	Wind Speed (m/s)	Average River Velocity (m/s)
Low Flow (Winter)	February	-14.68	5.19	0.31
Average Flow (Summer)	August	19.78	3.98	0.44
High Flow (Spring)	April	4.02	5.05	1.02
NOTE: A velocity of 1 m/s is equivalent to 2.25 miles per hour.				

The highest average flow velocity of the Red River coincides with the spring freshet (i.e., April-June), a result of rising temperatures and snowmelt. Average flow would typically occur during summer and fall seasons. August, the month with the warmest temperature, was selected to represent the maximum amount of evaporation. The lowest flow rate occurs in winter (i.e., February), and was typified by freezing conditions and probable ice cover on water.

The crude oil release volume was calculated as a full bore rupture, with a maximum time to response in the pipeline Control Center of 10 minutes, followed by a 3-minute period to allow for valve closure. The release volume therefore represents the volume of oil actively discharged in the period of time required to detect and respond to the event (taking into consideration the pipeline diameter, pipeline shutdown time, pipeline design flow velocity), followed by the volume of oil lost due to drain-down of the elevated segments of pipeline. The maximum

13-minute response time to valve closure is an Enbridge standard for safe operations and leak detection. This includes the combination of identification of the rupture, analysis of the pipeline condition, pipeline shutdown and full valve closure in the affected pipeline section. While 13 minutes is the maximum time for valve closure, this is a conservative assumption, since a response through to valve closure is expected to occur in less than 13 minutes in a full bore rupture leak scenario. Based on these assumptions, the site-specific hypothetical release volume was estimated [NONPUBLIC DATA HAS BEEN EXCISED] Bakken, CLSB, or CLWB crude oil.

7.6.5 Summary of Predicted Downstream Transport of Bakken and Cold Lake Crude Oils

A summary of the predicted downstream trajectory and mass balance of CLB and Bakken crude oils, under the three seasonal scenarios, is provided in Figures 7-6-6 and 7-6-7, respectively. These simulations are assumed to provide bounding conditions for a release of heavy or light crude oil types. The fate of most types of crude oil, if released, would lie within the envelope of predictions for the CLB and Bakken crude oil types. The Cold Lake crude oil was assumed to be CLSB for the high flow and average flow scenarios, and to be CLWB for the low flow (winter) scenario. As noted in Chapter 5.0, while OILMAP Land does provide an indication of the downstream extent of oiling and mass balance of oil within the modeled period, it does not quantify the amounts of oil components dissolved into the water column.

The maximum simulation duration using OILMAP Land was 24 hours, as it was assumed that emergency response measures to prevent or reduce further downstream transport of released oil would be in place within that length of time. Symbols on the drawings indicate the river seasonal flow condition (high corresponding to spring freshet, average corresponding to summer-fall conditions, and low corresponding to winter flow under ice). 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. Numbers other than these (e.g., 20.3) indicate the time in hours of the predicted termination of downstream transport of the released oil due to adhesion or holdup of the oil along the river banks. Tables inserted within the Figures also provide information on the mass balance (i.e., oil remaining on the surface of the river, adhering to river banks, or evaporated to the atmosphere) of the released oil at relevant points in time after the start of the release.

7.6.5.1 Red River Release During High Flow (Spring) Period

Under the high river flow scenario, CLB was predicted to travel approximately 10.5 miles downstream in the Red River within 5.2 hours of the release (Figure 7-37). Beyond this point in time the model predicted that the oil would have been lost from the water surface, mainly as a result of adhesion to shoreline (95.4%), with the balance evaporating.

Bakken crude oil was predicted to be transported approximately 40.3 miles downstream within 18.5 hours of the release (Figure 7-38). The transport of floating oils was predicted to pass through

Pembina, ND and St. Vincent, MN, and into Canada. At this time, approximately 58.6% of the Bakken crude oil was predicted to adhere to shorelines and approximately 41.4% to have evaporated into the atmosphere. None of the oil was predicted to remain on the water surface after 24 hours of the release.

The release of Bakken crude oil under high flow conditions was predicted to result in oiling farther downstream than for the CLB. The difference in the extent of downstream transport was a result of the difference in the shoreline oil retention between the two oil types. Because of its higher viscosity and adhesiveness, 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, in addition to affecting a greater overall length of the river. This result is based upon the assumption of 100% shoreline oiling coverage (i.e., all shoreline was oiled to its maximum holding capacity as oil made its way downstream). In the event of an actual release, the downstream extents of CLB and Bakken crude may be more similar, and the effects of CLB may extend farther downstream than predicted, with patchy coverage.

