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Chapter 10

Accidental Crude Oil Releases

10.1 INTRODUCTION

During the transport of crude oil by pipeline and by the alternative modes of rail and truck transportation, unplanned events may occur that can result in a release of crude oil. Although the probability of a large or major oil release at any specific location is extremely low, the probability of a release of some type along the entire pipeline during its lifetime is not low. In addition, the consequences of a large release can be significant. Therefore, in addition to the analysis of potential Project impacts during construction and normal operations, the potential for unanticipated releases and the potential consequences of such releases must be considered in this Environmental Impact Statement (EIS).

Modeling, statistics, and resource mapping can help predict the probability of an accidental oil release, how crude oil behaves in the environment, and what resources could be at risk should there be an oil spill. However, it is impossible to predict where a spill would happen, the quantity of oil involved, how far the impacts would extend, or exactly what resources would be affected. In part, this is because there are so many incident-specific factors involved. The weather, time of year, water levels, human error, and even what type of wildlife is present at the time a spill occurs all affect its probability and outcome. **Therefore, the analysis in this chapter cannot predict the impact of a spill. Instead, it provides a general assessment of the probability of spill occurring, a general evaluation of the behavior of crude oil in the environment, a general evaluation of how spilled oil affects the environment, and an assessment of the type and quantity of resources that are exposed along each alternative.**

This chapter first describes the relevant federal and state regulations for crude oil transportation by pipeline, rail, and truck and the causes of crude oil releases and then provides a baseline crude oil spill risk analysis (Section 10.1). Section 10.2 describes the behavior of crude oil in the environment, including case studies of prior releases. The crude oil trajectory and fates modeling is discussed in Section 10.3, followed by descriptions of the potential exposure of and impacts on specific resources if a spill were to occur (Section 10.4). Sections 10.5 and 10.6 describe spill prevention and response measures and clean-up and recovery measures, respectively. Lastly, Section 10.7 compares the potential exposure of resources of concern to crude oil releases for the alternatives.

10.1.1 Regulatory Context

Crude oil transport by pipeline, rail, and tanker truck is regulated by a number of state and federal guidelines and standards, which are described below.

10.1.1.1 Pipeline Safety Regulations and Standards

The federal (U.S. Department of Transportation [USDOT]) and state (Minnesota Office of Pipeline Safety [MnOPS]) regulatory requirements for oil pipelines, as well as industry standards for oil pipelines, are discussed below. These regulations and standards apply to each of the pipeline alternatives.

10.1.1.1.1 U.S. Department of Transportation Regulations

USDOT is mandated to regulate pipeline safety under Title 49 U.S. Code Chapter 601. The Pipeline and Hazardous Materials Safety Administration (PHMSA) is the agency within USDOT that has jurisdiction and is responsible for developing and enforcing regulations for the safe, reliable, and environmentally sound operation of interstate pipelines. PHMSA's regulations encompass design, construction, testing, operation, maintenance, and emergency response for hazardous liquid pipelines and related facilities.[1]

49 Code of Federal Regulations (CFR) 195 (Transportation of Hazardous Liquids by Pipeline) include Subparts A through H, establish reporting requirements, design requirements, construction requirements, pressure testing, operation and maintenance, integrity management, required qualifications of pipeline personnel, and corrosion control. For a new hazardous liquid pipeline, high consequence areas (HCAs)[2] must be identified prior to operation, and hazardous liquid pipeline operators are required to develop and submit to PHMSA a written Integrity Management Plan (IMP) within 1 year of the start of operation (49 CFR 195.452).

The Applicant's IMP must include identification of all pipeline segments that could affect HCAs; a baseline assessment plan to ensure integrity of these segments; a process for continual integrity assessment and evaluation; repair criteria to address issues identified by the integrity assessment method; a process to identify, evaluate, and implement preventative and mitigation measures to protect HCAs; and a description of how each element of the IMP would be implemented. Because populations can expand and environmental situations can change, HCA boundaries can change over time; therefore, new HCAs must be incorporated into baseline assessment plans within a year of identification (PHMSA 2016). As a part of IMP implementation, the Applicant would also have to perform periodic integrity assessments on line segments that could affect HCAs at least once every 5 years.

If a pipeline is approved for the Project, it is anticipated that the Applicant's IMP for the new pipeline system would be in large part similar to its existing IMPs for the existing Enbridge pipeline system. The new IMP would include a new baseline assessment plan, identification of HCAs specific to the Project, and other Project-specific information.

10.1.1.1.2 State Pipeline Regulations

Although PHMSA is responsible for regulation, inspection, and enforcement of safety regulatory requirements for interstate pipelines as described above, it also permits individual states to adopt additional or more stringent safety regulations for intrastate pipelines. In states where such an agreement is in place, the state is the delegated inspection authority for compliance with federal rules

[1] Parts 190, 194, 195, 198, and 199 are relevant to hazardous liquid (including crude oil) pipelines. Parts 194 and 195 address issues that are directly related to pipeline system integrity and oil spill risk assessment and environmental consequences. The regulations at 49 CFR 194 (Response Plans for Onshore Oil Pipelines) contain requirements for onshore oil spill response plans that are intended to reduce the environmental impact of oil unintentionally discharged from onshore oil pipelines. Parts 190, 198, and 199 address issues that are tangential to pipeline system integrity, including rulemaking procedures, regulations for grants and state aid for safety programs, and required drug and alcohol testing for operators of pipeline facilities.

[2] HCAs are areas or features where a crude oil pipeline failure, such as a release of crude oil, may have long-term and/or permanent and major impacts on resources. They are defined and discussed in more detail in Section 10.4.1.

while PHMSA retains enforcement authority. MnOPS, a division of the Minnesota Department of Public Safety, inspects pipelines within the state and has such an agreement with PHMSA to inspect pipelines.[3] PHMSA's Office of Pipeline Safety enforces its federal regulations based on the inspections conducted by MnOPS. PHMSA or MnOPS inspections or audits can occur at any time, but typically happen every 2 years. The scope of audits and inspections conducted by these regulators are broad and can include the following (Enbridge 2015c):

- Compliance with aerial patrol requirements;
- Review of integrity dig records to determine both adequacy and accuracy;
- Inspection of cathodic protection systems;
- Review of tank inspection records;
- Review of operation, maintenance, and contingency manuals;
- Review of pipeline integrity methodology;
- Review of leak detection methodology;
- Review of system maximum operating pressures;
- Review of facility integrity manuals;
- Inspections of facilities;
- Review of operation and maintenance procedures and records;
- Review of operator qualification records; and
- Examination of public awareness materials.

If MnOPS identifies a violation of Minnesota pipeline laws, it has the authority to issue civil penalties for violations of these laws.

Of the states affected by the pipeline alternatives, only Minnesota has an agreement with PHMSA. The Iowa Utilities Board has primary jurisdiction over the routing and siting of hazardous liquids (including crude oil) pipelines in Iowa but does not have safety jurisdiction over hazardous liquids pipelines—PHMSA retains that authority (Iowa Utilities Board 2017). Similarly, North Dakota, Illinois, and Wisconsin have not entered into agreement with PHMSA to monitor the safety of their pipelines; therefore, PHMSA regulates, inspects, and enforces interstate liquid pipeline safety requirements in those states.

10.1.1.1.3 Pipeline Industry Standards

In addition to adhering to PHMSA regulatory requirements, major oil transport pipelines must also comply with pertinent industry standards. If a pipeline system is selected for approval, the design of the system would be expected to comply with the industry standards and codes listed below. These standards and codes were established to improve pipeline system integrity and safety and to reduce the potential for accidental releases.

- American Society of Mechanical Engineers (ASME)/American National Standards Institute (ANSI) Code B31.4, "Liquid Transportation Systems for Hydrocarbons, Liquid Petroleum Gas, Anhydrous

[3] The agreement is codified under Minnesota Statutes, Chapter 299J, Pipeline Safety.

Ammonia, and Alcohols": This standard addresses requirements for materials of construction welds, inspection, and testing for cross-country hazardous liquid pipelines, including crude oil pipelines, to ensure that pipelines are constructed using the appropriate methods and materials to prevent leaks. ASME B31.4 434.15.2 (a) requires mainline block valves on the upstream side of major river crossings and public water supply reservoirs, and either a block valve or a check valve on the downstream side. 49 CFR Part 195, "Transportation of Hazardous Liquids by Pipelines," has incorporated ASME/ANSI B31.4 code by reference.

- American Petroleum Institute (API) 570, "Piping Inspection Code–Inspection, Repair, Alteration, and Re-Rating of In-Service Piping Systems": This code provides guidance on proper inspection and repair of pipelines the petroleum refining and chemical processing industries use, but it may be used for any piping system.
- API RP 1102, "Recommended Practices for Liquid Petroleum Pipelines Crossing Railroads and Highways": This recommended practice is a requirement of ASME/ANSI B31.4. This guide gives primary emphasis to provisions for public safety. It covers the design, installation, inspection, and testing required to ensure safe crossings of steel pipelines under railroads and highways. The provisions apply to the design and construction of welded steel pipelines under railroads and highways.
- API RP 1109, "Recommended Practice for Marking Liquid Petroleum Pipeline Facilities": ASME/ANSI B31.4 advises that this API RP 1109 be used as a guide. The recommended markers are signs that visually alert the public to the presence of a pipeline and the potential hazards associated with excavating near pipelines. Strategic placement of markers and signs also helps the pipeline operator to perform right-of-way surveillance, inspections, and other routine activities.
- NACE [National Association of Corrosion Engineers] RP 0169, "Control of External Corrosion on Underground or Submerged Metallic Piping Systems": ASME/ANSI B31.4 refers to sections of this recommended practice as a guide for an adequate level of cathodic protection. This standard presents acknowledged practices for control of external corrosion on buried or submerged piping systems. It takes into consideration the material of the pipe, the environment around the pipe, and the nature of the contents of the pipe in determining what types of corrosion prevention should be applied to prevent external corrosion from compromising the integrity of the pipe and resulting in a leak.

10.1.1.2 Rail Safety Regulations

Transport of hazardous materials by rail is primarily regulated by PHMSA and the Federal Railroad Administration (FRA). The role of these agencies as well as connected advisory boards and pertinent legislation is discussed below.

10.1.1.2.1 Federal Agency Regulations and Requirements for Rail Transport

The FRA has jurisdiction over railroad safety, including the transport of hazardous materials such as crude oil. Congress passed the Rail Safety Improvement Act of 2008, which directed the FRA to regulate railroad safety so as to reduce the likelihood of train derailments and collisions.

On May 1, 2015, PHMSA and the FRA issued a final rule defining high-hazard flammable trains (i.e., rail cars carrying flammable liquids such as crude oil and ethanol) and addressing safety concerns raised in response to significant rail incidents involving crude oil and other hazardous/flammable materials. High-hazard flammable trains are defined as having a continuous block of 20 or more tank cars loaded with a flammable liquid or 35 or more cars loaded with a flammable liquid dispersed through the train. Components of the requirements include enhanced braking; enhanced standards for new and existing tank cars; reduced operational speeds; implementation of risk assessments for rail routes; and provision of rail routing information to state, local, and tribal officials. The implementation of these preventative actions is meant to reduce the incidence of accidents involving high-hazard flammable trains.

In August 2016, PHMSA issued its final rule to codify tank car safety standards required by the Fixing America's Surface Transportation Act, signed in December 2015. Under these regulations, all DOT-111 tank cars used to transport crude oil, ethanol, and other flammable liquids must be phased out or retrofitted by 2025, and new tank cars must meet enhanced DOT-117 design or performance criteria. These new cars have increased shell thickness, thermal protection, full-height head shields, high-flow pressure-relief valves, protected top fittings, and upgraded bottom outlet valves for increased safety while transporting flammable materials (81 Federal Register 53935).

In addition to the FRA, the Surface Transportation Board (STB) is an independent adjudicatory and economic regulatory agency. The STB established the Rail Energy Transportation Advisory Committee in July 2007 to provide advice and guidance to the STB and to serve as a forum for discussion of emerging issues regarding the transportation of energy resources, including oil, by rail.

10.1.1.2.2 Minnesota Regulations and Requirements for Rail Transport

Minnesota has implemented new rail incident and response efforts. Minnesota Statute 115E.042 requires by June 30, 2015, annual communication to ensure coordination of emergency response activities between the railroad and local responders and the development and annual submittal of spill prevention and response plans. The Minnesota Department of Public Safety has completed its report outlining Minnesota's response capabilities for an oil transportation incident (Minnesota Department of Public Safety 2015). In addition, in April 2016 Governor Dayton appointed a State Rail Director to enhance railway safety, pursue needed infrastructure improvements, continue training and support for first responders, closely monitor rail movements, and work with communities and railroad companies to ensure the safe and efficient operation of rail systems across Minnesota.

10.1.1.3 Tanker Truck Regulations and Requirements

10.1.1.3.1 Federal Agency Regulations and Requirements for Truck Transport

Federal regulations and requirements for truck transport are established in 49 CFR 177, 178, 385, 107, 392, and 397 as described below.

- Federal regulations regarding the transport of hazardous materials, including crude oil, along public highways are provided in 49 CFR 177. Regulations cover vehicular tunnel sizes, driver training, emergency situation protocols, and other topics pertinent to transport of crude oil by tanker truck.
- 49 CFR 178 includes specifications required for the construction of tanker trucks, including USDOT Specification 407 (Cargo Tank Motor Vehicle). These specifications, including those pertaining to materials, structural integrity requirements, and pressure-relief devices, are meant to ensure safe transport of hazardous materials, including crude oil.

- Safety requirements under 49 CFR 385 include the requirement to obtain and maintain a safety permit to transport certain hazardous materials, including crude oil. Federal regulations at 49 CFR 107, Subpart G, require registration with PHMSA for transportation of hazardous materials, including crude oil.
- The Federal Motor Carrier Safety Administration regulations in 49 CFR Parts 392 and 397 set additional requirements for parking, attendance of hazmat vehicles, routing of hazardous materials shipments, and railroad crossings. These safety requirements apply to tanker trucks transporting crude oil.

10.1.1.3.2 Minnesota Regulations and Requirements for Truck Transport

Minnesota has adopted the Federal Motor Carrier Safety Administration regulations governing hazardous materials transportation, including crude oil.[4] The Minnesota Department of Transportation regulates truck transportation of crude oil through its Office of Freight and Commercial Vehicle Operations (OFCVO). OFCVO focuses on at-risk carriers and shippers who pose the greatest threat to highway safety such as those transporting flammable products, including crude oil. OFCVO works closely with the Federal Motor Carrier Safety Administration in administering and enforcing motor carrier laws and regulations that were established to increase the safety of transporting materials such as crude oil and to minimize the potential for accidental release of those materials.

Under the auspices of the Federal Motor Carrier Safety Administration, OFCVO investigators conduct onsite investigations and reviews of interstate carrier and shipper records and determine whether the carrier or shipper has adequate safety controls in place. Safety controls include driver qualifications; weight limitations; vehicle inspection, repair, and maintenance; driver safety; insurance requirements; and placard and labeling requirements. If a carrier or shipper does not meet the safety standards set by OFCVO, the carrier or shipper can be considered unfit, which may lead to severe penalties up to and including a shutdown of its operations.

Minnesota Statute 115E.045 requires the development and maintenance spill prevention and response plans for trucks transporting 10,000 gallons of oil or hazardous substances as bulk cargo or more per month.

10.1.2 Potential Causes of Unanticipated Releases

10.1.2.1 Crude Oil Transport by Pipeline Systems

Modern crude oil pipeline systems are designed, constructed, and operated with technology to minimize the potential for integrity failures and to rapidly detect and manage unanticipated releases. However, releases do still occur, including releases from pipelines, pump stations, mainline valves (MLVs), and storage tanks. According to the ASME (2010), threats of pipeline failure fall within three categories: time-dependent, stable, and time-independent. Time-dependent threats are those that tend to increase over time. Stable threats are those that are always present but only manifest when activated by a change in operations or the surrounding environment. Time-independent threats are those that are not influenced by time (ASME 2010).

Time-dependent threats (e.g., aging infrastructure) include external corrosion, stress corrosion cracking, and internal corrosion. External corrosion occurs when the pipeline walls, seam welds, or joint welds

[4] Minnesota Statutes §221.033

weaken from corrosive action from outside the pipe. External corrosion can be caused by the natural conditions of the substrate surrounding the pipeline. Stress corrosion cracking occurs when the combined action of corrosion and applied stress causes cracks. Internal corrosion weakens the pipe through corrosive action on the interior surface of the pipe.

Stable threats include manufacturing, construction, and equipment failure threats. Manufacturing threats are caused by defects in the pipeline system that originated during the manufacturing process, such as pipe seam defects and out-of-roundness. Construction threats result from defects caused during the construction, installation, or fabrication of the pipe and its components. Equipment threats result from a failure of the equipment to perform its intended design or its operational or functional purpose.

Time-independent threats include operational error, damage from weather or natural forces, and third-party damage. Operational errors are caused by human mistakes leading to the incorrect operation of the pipeline system that could ultimately lead to a release. Additionally, weather-related and other natural threats have the potential to damage the pipeline system. Natural forces that could stress or damage pipelines, pump stations, MLVs, and storage tanks include inclement weather (e.g., lightning strikes, flooding) or geological shifts (e.g., earthquakes, landslides, mudslides, ground settlement). Pipeline stress or corrosion can also occur due to the natural conditions of the substrate surrounding the pipeline. For example, many types of peat (which is common in Minnesota) exhibit negative buoyancy and place upward pressure on pipelines, causing stress on the pipe (Ryder et al. 2004). Third-party damage threats consist of potential actions by parties other than the pipeline operator that could compromise the integrity of the pipeline. Unintentional damage by third parties most often occurs when other parties are constructing in the vicinity of an installed pipeline and encounter the pipeline while excavating or conducting other ground-disturbing activities. Third-party damage could also include intentional vandalism or sabotage.

10.1.2.2 Crude Oil Transport by Rail

Crude oil releases associated with rail transport can result in a number of ways. Rail tank car loading or offloading[5] errors, hose failures, or rail tank car valve failures could lead to relatively small releases of crude oil within the loading or offloading facilities.[6] Derailments or other accidents while in transit could lead to larger spills that would generally not be within areas designed to contain releases. Such releases could also enter waterways if the tracks are adjacent to or near a waterbody.

There are relatively few incidents of crude oil rail accidents for analysis. Crude oil has only been transported in larger quantities by rail since about 2005 when the first 20-tank car “key trains” began operating at the rate of one train daily in the US. Between the years 2005 and 2015, there was an 84-fold exponential increase in crude transport by rail (Etkin 2017a). Much of this oil was being transported by “unit trains” with 100 to 120 tank cars. Since 2015, there has been a significant drop in the amount of crude oil transported by rail, though this may change based on economic market factors.

Since no specific analyses were conducted for the spill risk associated with crude-by-rail transport for this EIS for Enbridge Line 3 and to provide a more detailed perspective on recent developments, a review of data from existing modeling and statistical studies was conducted. These analyses were conducted in part for the State of Washington for DEIS and FEIS studies for crude-by-rail facilities in that

[5] Loading refers to crude oil being transferred to a rail car or tanker truck from a storage tank; offloading refers to crude oil being transferred from a rail car or tanker truck to a storage tank.

[6] Section 10.1.3 defines the size categories of releases.

state, as well as for peer-reviewed technical papers (Etkin et al. 2015b; Etkin 2016a, 2016b, 2017b, 2017). Risk analyses for crude-by-rail spills are challenging in that there are few data that exist on spills and accidents specifically for this mode of crude oil transport as it have been occurring for only limited time period (since about 2011). The studies and data reviewed involved the analyses of freight rail traffic and accidents, in general, with the review of a large number of technical reports and papers in the literature that address specific aspects of freight rail accidents.

Analyses of accidents from all freight rail transport (regardless of cargo) for the years 1975 through 2015 indicate that derailments are the most common type of accident (79 percent of incidents). Collisions between trains, highway-rail crossing accidents (collisions with trucks or automobiles at crossings), and other miscellaneous incidents, including fires in locomotives, are the other types of accidents that occur (Etkin 2016).

Derailments can be caused by collisions with other objects (e.g., vehicular traffic), operational errors (e.g., harsh handling such as hard braking or traveling at high speeds), mechanical failure of the tracks (e.g., broken rails), or mechanical failure of the wheels. According to a recent study, broken rails or broken wheels were the leading cause of derailments at all speeds (Liu et al. 2012). Human factor-related causes such as improper use of switches and violation of switching rules were also prevalent, as were equipment failures (e.g., bearing failure, broken wheel, and axle defects) (Liu et al. 2012). There has been an 80 percent decrease in rail accidents since 1975, with the sharpest drop occurring prior to 1985. Even in the last decade, there has been a 50 percent decrease in accidents (Etkin 2016b; Etkin 2017b). This finding corresponds with a study that indicates a 5.8 percent annual decrease in freight train derailments between 2000 and 2012 (Liu 2015).

The accident rate for freight rail transport averages 1.5 derailment accidents, 0.092 collisions, 0.089 highway-rail crossing accidents, 0.029 fire incidents, and 0.075 miscellaneous accidents per million train miles for loaded trains (Etkin 2017a). However, calculating the likelihood of a crude train spill needs to take into account a number of other factors. Not all train accidents involving loaded tank cars result in the release of cargo. For derailments, 15 percent to 22 percent of accidents with tank cars have resulted in spillage. In addition, there are a number of factors that make crude-by-rail transport different than other types of freight rail transport, which would affect potential accident rates.

In these studies (Etkin et al. 2015; Etkin 2016a, 2016b, 2017a, 2017b) modeling of crude-by-rail accident rates was conducted, taking into account potential increases in the likelihood of accidents (train length) and reduction in accident rates (electronically-controlled pneumatic braking, positive train control, wayside detection systems, track upgrades, and changes in operating procedures), to determine potential accident rates. In addition, the reduced likelihood of a tank car breach that would result in spillage with the use of newer types of tank cars and requirements for lower operating speeds was factored in. The resulting estimate of spill frequency was 0.0062 spills annually per million train-miles, assuming all safety improvements were in place and were effective. Without the benefit of the safety improvements, the spill frequency was 0.15 spills annually per million train-miles. The volume of spillage would be dependent on the number of tank cars involved in each accident, as well as the probability of breach. For a 120-car train, the expected median spill volume was estimated to be 9,280 bbl. For a 100-car train, the median volume was 8,686 bbl. There was a 10 percent chance that a spill would involve 20,000 bbl or more (Etkin 2017a). While it has not yet occurred, rail lines may also become the target of intentional sabotage or terrorism (U.S. Government Accountability Office 2012).