A larger proportion of the Bakken crude oil was predicted to evaporate to the atmosphere than was predicted for the CLB. This was due in part to the lighter and more volatile character of the Bakken crude oil. In addition, the greater downstream transport of the Bakken crude oil took more time, and resulted in more water surface area with oil, both of which could allow more of the released oil to evaporate. Volatile components of the CLB would continue to evaporate after becoming stranded on shoreline, but this process was not included within the OILMAP Land model for stranded oil.

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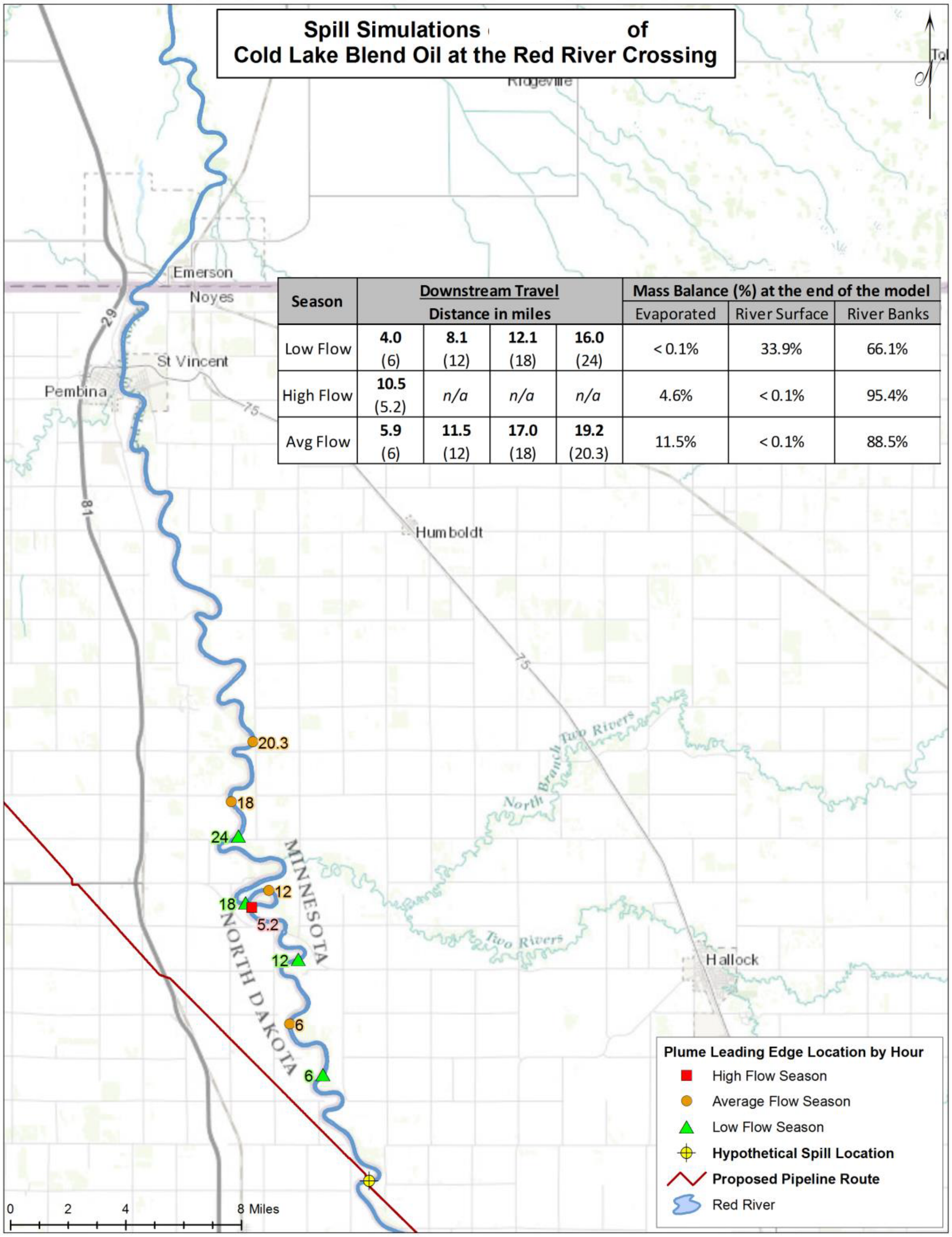
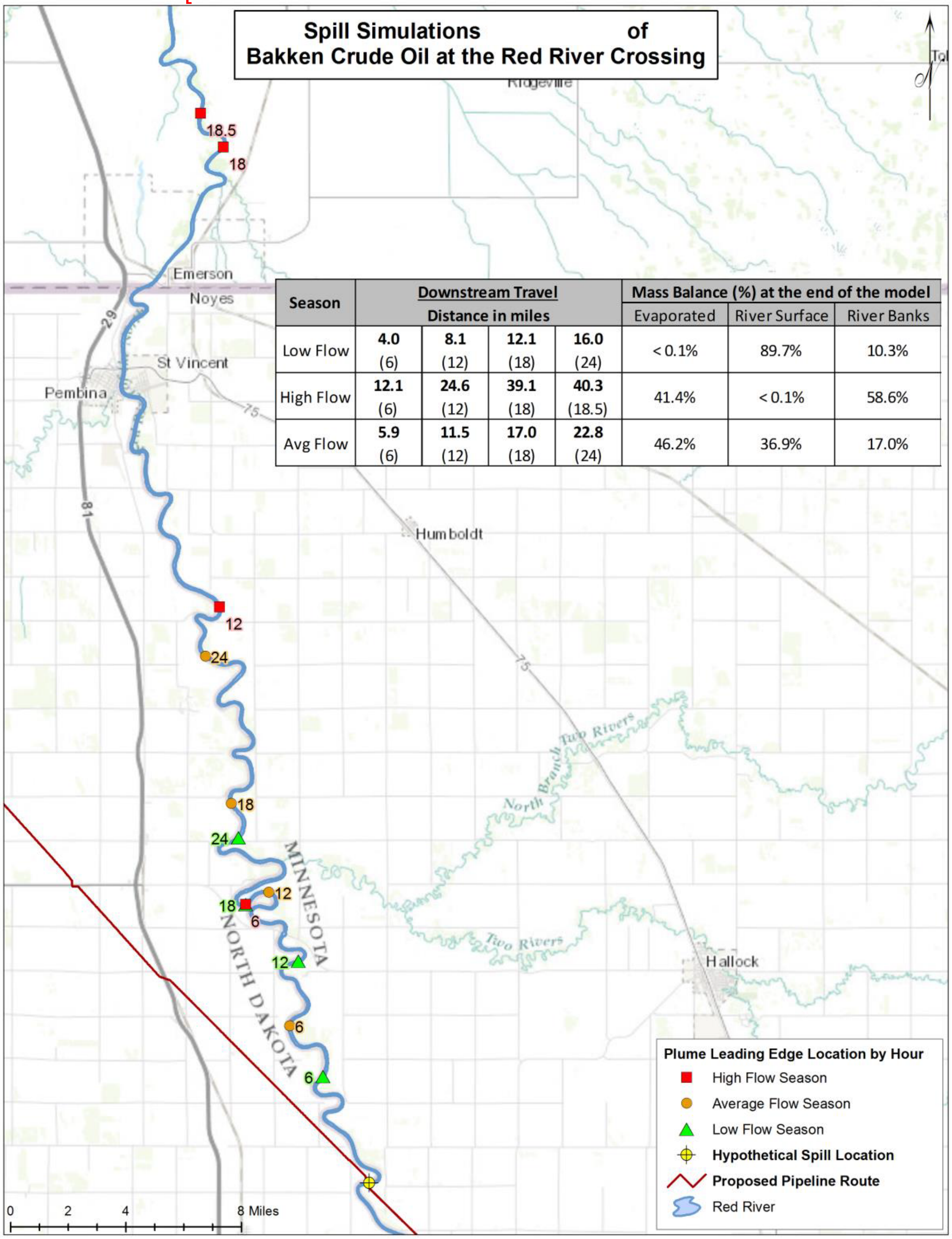


Season	Downstream Travel Distance in miles				Mass Balance (%) at the end of the model		
					Evaporated	River Surface	River Banks
Low Flow	**4.0** (6)	**8.1** (12)	**12.1** (18)	**16.0** (24)	< 0.1%	33.9%	66.1%
High Flow	**10.5** (5.2)	*n/a*	*n/a*	*n/a*	4.6%	< 0.1%	95.4%
Avg Flow	**5.9** (6)	**11.5** (12)	**17.0** (18)	**19.2** (20.3)	11.5%	< 0.1%	88.5%

...NONPUBLIC DATA HAS BEEN EXCISED]

Figure 7-37 Predicted Downstream Transport of Cold Lake Blend Oil at the Red River Crossing Location

[NONPUBLIC DATA HAS BEEN EXCISED...