The greatest concern about crude-by-rail train accidents is that they may involve fires and explosions. There have been 20 crude-by-rail accidents with spillage in the US and Canada since 2013.

Table 10.1-1. Notable CBR US and Canadian Accidents with Spillage 2013–2016

CBR Incident	Accident Date	Outcome Synopsis
Paynton, Saskatchewan	1/24/2013	Collision with road grader; 16 cars derailed; 4 cars spilled oil; 667 bbl spilled.
Parkers Prairie, Minnesota	3/27/2013	14 tank cars derailed; 1 car ruptured; 714 bbl spilled; no fire; minimal damage due to frozen ground
Calgary, Alberta	4/3/2013	7 tank cars derailed; 2 tank cars released oil; fire (put out by local firefighters); 640 bbl spilled
White River, Ontario	4/3/2013	22 cars derailed; 1 car spilled oil; 393 bbl spilled
Jansen, Saskatchewan	5/21/2013	Mixed train; 5 cars derailed; 575 bbl spilled.
Lac-Mégantic, Quebec	7/5/2013	63 tank cars derailed; 37,719 bbl spilled; 47 fatalities; 2,000 people evacuated; extensive damage to town
Aliceville, Alabama	11/7/2013	30 tank cars derailed; 12 tank cars burned; 10,846 bbl spilled; No injuries; fire; wetland impact
Casselton, North Dakota	12/30/2013	Collision; 20 crude cars derailed; explosion/fire; > 9,524 bbl spilled; 1,400 residents evacuated; no injuries
Plaster Rock, New Brunswick	2/7/2014	5 tank cars derailed; 5 tank cars burned; 45 homes evacuated; 3,000 bbl spilled; 45 homes evacuated; no injuries; no fire
Vandergrift, Pennsylvania	2/13/2014	19 tank cars derailed; 4 tank cars spilled oil; 108 bbl spilled; no fire; no injuries
Lynchburg, Virginia	4/30/2014	15 tank cars derailed; 3 tank cars burned; 1,190 bbl spilled; immediate area evacuated; some oil in river; no injuries
LaSalle, Colorado	5/9/2014	6 tank cars derailed; 1 tank car spilled oil; 155 bbl spilled; spill contained in ditch; no fire
Mount Carbon, West Virginia	2/16/2015	27 tank cars derailed; 14 tank cars burned; 9,800 bbl spilled; oil entered Kanawha River; drinking water impacts
Gogama, Ontario	2/14/2015	35 tank cars derailed; 7 tank cars caught fire; 4,900 bbl spilled
Galena, Illinois	3/5/2015	6 cars derailed; 2 cars burned; estimated 1,400 bbl spilled.
Gogama, Ontario	3/7/2015	69 tank cars derailed; 7 tank cars caught fire; 4,709 bbl spilled
Heimdal, North Dakota	5/6/2015	6 cars derailed and spilled oil; cars burst into flames; town evacuated; estimated spill 4,000 bbl.
Culbertson, Montana	7/17/2015	22 cars derailed; 4 cars leaked oil; 833 bbl spilled; no injuries, fire, or explosion.
Watertown, Wisconsin	11/8/2015	13 cars derailed; 1 car spilled oil; 12 bbl spilled.
Mosier, Oregon	6/3/2016	11 tank cars derailed; Several cars burned; 1,000 bbl spilled; some oil entered Columbia River

Source: Updated from Etkin et al. 2015.

The largest accident in the US involved 10,846 bbl of spillage and a fire in Aliceville, Alabama, in November 2013. The largest incident occurred in Lac-Mégantic, Quebec, in July 2013, in which nearly 38,000 bbl of Bakken crude oil spilled, and there were 47 fatalities in the resulting fire and explosions. There are a number of reasons that this type of incident would not likely occur in the US, notably that the practice of having a train be under the control of a sole operator, the poor condition of the train, and leaving the train unattended in an abnormal condition, would not be permitted in the US (reviewed in Etkin 2016).

The volatility of Bakken crude during transport has been identified as a major concern; however, there have been rail accidents with fire that have involved the spillage of diluted bitumen as well (e.g., the two incidents in Gogama, Ontario).

10.1.2.3 Crude Oil Transport by Truck

Crude oil releases associated with truck transport are typically related to the failure of equipment during loading or offloading or human error (Heavy Duty Innovations 2014). Loading crude oil to and offloading crude oil from a tanker truck involves transferring the oil through manifolds, hoses, and valves using a pump (typically mounted on the tractor or tank trailer) to move the oil in either direction. If any of the valves on the truck or the transfer pipes of the storage tank are not properly opened when the pump starts, crude oil under high pressure can blow out the hose or the fitting connecting to the truck's tank. These types of releases would be within the containment area of the loading or offloading facility. In addition, trucks traveling along highways and other roads are at risk of collisions and crashes due to the unpredictable nature of other drivers, driver fatigue, poor road conditions, and inclement weather conditions. When a truck crashes, the tank may be punctured or otherwise damaged, allowing the release of crude oil.

10.1.3 Baseline Crude Oil Pipeline Spill Risk Analysis

In order to quantify the incremental risk for the Line 3 Project, the potential spills that might occur need to be compared with the baseline risk of spills from existing, operating crude oil and refined product pipelines in the area. This section provides an overview of pipeline spill rates and trends in the inland[7] U.S. as a whole, as well as an analysis of historical data for existing crude oil pipelines in Minnesota. Additional analysis and supporting data is provided in Appendix S.

10.1.3.1 General Analysis Inland Pipeline Spills in the U.S.

10.1.3.1.1 Pipeline Spill Data

Data analyses on the crude and refined product pipeline spills were based on data available publicly from the PHMSA.[8] A total of 10,810 spill incidents were included. Criteria for inclusion of spill incidents in the database were:

- Spillage of 1 gallon or more;

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7 In this EIS, the term "inland" pipeline specifically excludes any pipelines offshore in marine waters, but does not exclude pipelines that cross inland waterways.

8 https://www.phmsa.dot.gov/pipeline/library/data-stats/raw-data

- Onshore/inland spill location;[9] and
- Incident occurrence during 1968 through 2015.[10]

The spill incidents were individually characterized with respect to:

- Year and data of incident;
- Location (state, county, city, latitude/longitude);
- General oil type (crude or refined);
- Detailed oil type (crude, gasoline, light oil,[11] and heavy oil[12]); and
- Amount of spillage (in barrels).

10.1.3.1.2 Analytical Results and Findings: Annual Spill Numbers and Volumes

Over the 48-year time period, there were a total of 6,433 crude pipeline spills, and 4,377 refined product spills in inland[13] areas of the U.S., involving a total of over 6.7 million bbl of spillage. These figures are for spills of 1 gallon or more.[14]

The data for significant pipeline spills of at least 10,000 gallons (238 bbl) were also analyzed separately.

Five-year averages of spillage for significant spills are shown in Figure 10.1-1. The annual numbers and total volumes are shown in Figures 10.1-2 and 10.1-3.

The average volume of pipeline spills has decreased significantly since the late 1960s, and particularly in the last dozen years. The average spill volume (all oil types) is now less than 50 percent of the average volume 10 years ago, and 12 percent of the volume in the late 1960s.

The vast majority of spillage is attributable to significant spills (238 bbl and larger). Overall, 93 percent of the volume of spillage can be attributed to the 37 percent of incidents that are considered significant by involving 10,000 gallons (238 bbl) or more.

9 Spills from offshore pipelines were excluded.

10 These were the data that were available at the time of the preparation of this document.

11 Light oil included diesel, jet fuel, kerosene.

12 Heavy oil included heavy fuel oil, transmix.

13 The term "inland" is used to exclude offshore and exclusively marine pipeline spill incidents.

14 Parts of these analyses appeared in Etkin 2014 and Etkin 2017.

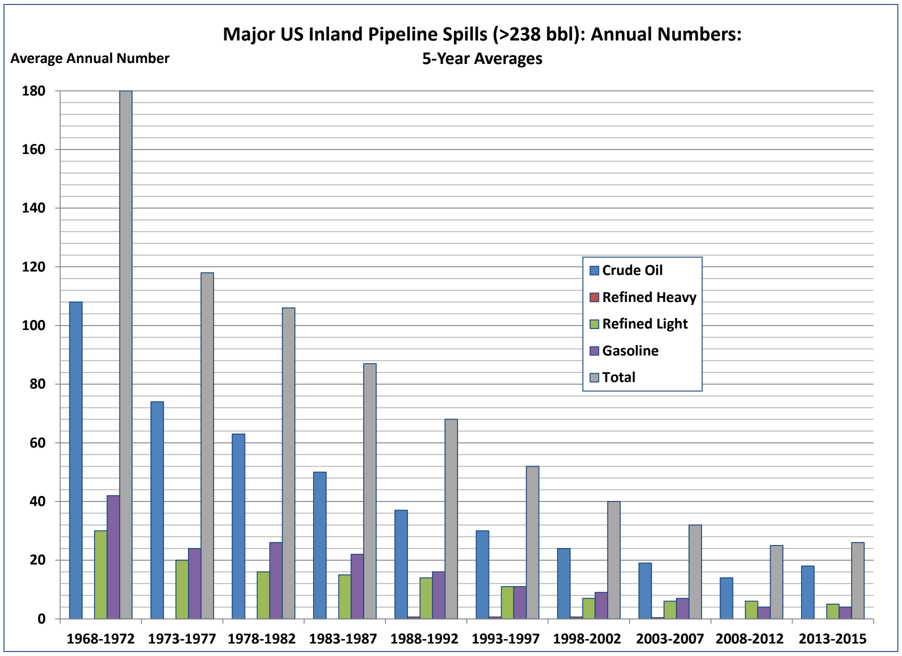


Figure 10.1-1. Significant U.S. Inland Pipeline Spills (>238 bbl): Five-Year Averages of Annual Spill Numbers

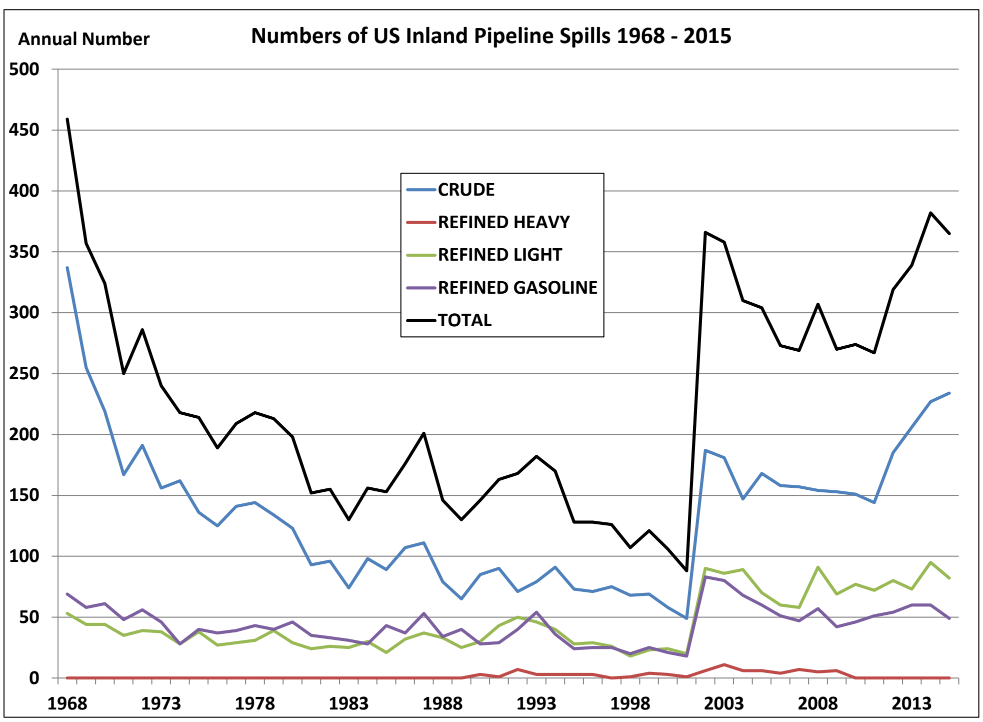


Figure 10.1-2. Annual Numbers of U.S. Inland Pipeline Spills (>1 gallon)

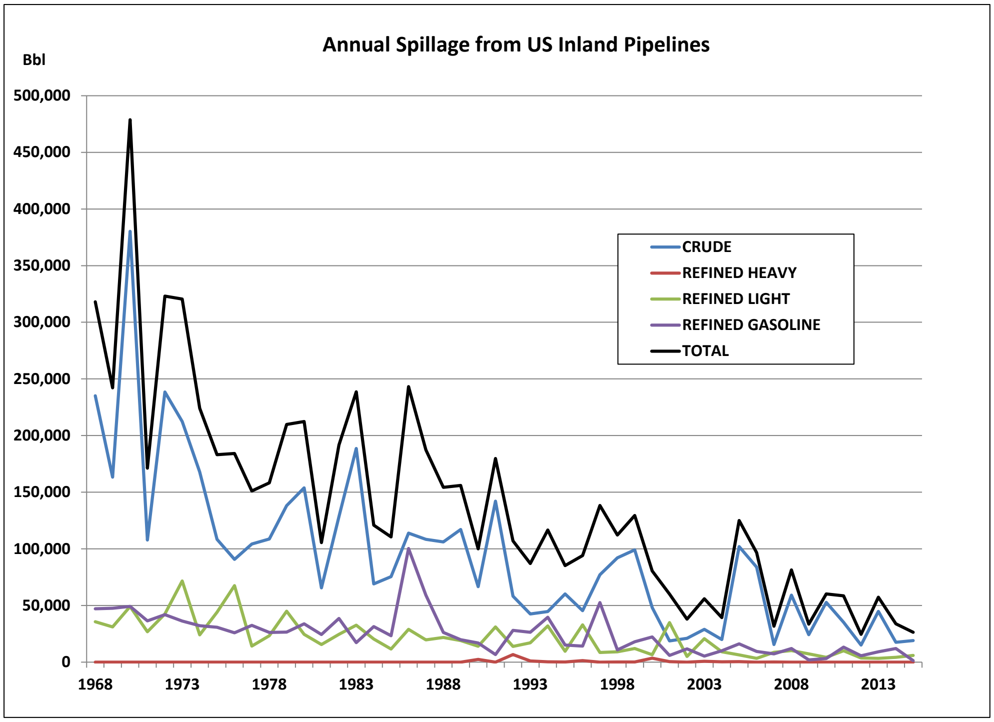


Figure 10.1-3. Annual Volume of Spillage from U.S. Inland Pipelines

10.1.3.1.3 Probability Distribution of Pipeline Spill Volume

The volumes of spills vary from a few drops or a small leak to a very large discharge. The distribution of volumes in the spills from inland oil pipelines over the years 1968 to 2015 indicates the majority of spills released less than 999 bbl, approximately 12 percent of spills ranged between 1,000 and 9,999 bbl releases, and less than 1 percent of spills involved releases of 10,000 bbl or more.

The cumulative probability distribution function of spill volume developed for spills in the last decade only (2006–2015), shown in Table 10.1-2, indicates a shift towards smaller spills in the last decade.

Table 10.1-2. Probability Distribution of Spill Volumes for U.S. Inland Pipelines (2006–2015)

Spill Volume	% Spill Incidents	Number Incidents
<1 bbl	33.51%	1,027
1-9 bbl	34.78%	1,066
10-99 bbl	18.76%	575
100-999 bbl	10.15%	311
1,000-9,999 bbl	2.58%	79
10,000-90,000 bbl	0.23%	7
100,000+ bbl	0.00%	0

10.1.3.1.4 Pipeline Spillage Rate per Volume Transmitted

To determine incident rates spillage should be viewed with respect to the amount of oil transported through pipelines, which also allows projections for future spillage rates. Two types of incident rates analyzed—spillage rate (volume of oil spilled per unit crude or refined product transported through pipelines) and incident frequency (numbers of spills per unit crude or refined product transported through pipelines).[15] Spill numbers, particularly crude spills, have increased since 1985. However, rates of significant spills (238 bbl and larger) have *decreased* (Figure 10.1-4). This may possibly be explained by increasingly higher reporting rates for smaller spills. Crude pipelines consistently have higher spillage rates than refined product pipelines.

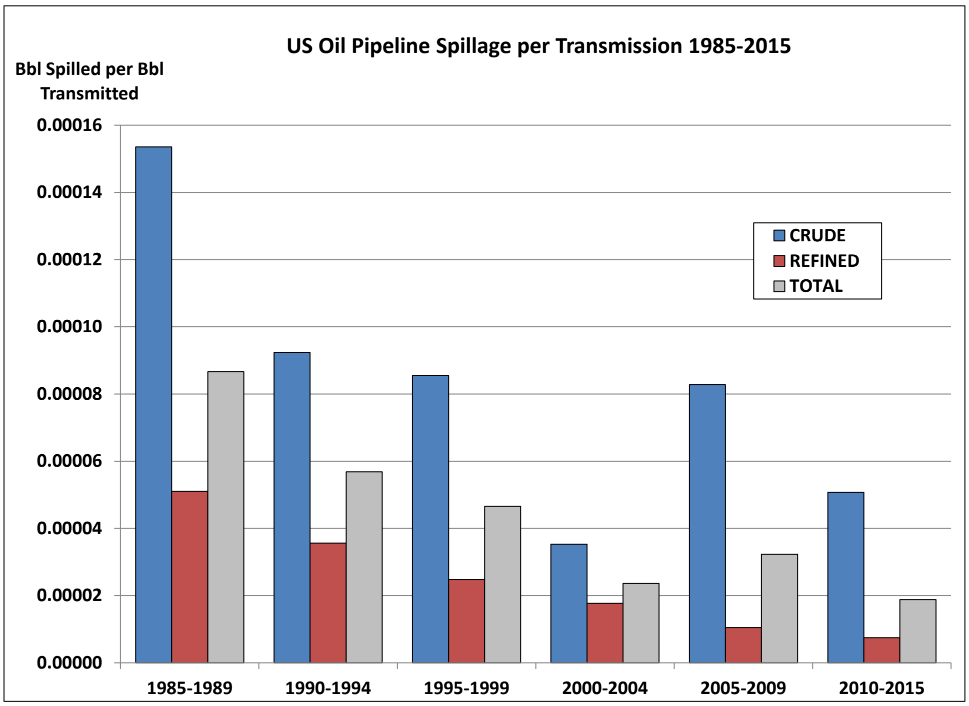


Figure 10.1-4. U.S. Inland Oil Pipeline Spill Number per Volume Transmission (1985–2015)

10.1.3.1.5 U.S. Inland Pipeline Spillage Summary

Based on the analytical results presented above, the following conclusions are reached concerning U.S. inland pipeline spills:[16]

- Each year, it can be expected that about 360 pipeline spills (of any volume) will occur, of which:
  - About 60 percent (216) would be crude spills;

[15] Oil pipeline transmission rates are from U.S. Energy Information Administration. In the U.S. Energy Information Administration data, refined products are combined into one category. Spill incidents from the various refined product categories are combined.

[16] Data from analytical results have been rounded to the nearest two significant digits.

  - About 25 percent (90) would be gasoline spills; and
  - About 15 percent (54) would be light refined product spills.
- Heavy refined product pipeline spills are relatively rare.
- Each year, throughout the U.S., it can be expected that there will be about 26 significant pipeline spills of at least 238 bbl (10,000 gallons), of which:
  - About 70 percent (18) would be crude spills;
  - About 15 percent (4) would be gasoline spills; and
  - About 15 percent (4) would be refined light product spills.
- Overall, half of the pipeline spills that do occur would be expected to involve 1 bbl or less. About 90 percent would involve 100 bbl or less. Only 5 percent would be expected to be 400 bbl or more, and only 1 percent would be expected to be 2,500 bbl or more.
- For future projections, assuming that pipeline operations and conditions are constant, any changes in spillage could be estimated from the number of spills per oil transmission and/or volumes of spillage per oil transmission:
  - Inland crude pipeline spills occur at the rate of about one pipeline spill (of any volume) for every 3.3 million bbl transmitted;
  - A significant inland crude pipeline spill of at least 238 bbl (10,000 gallons) might be expected once for every 42 million bbl of crude oil transmitted;
  - Inland refined product pipeline spills occur at the rate of about one spill (of any volume) for every 12.5 million bbl of refined product transmitted;
  - A significant inland refined product pipeline spill of at least 238 bbl (10,000 gallons) might be expected once for every 28 million bbl of refined product transmitted; and
  - About half of the significant refined product pipeline spills might be expected to be gasoline spills and the other half of light refined product spills.

10.1.3.2 Minnesota Pipeline Spill Analysis

The data presented thus far represent pipeline spills of both crude and refined products throughout the U.S. The following analyses specifically focus on crude pipelines that transit within and through Minnesota.

10.1.3.2.1 Minnesota Crude Pipeline Mileage in Comparison with Other States

According to PHMSA, the state of Minnesota currently has 2,416 miles of crude oil pipelines, making it the state with the seventh greatest crude transmission pipeline mileage. Its pipeline mileage is exceeded only by Texas, Oklahoma, California, Wyoming, Louisiana, and Kansas. In terms of “pipeline density,” i.e., the mileage of pipelines per square mile, Minnesota ranks eighth, exceeded by Oklahoma, Louisiana, Texas, Illinois, Wyoming, Kansas, and Mississippi. There is one crude pipeline mile for every 35 square miles of land in Minnesota. Oklahoma, Louisiana, and Texas—all oil-producing states—have 2.3, 2.2, and 1.8 times as many pipelines per square mile, respectively, in comparison with Minnesota.

10.1.3.2.2 Minnesota Crude Pipeline Spill History

During the years 1968 through 2016, there were a total of 118 crude pipeline spills (of one bbl or more) reported in Minnesota.[17] A total of 184,239 bbl of crude oil spilled in this time period. Over this whole time period, there has been an average of 2.45 spills per year, though the average annual number has increased in the last 10 to 20 years (3.5 spills per year since 1997, and 2.5 spills per year since 2007 compared to only 1.7 spills per year up to 1997). This may be an artifact of the data in that in the earlier years the reporting of pipeline spills was less rigorous. Smaller spills (of less than a few bbl) were not reported consistently.

The five-year average data are shown in Table 10.1-3. The average annual number of spills has increased; however, the average annual volume and the average volume per spill have both decreased.

The frequency distribution of spill volumes (volume for each individual incident) varies from 0.01 bbl (0.42 gallons or less than 2 quarts) to 40,500 bbl. Just over 69 percent of spill incidents involved less than 100 bbl, about 85 percent less than 1,000 bbl, and nearly 97 percent less than 10,000 bbl.