Season	Downstream Travel Distance in miles				Mass Balance (%) at the end of the model		
					Evaporated	River Surface	River Banks
Low Flow	4.0 (6)	8.1 (12)	12.1 (18)	16.0 (24)	< 0.1%	89.7%	10.3%
High Flow	12.1 (6)	24.6 (12)	39.1 (18)	40.3 (18.5)	41.4%	< 0.1%	58.6%
Avg Flow	5.9 (6)	11.5 (12)	17.0 (18)	22.8 (24)	46.2%	36.9%	17.0%

...NONPUBLIC DATA HAS BEEN EXCISED]

Figure 7-38 Predicted Downstream Transport of Bakken Crude Oil at the Red River Crossing Location

7.6.5.2 Red River Release During Average Flow (Summer-Fall) Period

Under average river flow, CLB crude oil was predicted to travel up to 19.2 miles downstream, within 20.3 hours of the release (Figure 7-37). After this time, there would be little CLB on the river's surface as the model predicted that most of the released oil would have stranded along shorelines (88.5%) or evaporated (11.5%). Emergency response measures to prevent further possible downstream transport of oil would be in place within 24 hours of the release.

Under average river flow, Bakken crude oil was predicted to be transported approximately 22.8 miles downstream, over the full 24-hour modeled period (Figure 7-38). Approximately 17.0% of the Bakken crude oil was predicted to oil the shorelines of Red River, with 46.2% predicted to evaporate into the atmosphere, and 36.9% to remain on the river surface at the end of the 24 hour simulation. If left unmitigated, the remaining Bakken crude oil on the river surface after 24 hours could be expected to continue downstream. The oil would continue to weather and would oil shorelines until all of the oil was removed from the water surface.

Under average flow conditions, the CLB was predicted to travel farther downstream than during high river flow condition. This is a result of less interaction between the released oil and shorelines. Under average flow conditions the stream shorelines are assumed to be a mixture of grass and mud. Under high flow conditions, with water spreading into riparian areas, shorelines of the Red River are assumed to be vegetated. As a result, it was assumed in the modeling exercise that under average flow conditions, the shorelines would hold less of the viscous CLB oil type than during high flow conditions. The muddy shoreline present under average flow conditions is assumed to be capable of retaining about 150 bbl of CLB crude oil per mile of shoreline, whereas a grassy shoreline is assumed to be capable of retaining about 1,260 bbl of CLB crude oil per mile.

Slightly more of the released CLB crude oil was predicted to evaporate under the average river flow condition than under the high river flow condition (Figure 7-37). This difference is due largely to the warmer temperatures in the summer-fall season as compared to the spring freshet, as well as the shorter length of time that the oil was free on the water surface (i.e., the simulation for the average flow period terminated after 20.3 hours compared to the shorter duration of 5.2 hours for the high flow period.

When compared to the CLB under average river flow conditions, the Bakken crude oil was predicted to be transported farther downstream before reaching the 24 hour model limit of the simulation. This difference was attributable to the lower shoreline oil retention value for the low viscosity Bakken crude oil, when compared to the more viscous and adhesive CLB. Although not modeled here, it is expected that a medium crude oil would exhibit fate and transport properties intermediate between those of the Bakken and CLB crude oil types, with a tendency to behave more like the Bakken crude oil. This is because the viscosity and adhesiveness properties of a medium crude oil would typically be higher and, therefore, more similar to those of the Bakken crude oil, than to the CLB.