During the 49-year time frame, there were 32 significant crude pipeline spills (>238 bbl), of which three occurred in the last decade and eight in the last 20 years. These significant spills account for over 98 percent of the total volume of spillage. There have been no pipeline spills in excess of 238 bbl in Minnesota in the last six years. There have been no spills of over 10,000 bbl since 1991.

Table 10.1-3. Five-Year Average Crude Pipeline Spill Data for Minnesota

Years[a]	Annual Number Spills (1 bbl or more)	Annual Volume Spilled (bbl)	Average Volume/Spill (1 bbl or more)
1968–1972	2	3,270	1,318
1973–1977	2	10,565	3,470
1978–1982	1	6,831	4,472
1983–1987	2	1,880	1,120
1988–1992	1	8,214	8,158
1993–1997	2	1,178	455
1998–2002	4	2,551	818
2003–2007	5	976	192
2008–2012	3	1,363	257
2013–2016	2	31	14
Overall Average	**2.4**	**3,760**	**2,068**

[a] The period 2013-2015 is a four-year average.

[17] There were two spills of less than 1 bbl (0.21 bbl and 0.15 bbl) in 2016 and one spill of 0.76 bbl thus far in 2017 that are not included in this analysis.

10.1.3.2.3 Minnesota Significant Crude Pipeline Spills

Data on the 32 significant crude pipeline spills (>238 bbl) in Minnesota are shown in Table 10.1-4 in chronological order.

Table 10.1-4. Significant Crude Pipeline Spills in Minnesota (1968–2016)

Date	Operator[a]	County (City)	Bbl Spilled	Cause
12/8/1968	Enbridge	Red Lake	4,000	Defective weld
7/14/1972	Enbridge	Marshall	8,000	Equipment rupturing line
8/23/1972	Enbridge	Clearwater	3,000	Incorrect operation by carrier
9/9/1972	Enbridge	Carlton	700	Equipment rupturing line
8/13/1973	Enbridge	Marshall	17,000	Incorrect operation by carrier
9/5/1973	Enbridge	Kittson	400	Equipment rupturing line
9/11/1973	Enbridge	Polk	5,000	Incorrect operation by carrier
12/4/1973	Enbridge	Marshall	18,700	Other (no further information available)
7/12/1974	Enbridge	Clearwater	6,900	Defective pipe
4/3/1975	Enbridge	Clearwater	350	Other (no further information available)
11/4/1977	Koch	Todd (Staples)	4,398	Defective pipe
8/20/1979	Enbridge	Beltrami	10,500	Defective pipe
1/11/1980	Koch	Benton	11,847	Defective weld
6/26/1980	Enbridge	Kittson	2,400	Defective pipe
7/21/1982	Enbridge	Clearwater (Clearbrook)	9,200	Other (No further information available)
2/11/1984	Koch	Benton (Foley)	2,196	Defective pipe
11/7/1985	Koch	Anoka (Burns)	5,980	Other (No further information available)
2/10/1986	Koch	Dakota (Inner Grove Hts)	300	Failed weld
9/6/1986	Enbridge	Polk	265	Other (Contractor failed to tighten)
3/6/1987	Enbridge	Clearwater	500	Failed weld
3/26/1989	Enbridge	Pennington (Sanders Twp)	300	Failed weld
3/3/1991	Enbridge	Itasca	40,500	Other (Split in heat affect zone)
8/24/1996	Enbridge	Kittson (Donaldson Station)	5,000	Corrosion
1/3/1997	Marathon	Washington (Cottage Grove)	475	Other (Tank farm pipeline)
9/16/1998	Enbridge	Red Lake (Plummer)	5,700	Excavation damage
2/22/1999	Enbridge	Marshall (Radium)	400	Other (Loose bolts on flange)
7/4/2002	Enbridge	Itasca (Cohasset)	6,000	Material and/or weld failures
2/19/2004	Enbridge	Itasca (Grand Rapids)	1,003	Natural forces (earth movement)
6/27/2006	Koch	Morrison (Little Falls)	3,200	Other outside force damage
11/28/2007	Enbridge	Clearwater (Clearbrook)	325	Incorrect operation by carrier

Table 10.1-4. Significant Crude Pipeline Spills in Minnesota (1968–2016)

Date	Operator[a]	County (City)	Bbl Spilled	Cause
3/23/2008	Koch	Clearwater (Clearbrook)	1,600	Natural forces (earth movement)
12/4/2009	Koch	Todd (Staples)	5,000	Incorrect operation by carrier

[a] Minnesota Pipeline and Wood River Pipeline are grouped under Koch; Lakehead is grouped under Enbridge.

A summary of Minnesota crude oil pipeline releases of any size per incident type, barrels spilled, and barrel spilled per pipeline mile operated by Enbridge and all Minnesota operators is presented in Table 10.1-5.

Table 10.1-5. Minnesota Crude Oil Unintentional Spill Incidents 2002-2016[a]

Causes of Pipeline Failure	Number of Incidents	Bbl Spilled	Bbl Spilled/ Mile-Year[b]	Number of Incidents	Bbl Spilled	Bbl Spilled/ Mile-Year[b]
	All Minnesota Pipeline Operators			Enbridge		
Corrosion Failure	3	30	0.001	2	10	0.001
Equipment Failure	32	242	0.006	24	202	0.011
Excavation Damage	1	50	0.001	1	50	0.003
Incorrect Operation	17	5,410	0.136	10	397	0.021
Material Failure of Pipe or Weld	14	6,477	0.163	12	6,294	0.337
Natural Force Damage	14	2,675	0.067	10	1,052	0.056
Other Outside Force Damage	2	3,200	0.080	0	0	0.000
TOTAL	**83**	**18,085**	**0.455**	**59**	**8,005**	**0.429**

[a] Base on PHMSA incident data and operator reports.

[b] Barrel spilled per miles of pipeline in operation averaged over the years of the data set.

10.1.3.2.4 Comparison of Minnesota and U.S. for Significant Crude Pipeline Spills

The rate of significant crude pipeline spills (>238 bbl) in Minnesota was compared with the crude pipeline spillage in the U.S. as a whole for the last 16 years (2001 through 2016), and for the last seven years (2010 through 2016). The latter time period was selected because this was the only time frame for which state-specific pipeline transmission rates were available from PHMSA. Overall, the Minnesota crude pipeline rate was considerably less than that of the nation as a whole, with respect to spillage per pipeline miles and barrels transmitted (Table 10.1-6).

Table 10.1-6. Crude Pipeline Spillage: Minnesota vs. U.S. Nationwide[a]

Spill Rate[b]	Average 2001–2016			Average 2010–2016		
	MN	US	MN/US Ratio	MN	US	MN/US Ratio
Significant Spills/Pipeline Mile-Year	0.00023	0.0003	0.767	0	0.00026	0.000
Bbl Spilled/Pipeline Mile-Year	0.43	0.69	0.623	0.015	0.53	0.028
Significant Spills/Million Bbl Transmitted	0.0014	0.025	0.056	0	0.024	0.000
Bbl Spilled/Million Bbl Transmitted	4.3	56	0.077	0.16	51	0.003

[a] U.S. data is for all states inclusive of Minnesota.

[b] Pipeline mile-year is a mile of pipeline in operation for one year. Crude transmission bbl-miles for Koch and Enbridge based on PHMSA data for 2015 and mileage data.

10.1.3.2.5 All Crude Pipeline Spills (2000–2016)

Analysis of the data for crude pipeline spills of *all sizes* that occurred since 2000 indicates there were 91 spill incidents, with one incident occurring in 2017.[18] For the years 2000 through the present (end of June 2017), there were 91 incidents of which nearly 30 percent involved less than one bbl. The average spill volume was 201 bbl. The median (i.e., 50th percentile) was 2.0 bbl. For the years 2010 through the present, there were 37 incidents of which over 81 percent involved less than one bbl. The average spill volume was 7.8 bbl. The median was 0.54 bbl. The spill volumes have been significantly smaller since 2010.

10.1.3.3 Summary of Findings for Minnesota Crude Pipeline Spills

In order to quantify the incremental risk for the Line 3 Project, the potential spills that might occur need to be compared with the baseline of spills occurring from existing pipelines in the area. The analyses of historical data conducted in this chapter provide an overview of pipeline spill rates and trends in the inland U.S. as a whole for existing crude oil pipelines in Minnesota.

10.1.3.3.1 U.S. Crude Pipeline Spills

For crude oil pipeline spillage in the U.S. as a whole, the following conclusions were reached:

- There are about 53,045 miles of crude oil pipeline throughout the U.S.
- The frequency of crude pipeline spills in the U.S. has decreased significantly over the last 48 years.
- Crude pipeline spills have become increasingly lower in volume.
- Projecting into the future, half of the pipeline spills that do occur would be expected to involve 1 bbl or less, and about 90 percent would involve 100 bbl or less. Only 5 percent would be expected to be 400 bbl or more, and only 1 percent would be expected to be 2,500 bbl or more.

[18] There was one crude pipeline spill incident of 0.76 bbl reported for 2017 – on 5 June 2017 in Clearwater.

- Inland crude pipeline spills occur at the rate of about one pipeline spill (of any volume) for every 3.3 million bbl transmitted.
- A significant inland crude pipeline spill of at least 238 bbl (10,000 gallons) might be expected once for every 42 million bbl of crude oil transmitted.

10.1.3.3.2 Minnesota Crude Pipeline Spills

For crude oil pipeline spillage in Minnesota, the following conclusions were reached:

- Minnesota currently has about 2,416 miles of crude oil pipelines.
- Since 1968, there were a total of 118 crude oil pipeline spills of one bbl or more with a total of 184,332 bbl spilled.
- The annual number of reported pipelines has increased; however, this can be attributed to the increase in reporting of smaller spills that previously had not been reported.
- During 1968 through 2016, there were 32 significant pipeline spills (>238 bbl or 10,000 gallons).
- There have been no significant crude pipeline spills in Minnesota in the last six years, and no spills over 10,000 bbl since 1991.
- The rate of spillage in Minnesota has been lower than that in the U.S. as a whole, accounting for pipeline mileage and amount transmitted.
- The rate of significant spills per pipeline mile-year in Minnesota was 77 percent that of the U.S. as a whole during 2001 through 2016. There were no significant spills in 2010 through the present.
- The volume spilled per pipeline mile-year in Minnesota as 62 percent that of the U.S. as a whole during 2001 through 2016, and 3 percent that of the U.S. during 2010 through 2016.
- The number of significant spills per volume transmitted in Minnesota was 6 percent that of the U.S. as a whole during 2001 through 2016. There were no significant pipeline spills in Minnesota since 2010.
- The volume of spillage per amount transmitted in Minnesota was 8 percent that of the U.S. as a whole in 2001 through 2016, and 0.3 percent that of the U.S. as a whole since 2010.
- Since 2010, 62 percent of crude pipeline spills have involved less than 0.1 bbl (4.2 gallons); 81 percent have involved less than 1 bbl.
- A spill of less than 0.1 bbl might be expected once every four months; a spill of less than 10 bbl, once every 16 months; and a spill of less than 100 bbl once every 7.5 years.

Using a conservative (cautionary over-estimating) approach, it was estimated that the volumes of spillage in the seven hypothetical Line 3 spill scenarios—ranging from 8,625 bbl to 16,239 bbl—might be expected once in 26 to 99 years somewhere in the state of Minnesota. *This does not indicate that the incidents would occur at the specific sites selected for modeling.*

10.1.4 Release/Spill Volume Categories

For pipelines, the total volume of a release is influenced by several factors, including size of the breach, pipeline pressure, fluid properties (e.g., temperature and viscosity), time required to detect a release, time to isolate a leak and shut down the pipeline, distance between isolation valves, and effectiveness of the isolation (Stantec and Barr Engineering 2017). For rail, the total volume of the spill depends on the number of rail tank cars affected and the severity of the incident. A spill could be limited to the partial contents of a single tank car or the complete contents of many tank cars. Each tank car has a capacity of up to 800 barrels (bbl; 33,600 gallons) of oil. Therefore, a full unit train of 110 tank cars could transport 88,000 bbl (3.7 million gallons) of oil. For tanker trucks, most spills would be limited to the contents of a single tank. Tanker trucks can carry approximately 190 bbl of oil (7,980 gallons).

The five categories of spill sizes established for the assessment of crude oil releases in the EIS for the Line 67 Expansion Project (U.S. Department of State [DOS] 2017) were determined to be useful in the assessment of potential spills in this EIS as well. Categories for this EIS consist of the following:

- Incidental spills: less than 0.1 bbl (5 gallons);
- Small spills: equal to or greater than 0.1 bbl (5 gallons) and less than or equal to 50 bbl (2,100 gallons);
- Medium spills: greater than 50 bbl (2,100 gallons) and less than or equal to 1,000 bbl (42,000 gallons);
- Large spills: greater than 1,000 bbl (42,000 gallons) and less than or equal to 10,000 bbl (420,000 gallons); and
- Major spills: greater than 10,000 bbl (420,000 gallons).

Incidental spills (less than 0.1 bbl [5 gallons]) are considered minor by PHMSA and reporting is not required at that threshold (the minimum-volume reporting requirement that has been in effect since 2002); therefore, no historical data exist for incidental spills for use in the analysis described below. The behavior of small, medium, large, and major spills in the environment is discussed in Section 10.2.1.3.

10.2 BEHAVIOR OF CRUDE OIL RELEASES

When released into the environment, each type of crude oil exhibits unique behavior that depends on many factors. The primary factors that determine the fate of crude oil released into the environment (regardless of the transport mechanism from which it is released) include the chemical and physical differences between light and heavy crude oils, weathering of the oil over time, the type of environment into which oil is released (e.g., water versus soil), and the size of the spill. These factors are addressed in Sections 10.2.1 and 10.2.2. Section 10.3. presents a summary of the findings of Stantec et al.'s spill trajectory and fate modeling of large-volume crude oil releases (Stantec et al. 2017), including context for the analysis of potential exposures presented in Section 10.4.

10.2.1 Factors Affecting the Behavior of Crude Oil Releases

The physical and chemical properties of the crude oil are the primary influences in determining how a spill spreads and how long it lasts in the environment. These properties are addressed in Section 10.2.1.1. When crude oil is released into the environment, it is physically and chemically altered over time through various processes collectively called "weathering." These processes and their effects on crude oil in the environment are discussed in Section 10.2.1.2. The influence of spill size on crude oil behavior in the environment is addressed in Section 10.2.1.3.

10.2.1.1 Physicochemical Characteristics of Crude Oil

Crude oil is a complex mixture of thousands of compounds. An "average" crude oil contains approximately 84 percent carbon, 14 percent hydrogen, 1 to 3 percent sulfur, 1 percent nitrogen, 1 percent oxygen, and 0.1 percent minerals and salts (API 2011). Carbon and hydrogen are present in oil as a large group of compounds called hydrocarbons, which include alkanes (also called *paraffins*); cycloalkanes (also called *naphthenes*); aromatics, including benzene, toluene, ethylbenzene, and xylenes (BTEX); polycyclic aromatic hydrocarbons (PAHs); and polar compounds, including resins and *asphaltenes* (API 1999). The proportions of these compounds in a particular type of crude oil determine its propensity to evaporate or persist in the environment. The greater the percentage of the lighter compounds aromatics and alkanes, the more evaporates in the hours and days after spilling. These components also tend to be the more toxic parts of the oil. The heavier components, such as the PAHs and polar compounds are more persistent in the environment. The heavier components are also those that adhere to substrates and create the greatest difficulties for cleanup.

The following properties of crude oil differ based on the proportions of the above compounds present and affect its behavior in the environment.

- API gravity,[19] a measure of how dense an oil is compared to water (the lower the API, the denser the oil);
- Viscosity, a measure of how readily a crude oil will flow when released;
- Flash point, the lowest temperature at which a crude oil will vaporize and ignite in air;
- Vapor pressure, a measure of how quickly a crude oil will evaporate; and
- Solubility, a measure of the propensity of a crude oil to dissolve in water.

The proposed Project would transport crude oil ranging from light to heavy crude oil, with an assumed annual proportion of 65 percent heavy crude oil, including diluted bitumen (dilbit; see Section 10.2.1.1.2), and 35 percent light crude oil (Enbridge 2016a). The physicochemical properties of light and heavy crude oils differ, and these properties influence the fate, transport, and potential impacts of crude oil in the environment and toxicity to humans and other biological receptors as described below. Crude oils are further differentiated based on their sulfur content. Crude oils that contain less than 1 percent by weight total sulfur are referred to as "sweet," and those that contain more than 1 percent by weight total sulfur are "sour" (API 2011). Both light and heavy crude oils can be sour or sweet.

10.2.1.1.1 Light Crude Oil

Light crude oils are less dense than medium and heavy crude oils due to having a higher percentage of low-molecular-weight or "light" hydrocarbon fractions (i.e., alkanes, cycloalkanes, and BTEX). They are liquids at room temperature and tend to have a lower viscosity, higher API gravity, higher vapor pressure, higher water solubility, and higher flammability than heavier oils. This means a light crude oil released into the environment would likely float on water surfaces (high API gravity), evaporate more

[19] If a crude oil has an API gravity greater than 10, the oil is lighter than water and will float; conversely, a crude oil with an API gravity less than 10 will sink in water.

readily (high vapor pressure), and dissolve more relatively easily in water (higher water solubility). Under certain conditions, volatile components of light crude oil can ignite explosively (high flammability).

The light crude oils that the Applicant is proposing to transport via the Project would have densities ranging from an API gravity of approximately 30 to 45 (Enbridge 2016b). The Applicant provided examples of light crude oil that could be transported by the proposed Project and these include Bakken crude oil, North Dakota Sweet, High Sweet Clearbrook, Mixed Sweet Blend, Pembina, Gibson Light, Pembina Sweet Blend, Rangeland Sweet, Rainbow Light, Federated, Light Smiley, and Manitoba Sweet Tundra.

10.2.1.1.2 Heavy Crude Oil

In contrast to light crude oil, heavy crude oils and dilbits exhibit higher density, lower vapor pressure, lower solubility, and higher concentrations of nitrogen, oxygen, sulfur, heavy metals, and PAHs. The specific characteristics of heavy oils are attributed to the biodegradation process in which microorganisms on a geological time scale degrade light and medium hydrocarbons, concentrating PAHs, resins, and asphaltenes in the reserves. Heavy oils can also be created via physical rather than biological means. Water washing and phase fractionation physically remove the lighter petroleum fragments (Santos et al. 2014). The result is that heavy crude oils do not flow as easily as light crude oils. In addition, refining heavy oils is more difficult and costly and produces lower proportions of high added value products such as liquefied petroleum gas, gasoline, kerosene, and diesel (Santos et al. 2014).

The most viscous heaviest and thickest of the heavy crude oils is bitumen from oil sands. In its original state, bitumen is dense and requires unique handling, which involves the addition of diluting agents (diluent) to facilitate transport. Bitumen is separated from its host rock or sand by heating, which reduces its viscosity and allows it to flow to a collection point. It is too dense and viscous for transportation by pipeline without heating or altering the material. To reduce viscosity and density, a diluent must be added to facilitate its flow.

Bitumen is mostly composed of larger heavy hydrocarbons with an API gravity of typically < 10 degrees. Alberta bitumen has an API gravity as low as 8 degrees (Environment Canada 2013). Diluents are composed of light hydrocarbons such as natural gas condensate and naphtha, which increase the API gravity of the dilbit to around 23 degrees. The resulting dilbit is a highly viscous oil similar in appearance to other heavy crude oils, but with unique properties specific to dilbit. Typically, dilbit consists of approximately 30 percent diluent and 70 percent bitumen (Crosby et al. 2013). Natural gas condensate (a byproduct of natural gas production) is currently the primary type of diluent used for Canadian heavy crude oil and is composed of hydrocarbons such as propane, butane, pentane, and hexane (Crosby et al. 2013).

However, different diluents may be used at different times of the year or under varying circumstances to change the nature of the resulting blend and to accommodate environmental conditions, particularly ambient temperatures. For example, there are Summer and Winter Blends of Cold Lake Diluted Bitumen that have somewhat different properties. Cold Lake Summer Blend has an API gravity of 20.73 (a density of 0.9295). Cold Lake Winter Blend is lighter with an API gravity of 22.69 (a density of 0.9177) (based on information in the Crude Monitor 2016.) Note that both blends are lighter than fresh water and will float. Oil with an API gravity of 10 degrees or higher are less dense than fresh water at 15^{o}C and will typically float (Environment Canada 2013).

10.2.1.2 Weathering Processes

Immediately following the release of crude oil into the environment, the weathering process begins. This is a process in which the physical and chemical characteristics of the oil interact with the physical and biochemical features of the environment it has reached. This interaction determines how the oil will behave and its fate in the environment, with the rate and degree of weathering dependent on the crude oil type and environmental conditions at the spill location. The following weathering processes, which are illustrated in Figure 10.2-1, influence how crude oil behaves:

- **Spreading and thinning** of spilled oil reduces the amount of oil in one location but increases the surface area over which oil is present. This increased surface area enhances surface-dependent fate processes such as evaporation, biodegradation, photodegradation, and dissolution. Spreading from the spill source is constrained by natural conditions in the release site vicinity. For instance, oil reaching rivers and creeks would likely spread farther than in wetlands, ponds, and lakes. Lighter oils would also likely spread more quickly than heavier oils due to their lower viscosities.
- **Adhesion** of oil to surfaces, such as shorelines, vegetation, and other surfaces along the spill path also reduces the spill volume and increases surface area for surface-dependent fate processes but accounts for a large portion of the spill impacts. Adhesion also allows for accumulation of sediment particulates, vegetation and other matter which promotes the formation of petroleum masses, such as tar balls.
- **Dispersion** includes the entrainment of oil droplets in the water column (i.e., the spreading of oil vertically in water) as well as mixing of oil and dissolved fractions in the water column. It is enhanced by the turbulence or mixing energy of a waterbody, which is increased by rain events, wind, and water currents. Oil can also be dispersed through adhesion to particulate matter (e.g., organic matter, silt, and clay) suspended in the water column. Light oil tends to produce smaller oil droplets due to its lower viscosity compared to heavy oil and is more prone to dispersion.
- **Evaporation** occurs when the lighter components of crude oil volatilize. Evaporation begins as soon as oil reaches the environment, and approximately 80 percent of evaporation occurs in the first 48 hours following a release. It results in a heavier, denser, and more viscous oil remaining in the environment as compared to the released oil. Evaporation is greater and more rapid for light crude oils because they contain a greater percentage of light constituents than heavy oils, which do not evaporate as readily.
- **Dissolution** occurs as water-soluble components dissolve into the water column from a surface slick. It is estimated that only 2 to 5 percent of spilled oil in water undergoes natural dissolution following a release because the compounds that most readily dissolve (e.g., BTEX) also most readily evaporate (Neff 1990). However, these compounds are also the most toxic to aquatic life. Dissolution increases with decreasing hydrocarbon molecular weight, increasing water temperature, decreasing salinity, and increasing concentration of dissolved organic matter. Because light crude oils contain a higher proportion of BTEX compounds than heavy oils, they are more prone to dissolution.
- **Emulsification** creates mixtures of small droplets of oil and water known as emulsions. Two types of emulsions, water-in-oil (also referred to as a mousse) and oil-in-water, are formed by wave action. Emulsions are not prone to other types of weathering, leading to increased crude oil persistence in the environment. Emulsification occurs less frequently in fresh water than in

saltwater, and it occurs more frequently in large waterbodies with more wave action and currents than in smaller waterbodies. Heavy crude oils that contain higher concentrations of heavy asphaltenes and resins emulsify more readily than light crude oils (API 1999).