7.6.5.3 Red River Release During Low Flow (Winter) Period

Under low river flow conditions, CLWB was predicted to be transported a total of 16.0 miles downstream over the full 24-hour modeled period (Figure 7-37). Approximately 66.1% of the CLWB was predicted to become trapped under ice along the margins of the Red River, with 33.9% remaining in the river below the ice at the end of the 24 hour simulation. If left unmitigated, the CLWB remaining in the Red River after 24 hours could be expected to continue to move downstream until all of the oil was trapped along the river margins, or had accumulated in fissures and hollows in the river ice. This would provide only temporary storage of the oil, and oil would be expected to re-mobilize in response to changes in flow rates, and particularly during the spring breakup of ice. With the CLWB below the ice of the river, evaporation of oil to the atmosphere would be negligible in the short-term. However, emergency response measures to prevent further possible downstream transport of oil would be in place within 24 hours of the release.

Under low river flow, Bakken crude oil was predicted to be transported approximately a total of 16.0 miles downstream over the full 24-hour modeling period (Figure 7-38). Approximately 10.3% of the Bakken crude oil was predicted to become trapped along the river margins, while the remaining 89.7% was predicted to remain in the river, below the ice, at the end of the 24 hour simulation. If left unmitigated, the remaining Bakken crude oil in the river after 24 hours would be expected to continue to move downstream, with some accumulating along the river margins and some accumulated in fissures and hollows under the river ice.

As with the CLWB, the accumulation of released Bakken crude oil under the ice would be unstable, and oil would be expected to re-mobilize in response to changes in flow rates, and particularly during the spring breakup of ice. Evaporation of the Bakken crude oil to the atmosphere would also be negligible in the short-term. Less of the Bakken crude oil was predicted to accumulate at the river margins under the ice, when compared to the CLWB under low river flow conditions. This was due to the differences in shoreline oil retention between the two oils (i.e., lower viscosity and adhesion of the Bakken crude oil). For this reason, the Bakken crude oil was predicted to have greater mobility under the ice in winter.

7.6.6 Qualitative EHHRA for the Red River

In this section, the likely environmental effects of a crude oil release at the pipeline crossing location on the Red River are described. A worst case crude oil release from a mainline pipeline, such as described here, would be an unlikely event (Chapter 4.0). 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 bitumens such as CLB). Therefore, the following discussion describes the likely environmental effects of a crude oil release on relevant ecological and human environment receptors (identified in Section 7-6-3), using the predicted geographic extent of effects of released Bakken or CLB crude oil types over the 24 hour simulations as bounding conditions. Effects of season (including temperature, river flow conditions, and receptor presence/absence and sensitivity) were also considered in the analysis. The rationale supporting the effects analysis, based on case studies describing the effects of crude oil releases on the various ecological and human environment receptors, was provided in Section 7.1 and Table 7-72.

7.6.6.1 Terrestrial Receptors

For this modeling scenario, the hypothetical release of crude oil is assumed to enter the Red River 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 using conventional clean-up techniques. The environmental effects of a crude oil release on land cover receptors will not be considered further for this scenario.

7.6.6.2 Aquatic Receptors

The aquatic environmental and ecological receptors that are considered in the assessment for the Red River are river water and river sediment quality, shoreline and riparian river bank habitat, benthic invertebrates, and fish.

Crude oil released to the Red River during the spring (high flow condition) is predicted to travel downstream, interacting with vegetation and seasonal shoreline areas in the riparian floodplain as it moves north. The distance travelled would depend upon river flow and oil type. Based on OILMAP Land simulations, light oil is predicted to travel father downstream than heavy oil. For heavy oil, stranding on shore would be the primary fate, with only small amounts of evaporative weathering of the oil occurring within the first 24 hour period. For light oil, stranding would remain the primary fate, but considerably more of the released oil could be lost to evaporation.

The effects of oil releases on benthic invertebrates and fish depend on 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 the river water could potentially disperse the 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, the potential for acute toxicity to fish and invertebrates would be greater for the light oil than for heavier oils. However, the large volume of water flow associated with the spring period freshet in the Red River may also dilute and limit the maximum dissolved hydrocarbon concentration in water, as compared to periods of lower water flow.

There would also be high potential for chronic effects of released crude oil on fish eggs and embryos (i.e., induction of deformities or mortality collectively termed blue sac disease). Many of the fish species present in the Red River spawn in the spring and early summer. The eggs and embryos of these species could be exposed to total PAH concentrations in the river water that could be sufficiently high to induce deformities or cause mortality. In addition the potential for phototoxicity, caused by an interaction of ultraviolet (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. Small fish that are lightly pigmented or transparent (i.e., embryos, larval and juvenile fish) are most susceptible to phototoxicity. The risk of phototoxicity would be mitigated by high concentrations of suspended sediment present in the water of the Red River, which would reflect, scatter and absorb light, limiting the penetration of UV light into the water column.