- **Photodegradation** occurs when ultraviolet light from the sun breaks down the chemical bonds of the oil constituents. This process, which is a pronounced component of weathering on sunny days and in summer months, can be a significant factor in the degradation of lighter hydrocarbons and, therefore, lighter crude oils. Photodegraded compounds tend to be more water soluble and more prone to further degradation processes. Photodegradation has also been shown to increase the toxicity of certain PAHs (NOAA 2017a).
- **Adsorption** is the binding of oil to particles in soil, sediment, and water. In water, PAHs and other higher-molecular-weight hydrocarbons may bind to suspended particulates, and this process can be substantial in highly turbid or eutrophic waters (i.e., waters rich in phosphates, nitrates, and organic nutrients). Organic particles in soils or suspended in water tend to be more effective at adsorbing oils than inorganic particles (e.g., clays). Adsorption and sedimentation decrease the concentration of hydrocarbons present in the water column but also make them less susceptible to further degradation, increasing persistence in the environment.
- **Biodegradation** is the breakdown of oil compounds by naturally occurring microorganisms. This is not a substantial process in controlling the fate of crude oil released into waterbodies previously unexposed to oil. Saturated alkanes, which are more prevalent in light crude oils than in heavy crude oils, are the most readily biodegraded components of crude oil. Thus, while this process is very slow for all crude oils, heavy oils are less susceptible to biodegradation than light oils.

10.2.1.2.1 Effect of Weathering on Dilbit

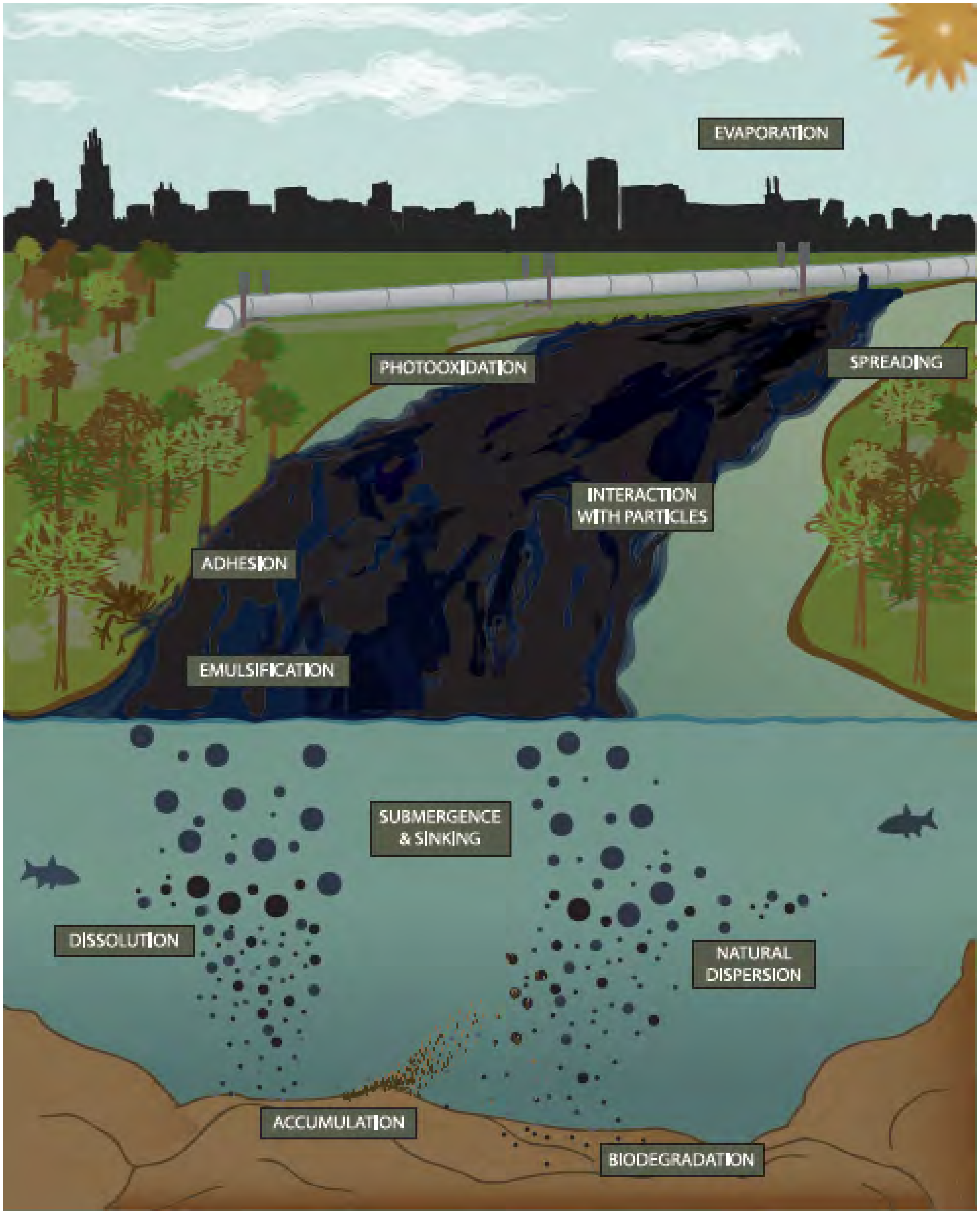
When a conventional heavy crude oil reaches the aquatic environment, the amount that is typically lost to evaporation will be dependent on the composition of the oil and its vapor pressure. Generally, heavier crude oil is less likely to evaporate than light crude oil. Dilbit, however, is different than heavier crudes in that it contains more of the lighter components that have been added in the diluent. These lighter components typically evaporate when exposed to air. However, once the lighter components of dilbit evaporate, the remaining heavier fraction may sink if the density of the remaining oil exceeds that of fresh water (1.0 grams per milliliter).

There are two main mechanisms by which any oil, including dilbit, may sink or become submerged (suspended below the water surface in the water column)—through increases in density due to evaporation and by combining with heavier sediment or particles. The possibility of sinking or submergence of oil is a major concern as it can significantly complicate cleanup operations.

The nature of dilbit as it weathers has been the subject of considerable debate and research. Some research has indicated that as dilbit weathers, it exhibits bimodal behavior as diluent volatilizes and bitumen dominates the chemistry of the weathered oil (Fingas 2015a). According to a review conducted by the Royal Canadian Society (2015), “current questions include whether blending bitumen with a diluent yields a homogeneous fluid equivalent to a conventional heavy oil and, conversely, whether loss of diluent restores dilbit to the original bitumen composition and properties.”

There is considerable debate whether 100 percent of the diluent component of bitumen blends can actually be lost by natural evaporation (Fingas 2015b; King et al. 2014) or whether the residual bitumen/heavy oil will retain some of the diluent components as intimately blended constituents, conferring novel properties on the partially weathered oil (Winter and Haddad 2014). This is particularly important for predicting if weathered dilbit or other diluted bitumen variations will float or sink in water. It is possible that some higher molecular weight components of the diluent would be retained in the weathered oil, but at concentrations too low to significantly change the physical behavior of the residual oil compared with the original bitumen or heavy oil stock.

It is possible that there would be sufficient evaporation of lighter hydrocarbon components that the remaining portions of the oil would have densities greater than that of fresh water. If this occurs, it would generally occur after several days had passed and at least 30 percent of the oil had evaporated (Hollebone 2015).



Source: National Academies of Sciences, Engineering, and Medicine 2016

Figure 10.2-1. Diagram of Crude Oil Weathering Processes

Sinking and submergence of oil may occur when it comes in contact with particles and sediment. The formation of oil-particle aggregates (OPAs) can occur with any type of oil, including dilbit, even when its density is less than that of the water, particularly under turbulent underwater conditions (National Academies of Sciences, Engineering, and Medicine 2016). The spill of dilbit in Marshall, Michigan, involved the release of the Cold Lake Blend and Western Canadian dilbit products into a river experiencing flooding, turbidity, high velocities, and high water volumes. In that case, some of the oil floated, some submerged, and some sank.

Water temperature may also affect the likelihood of sinking and submergence. Weathered dilbit has been shown to be more likely to sink in cooler water (Short 2013).

Besides potential submergence and sinking, another property of weathered dilbit that is of concern is its adhesion potential. When diluted bitumen weathers, its adhesion increases significantly so that it sticks to substrates and surfaces that it contacts (Hollebone 2015; Environment Canada 2013). The adherence of spilled dilbit to shorelines, subsurface features, aquatic vegetation, and other surface complicates the cleanup process, but it also means this portion of the spill doesn’t travel as far downstream. Adherence and coating of organisms, such as turtles, amphibians, insects, birds, and mammals can have a significant effect on the degree of natural resource damages.

In general, the toxic properties of both bitumen and diluents are similar to those of other crude oil products, including conventional heavy crude; however, little research has been conducted specifically on the toxicity of dilbit to organisms. The components of the diluents are commonly found in other crude oils. Both crude oil and bitumen may contain several potentially toxic metals, stable and persistent resins, and asphaltenes.

In the event of a land surface release, the dispersion of dilbit through soils would be slower than for other crude oils, including heavy crude oils with similar viscosities; light and medium crude oils would penetrate soils the fastest (Tsaprailis 2014). Immediately upon release, dilbit behaves much like heavy crude oil; however, weathering, temperature, and dispersion alter its properties, causing it to behave more like the original bitumen. As the diluent components volatilize, the heavier components of dilbit remain and the increasing viscosity results in slower spreading and greater adherence to soil particles. Heavy crude oils may lose up to 10 percent of their initial volume following a spill due to evaporation in the first few days (National Research Council 2003). Dilbit has been shown to lose between 11.7 and 15.9 percent of its mass within the first 6 hours of a release (Environment Canada 2013).

The heavy crude oils that the Applicant is proposing to transport via the Project would have API densities of approximately 21 to 25 (Enbridge 2016b). The Applicant provided examples of heavy crude oil that could be transported by the proposed Project; these include Premium Conventional Heavy, Conventional Heavy, Cold Lake Blend (dilbit blend), and Cold Lake Winter Blend (dilbit blend).

10.2.1.3 Influence of Spill Size on Crude Oil Behavior

Different spill sizes influence the transport, fate, and potential environmental consequences of a release. This section describes behavior of releases from small to major spills using the categories of spills defined in Section 10.1.3.