Entrainment of small crude oil droplets in the water column also enhances the potential for light crude oils to interact with suspended sediment particles in the water column resulting in the formation of OPAs. Such aggregates may subsequently be preferentially deposited in areas of still or slowly moving water, such as oxbows and backwaters. Formation of true oil-particle aggregates is less likely to occur with heavy crude oils such as diluted bitumen, as the higher viscosity of the oil precludes the ready formation of fine droplets in the water column (Zhou et al. 2015). However, heavy oils can still contact sediment particles along the shoreline, and some accumulation of both light and heavy oils in depositional areas 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.

Crude oil released during the summer-fall (average flow) period is predicted to travel downstream, stranding on muddy river banks and losing volatile components of the oil to evaporation as it moves north. Results provided in Section 7.6.5 provide bounding cases for the products likely to be carried in the pipeline. The OILMAP Land simulations indicate that crude oil would be carried between 19.2 and 22.8 miles downstream from the point of release under summer-fall average-flow conditions. For heavy oil, stranding on shore would be the primary fate, with only small amounts of evaporative weathering of the oil occurring. For light oil, evaporation would be the primary fate, with a considerable amount of released oil potentially remaining on the surface of the Red River, and only a modest amount adhering to the river banks. The lower river flow in summer-fall compared to spring could result in higher concentrations of water soluble components in the river; however, along with lower flow rates, there would also be less turbulence in the water column and a reduced tendency for crude oil to be dispersed as fine droplets in the water column. As a result, and taking into consideration the relatively large size of the Red River, narcotic effects on fish and benthic invertebrates are unlikely during the summer season. Also taking into consideration the lower river flow and turbulence, deposition of crude oil residues to sediment in areas of still water is less likely during the summer season than during the spring period.

Crude oil released during the winter (low flow) period could potentially pool on the frozen river surface. If the release was to occur directly to the river below the ice (as is assumed in the OILMAP land model), or if there were openings in the ice that the released oil could penetrate, the oil could travel downstream under the ice, accumulating in the narrow gap between the ice and the river sediment, or accumulating in hollows under the ice as it moved north. Results provided in Section 7.6.5.3 provide bounding cases for the products likely to be carried in the pipeline. The OILMAP Land simulations indicate that crude oil would be carried approximately

16 miles downstream from the point of release under winter low-flow conditions. For both oil types, the winter ice would effectively inhibit evaporation, while providing greater potential for dissolution into the water column during the period of lowest dilution flow. The more viscous heavy oil would be predominantly trapped along the river margins, whereas a large fraction (about 33.9%) of the light crude oil would remain mobile at the interface between the river water and the underside of the ice. Therefore, a spill in winter could cause mortality to fish due to narcosis. This result would be more likely for the light crude oil, which would spread out over a larger area, than for the heavy crude oil, which would tend to remain in thicker localized accumulations. Fish eggs and larvae would generally not be present during the winter, so effects on these life stages due to blue sac disease are not likely, although crude oil residues in water and sediment could, if not adequately remediated, affect fish eggs and larvae in the following spawning season. Phototoxicity is not likely to occur following a release of crude oil in winter due to short day length and lower light intensity in winter, reflection and absorbance of light by snow and ice cover on the river, and absorbance of UV light by DOC in the water beneath the ice.

Both crude oil types could be accumulated in sediment, and both would be subject to re-mobilization with spring breakup of the ice, and increasing water flow rates.

7.6.6.3 Semi-Aquatic Wildlife Receptors

Habitat downstream of the hypothetical release location supports amphibians (e.g., salamander, mudpuppy), reptiles (e.g., turtles, snakes), semi-aquatic birds (e.g., ducks, geese) and semi-aquatic mammals (e.g., muskrat, otter). Details on predicted environmental effects for amphibians and reptiles, birds and mammals are provided below.

7.6.6.3.1 Amphibians and Reptiles

Crude oil released to the Red River during the spring (high flow) and summer-fall (average flow) seasons is predicted to travel downstream, interacting with vegetation and seasonal shoreline areas. The distance travelled would depend on the flow conditions, as well as oil and shoreline type. The OILMAP Land simulations indicate that light oil will travel father downstream than heavy oil. A crude oil release during the summer-fall period would not be likely to have direct effects on riparian habitat and, therefore, effects on reptiles (e.g., snakes) in the riparian zone would be minimal. Downstream transport of released crude oil in summer-fall would not travel as far north as in spring (between 19.2 and 22.8 miles downstream from the point of release) meaning that possible oil-organism interactions would be fewer in this season than in spring.

Within the oil-exposed habitats along the river that support amphibians (adults, juveniles, and eggs), oiling effects including mortality would be observed. 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 less likely. Reptiles like lizards and snakes are primarily terrestrial species and are less intimately associated with aquatic environments. As a result, exposure of these animals to released crude oils would be limited. After the Kalamazoo River oil spill in 2010 snakes did not appear to be highly exposed to spilled oil. A release of light crude oil during the spring would likely have a greater effect than in summer due to the greater predicted downstream transport distance and interaction with greater areas of riparian and wetland habitats than later in the year.

Amphibians and reptiles undergo a winter dormancy period when temperatures drop below approximately 41 to 45°F. At this time, amphibians and turtles typically bury themselves in river bottom substrates or other similar habitats. Therefore, during the winter (and likely up until April or May when winter ice is gone), these animals would have very little exposure to released oil moving on the water surface or within the water column.

7.6.6.3.2 Birds

Aquatic and semi-aquatic birds are those that use rivers, wetlands, and riparian areas as components of their habitats, 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. What they have in common is that if exposed to external oiling, their ability 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.

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 flow) season, many migratory birds would be returning to riverine habitats in Minnesota and North Dakota, 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 are likely to die as a result of hypothermia. Only birds in the affected river reach, which could range from 10.5 to 40.3 miles in extent, would be affected; birds upstream, farther downstream, or occupying other nearby habitats would likely be less affected 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.

Environmental effects of a crude oil release in the summer-fall period are likely to be of similar or lesser magnitude. With rising water temperatures, mortality of lightly oiled adult birds due to hypothermia becomes less likely than in the spring. 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. 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 where birds can physically contact oil, which could range from 19.2 and 22.8 miles downstream along the Red River from the release point.

In the winter months, ice cover on the Red River would strongly limit the opportunities for aquatic and semi-aquatic birds to occupy this habitat. Therefore, adverse effects on the health of aquatic and semi-aquatic birds are not likely for a release of crude oil during the winter.

7.6.6.3.3 Semi-aquatic Mammals

While the semi-aquatic mammal species found in Minnesota include terrestrial species such as moose and raccoon, this assessment focuses 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 more likely to come into contact with an oil release in water than 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 the Red River where effects may occur, and the magnitude of effects, is related to the type of oil released, season and flow rate. Effects on semi-aquatic mammals relate more to the amount of time spent in the water (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 (high flow) season, with cold water temperatures prevailing, semi-aquatic mammals contacted by crude oil are likely to die as a result of hypothermia. Based on the OILMAP Land simulations, the potentially affected river reach could range from 10.5 to 40.3 miles in extent. Therefore, although mortality of a considerable number of semi-aquatic mammals could be expected, large-scale (i.e., regional) population level effects are unlikely. Environmental effects of a crude oil release in the summer-fall period are likely to be of similar or lesser magnitude than in spring. With rising water temperatures, mortality of lightly oiled semi-aquatic mammals due to hypothermia is less likely. Chronic adverse effects on the health of semi-aquatic mammals that survive their initial exposure to crude oil are also possible as a result of ingesting crude oil residues while grooming, or while consuming food items. However, as in the spring, effects are expected to be limited to areas of oil exposure.

In the winter months, muskrat and beaver are likely to reduce their activity levels, although American mink and river otter would remain active. Animals that became oiled in the winter would likely die rapidly as a result of hypothermia.

7.6.6.4 Human and Socio-Economic Receptors

Crude oils are complex mixtures of hydrocarbon compounds. Light crude oils typically contain more VOCs as compared to heavier crude oils, although diluted bitumen may contain similar amounts of VOCs to some light crude oils, depending upon the type and amount of diluent. 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) primarily within the first 24 hours of an oil release. The communities of Pembina, North Dakota and St. Vincent, Minnesota could potentially be exposed to hydrocarbon vapors under certain circumstances, and were identified through the HCA analysis as being "other" (i.e., smaller) population areas. Under high flow conditions in the Red River, the OILMAP Land modeling indicated that the leading edge of released Bakken crude oil could reach these urban areas in under a day. Setbacks afforded by the riparian floodplain of the river generally assure that residences are approximately 120–140 yards away from the river as it passes through Pembina and St. Vincent, although this distance would be reduced during the spring freshet. Under the winter release scenario, the ice cover is assumed to strongly limit release of volatile hydrocarbons to air.

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. The case studies (Section 7.1) do not reveal any instances of human fatality as a result of inhalation of crude oil vapor. Similarly, ATSDR (1995) reports 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.

The potential for inhalation exposures to the public would be greatest near and downwind from the release site while the released oil is on the water surface (i.e., 3 miles east of Bowesmont, North Dakota and 9 miles southwest of Hallock, Minnesota, as well as near the Red River). There are three residences within a mile of the proposed Red River crossing location. In the unlikely event of a crude oil release, residents close to or downwind of the release trajectory would become aware of a strong hydrocarbon odor.

Most of the volatile hydrocarbons would be lost within the first 24 hours following a release of crude oil. 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 emergency response takes place.

The HCA analysis did not identify drinking water intakes that could be affected downstream of the Red River crossing. Based on a search of municipal water supplies for Pembina, North Dakota and St. Vincent Minnesota, it appears that neither of these communities consistently obtains drinking water from the Red River. Rather, people in Pembina, North Dakota can purchase drinking water from the Northeast Regional Water District (http://www.northeastregionalwater.com/index.html) and drinking water is supplied to St. Vincent by the North Kittson Rural Water company (http://www.health.state.mn.us/divs/eh/water/com/waterline/featurestories/ruralwater.html). In the unlikely event of a crude oil release, notifications would be sent to people in the area so that drinking water intakes (should there be any) could be suspended if required.

Relatively little has been published regarding the long-term effects of exposure by humans to crude oil releases. Health effects observed in residents and clean-up workers in the months following an oil release 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.

Effects of a crude oil release on human receptors would generally be similar for the spring (high flow) and summer-fall (average flow) seasons. In summer, the warmer temperatures and slower river flow velocities in the summer would promote more rapid evaporation of volatile hydrocarbons in a smaller area. In the spring freshet period, higher river flow velocity would transport the released oil farther downstream within the first 24 hours, potentially resulting in effects to a larger number of people. The flow modeling suggests that the light crude oil (Bakken) is likely to be transported farther downstream within 24 hours than the heavy crude oil (Cold Lake diluted bitumen). As a result, a release of the light crude oil may affect a larger number of individuals than a release of the heavy crude oil type. Both Bakken crude oil and Cold Lake diluted bitumen are expected to contain similar overall amounts of volatile hydrocarbons, so differences related to the type of released oil are likely to be minor.

No overland transport of released crude oil was modelled for this hypothetical release location. Infiltration of crude oil into soil and subsequently into groundwater would be limited.

During the spring freshet period, the Red River is susceptible to flooding and can overtop its banks and spread into the surrounding farmland. A release of light and medium crude oils during this period would provide a potential pathway for oil deposition to soil in low-lying areas. Light and medium crude oils would be expected to become dispersed over a large area, and are readily biodegraded, so that persistent accumulation of these oil types in riparian areas or temporarily flooded farmland is unlikely. Heavy crude oils and diluted bitumen are more likely to be deposited as thicker layers of more persistent oil, and would likely require more active remediation of affected areas. Soils in the area are predominantly lacustrine clays, silts, and sands (MN DNR 2006) and these soils typically have low to medium permeability (compared to sand/gravel soils). Therefore, penetration of crude oil into flooded soils, and effects on groundwater quality (as a potential source of potable water) are unlikely.

The Red River provides recreational opportunities (e.g., fishing, hunting, boating, swimming, camping) at many locations north of the release location. 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 migration route. 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 for contact with constituents in the oil.

7.6.6.5 Summary and Conclusions

Expected environmental effects to key ecological and human environment receptors after a hypothetical large crude oil release to the Red River were assessed for both light crude oil (e.g., Bakken crude oil) and heavy crude oil (e.g., diluted bitumens such as CLB). The discussion of expected environmental effects on receptors 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. Selected receptors for qualitative assessment are highlighted in Table 7-72, discussed in detail in Sections 7.6.6.1 to 7.6.6.4, and summarized here in Table 7-74.