10.2.1.3.1 Small Spills

Small spills are defined as spill volumes greater than or equal to 0.1 bbl (5 gallons) and less than or equal to 50 bbl (2,100 gallons). These are the most common and most likely release volumes for the Project and its alternatives. Small spills tend to affect limited areas and dilute quickly in the environment as they spread and disperse. Despite the limited range of effects, small releases can persist in the environment for long periods of time and can cause localized contamination requiring cleanup and remediation.

10.2.1.3.2 Medium Spills

Medium spills range from greater than 50 bbl (2,100 gallons) to less than or equal to 1,000 bbl (42,000 gallons) and are less common than small-volume releases (DOS 2017). Medium spills on land or water would likely spread and disperse over a greater area than small spills. A medium spill on land could result in oil adsorbing or otherwise adhering to soil particles and being transported over extended distances by processes such as wind or water erosion. A medium spill in water could cause oil to spread over a greater area of shoreline and water surface and a higher concentration of oil to be dispersed within the water column as compared to a small spill.

Tanker trucks can carry approximately 190 bbl of oil (7,980 gallons); therefore, the majority of spills from tanker trucks would likely fall within this spill category, as it is unlikely that multiple tanker trucks would crash at the same time in the same place. Medium spills could also result from rail car accidents involving the compromise of a single tank car, which has a capacity of up to 800 bbl (33,600 gallons). Pipeline damage resulting from outside forces such as excavators and major earth movement or corrosion of the pipe could result in spills within this size class.

10.2.1.3.3 Large Spills

Large releases could result from rail car accidents involving more than one tank car. The failure of 12 tank cars in a unit train could release up to 9,600 bbl (403,200 gallons) of crude oil. Pipe damage resulting from outside forces such as excavators and major earth movement, or corrosion of the pipe, could also result in a large spill.

Large spills can result in significant volumes of crude oil on the ground surface, which could migrate over the land surface and affect vegetation, soil invertebrates, and other receptors of concern (DOS 2014). Rapid response and cleanup of these incidents would reduce the exposure and impacts on resources. Large spills along a subsurface pipeline can result in movement of oil through soils, contact with the water table, and impacts on groundwater resources adjacent to and beyond the vicinity of the release location and pipeline trench (DOS 2014). Vertical upward migration can result in substantial accumulation of crude oil on surface soil, migration along the ground surface, and potential impacts on vegetation and other receptors. Oil may pool in low-lying areas and infiltrate into the soil and contact groundwater (DOS 2014). Large spills from a rail accident would begin at the soil surface but could spread downward into the soil, depending on the properties of the oil. Even with such soil infiltration, with this volume of oil, the spill could spread overland to contaminate water sources.

10.2.1.3.4 Major Spills

Major spills are defined as spills greater than 10,000 bbl (420,000 gallons). The release of this volume of crude oil could result from catastrophic pipeline ruptures or a rail incident that breaches more than 12 cars. For pipelines, very large releases are assumed to result with the release of the total volume of crude oil from the pipeline segment between the two nearest shutoff valves. Major spills from pipelines could occur as the result of a complete break in the pipeline from major earthquakes, flooding, bank erosion or scouring at waterbody crossings, mechanical damage during third-party ground-disturbing activities, or vandalism, sabotage, or terrorist acts. Major pipeline ruptures can be defined as low-probability, high-consequence events in the context of risk assessment.

Major spills from rail transport could occur as the result of major environmental events (e.g., earthquake, flooding), rail breakage, bridge collapse, track operational malfunctions due to human error, collisions with other trains or vehicles at crossings, or mechanical damage from vandalism or sabotage of the tracks by the public or terrorists.

As with other spill sizes, the extent of oil exposure and resulting potential effects in the environment can vary based on a multitude of factors (e.g., type of crude oil, crude oil behavior, environmental conditions, and presence of resources and receptors; discussed in detail in the sections below), including spill prevention, preparedness, and response (Section 10.5). In the event of a crude oil spill, rapid and well-coordinated response actions can effectively contain and control the release, thereby reducing potential environmental impacts. The potential effects of a major spill would be similar in nature, but greater in scale (i.e., extent of exposure and adverse effects on environmental and human receptors) than large spills. A major spill would tend to migrate farther from the incident location, potentially affecting greater areas of land, water, and subsurface soil and groundwater. Oil could infiltrate deeper into soil with greater impacts on groundwater, including drinking water sources (DOS 2014).

Major spills of oil released directly into waterbodies, such as at surface water pipeline crossings or at railroad bridge crossings of rivers, would result in the majority of the oil being transported beyond the release location, especially under high-flow conditions, with substantial transport potential (DOS 2014).

10.2.1.4 Pinhole Releases

Enbridge funded a study on failure probabilities related to potential pinhole leaks (Stantec and Barr Engineering 2017). The study is available online on the DOC-EERA Project website (https://mn.gov/commerce/energyfacilities/line3/), on the Project eDockets site (Line 3 Route Permit PUC eDockets), and by CD included with hard copies.

One objective of the pinhole release work (Stantec and Barr Engineering 2017) was to provide information on the possibility of a release occurring that was below the pipeline supervisory control and data acquisition (SCADA) detection threshold[20] and would also not be detected with routine surveillance methods until sufficient release had occurred to present a readily visible oil plume. For a physical perspective, a pinhole is characterized a "1/32-inch hole" (Stantec and Barr Engineering 2017). The work characterized the anticipated frequency, potential causes, size, rate of release, and maximum release volume from potential pinhole releases. The work determined that release volumes from small-flow releases ranged between 633 to 4,900 bbl, at 1 to 0.1 percent of 760,000 bbl per day throughput respectively, with a range of corresponding release times from 120 min to 14 days. The 1/32-inch pinhole leak was estimated to 784 bbl before detection 28 days after the start of release.

Small spills could result from pinhole releases of crude oil from subsurface pipeline segments. Subsurface pinhole releases would typically disperse to soil and more permeable trench materials immediately surrounding the pipeline (DOS 2014; Stantec et al. 2017). Where pipelines are in shallow

[20] The SCADA system, in conjunction with computational pipeline monitoring or model-based leak detection systems are designed to detect leaks to a level of approximately 1% of the pipeline flow rate.

water tables, released oil would migrate upward; eventually reaching the surface where visual detection and response would occur (Stantec et al. 2017). In areas of deeper water tables, the release typically migrates radially outward from the release and down-gradient until it reaches groundwater where it will travel laterally with ground water flow but potentially at a slower rate (Cozzarelli et al. 2001).

If pinhole releases remain undetected for long periods of time, ultimately releasing volumes that would be classified as medium or even approaching large spills if the released oil does not reach the surface for long periods of time. Unnoticed pinhole leaks can lead to the infiltration of crude oil through unsaturated, permeable soils and result in contact with the water table and surficial groundwater aquifers (DOS 2014; Stantec et al. 2017; Exponent 2013). Surficial aquifers where overlying geologic materials are more permeable are generally most susceptible to contamination from a pinhole release of crude oil (Stantec and Barr Engineering 2017). Pipelines monitored with SCADA systems, in conjunction with computational pipeline monitoring or model-based leak detection systems, greatly lower the potential for long undetected releases.

10.2.2 Crude Oil Behavior in the Environment

The general behavior of crude oil that is released into the terrestrial, aquatic, and human environment is described below. Section 10.4 discusses these aspects of oil behavior and the potential effects of a spill on specific resources.

10.2.2.1 Terrestrial Environment

When crude oil spills onto land or into soils beneath the ground surface, its movement will depend on the soil type, oil viscosity, and the depth to the water table (National Academies of Sciences, Engineering, and Medicine 2016). Dilbit and other heavier crude oils would disperse more slowly than lighter crude oils in terrestrial environments due to their higher viscosity. Because dilbit contains a higher concentration of asphaltenes and resins compared to light oils, it is not as prone to evaporation and is, therefore, more persistent in terrestrial environments.

Spilled oil will typically spread over land until it reaches a depression, a surface waterbody, or is absorbed into the ground. In addition to topography, migration of the oil can be affected by vegetation cover and seasonal conditions.

Oil released on land is typically more easily contained than oil released into water. The rapid installation of containment features (e.g., dikes, impoundments, and physical barriers) around the spill area deters spreading and enhances clean-up activities.

10.2.2.2 Aquatic Environment

Oil spilled into surface waterbodies generally floats initially and is transported by winds and currents, depending on the waterbody type and conditions during the spill. Spills tend to spread shorter distances in standing water such as lakes and ponds with minimal currents; however, wind can increase oil dispersal in those surface waters. Currents in streams and rivers transport oil downstream, and thus impacts are likely to occur over greater areas than in lakes or ponds. However, crude oil concentrations in the water decrease as the oil thins out during spreading or adheres to shorelines and other surfaces. Both dilbit and light crude oil would be expected to initially float. Evidence from previous dilbit spills (in Marshall, Michigan, in 2010 and Burnaby, British Columbia, Canada, in 2007) has shown that dilbit floats on water until its density is altered by weathering or the entrainment of sediment, which can cause the oil to submerge and sink (Witt O'Brien's et al. 2013).

As the time after a release increases, multiple processes act to entrain oil and its constituents into the water column, which in turn affects water quality and aquatic biota. Although most of the compounds in oil are insoluble, BTEX and some of the lighter PAHs are volatile and soluble in water and can contaminate the water column. Turbulence, which is common in rivers and streams, is a key process that enhances dissolution of oil constituents, particularly BTEX. In lakes and larger rivers, wind-driven waves can also create turbulence that drives crude oil downward and facilitates dissolution of BTEX in the water column (Witt O'Brien's et al. 2013). Therefore, in larger, fast-moving rivers and creeks, oil would be quickly dispersed downstream and diluted with the flow of the river, while in smaller flowing streams and backwater eddies an oil spill could have a greater effect on the water column and surrounding habitat due to the lower relative volume and rate of water flow.

As crude oil mixes with water it forms emulsions that are thicker and stickier than the original oil. Over time, winds, waves, and currents continue to spread and disperse the emulsified oil patches into smaller pieces, or "tarballs," which are very persistent in aquatic environments (NOAA 2017b). As dilbit weathers and the condensate component evaporates, its density increases has a greater tendency to submerge in comparison to lighter crude oils. As with heavy crude, dilbit's asphaltenes, waxes and resins increases its potential for accumulation and the formation of petroleum bodies (National Academies of Sciences, Engineering, and Medicine 2016).

Wetlands, including marshes, swamps, peat bogs, and fens, are particularly sensitive to oil spills. In wetlands, small areas of shallow water, finer sediments with high organic content, greater vegetation cover, and high biochemical oxygen demand (leading to anaerobic conditions) would affect the dispersion and weathering of spilled crude oil. Oil spilled into wetlands could be widely dispersed by wind or water movement, and would typically become stranded on fine sediments or vegetation. In this case oil would not likely travel as far as it would in open water. Transport out of the wetland may occur via small stream discharge points. If the spilled oil becomes entrained within anaerobic sediments, the rate of biodegradation may be significantly reduced (Boufadel et al. 2015).

Oil released into aquatic environments is more difficult to recover in large quantities because water surface and weather conditions must be sufficiently calm to permit recovery equipment to function well and for response personnel to safely operate the equipment (International Tanker Owners Pollution Federation Limited 2016).

10.2.2.3 Human Environment

Crude oil can reach public and private lands used for commercial, agricultural, industrial, residential, and recreational purposes. Water intakes in shallow lakes and rivers can be susceptible to contamination from an oil spill, and paved surfaces and conduits such as ditches/sewers can act as preferential pathways for spills, extending the spread of oil. If a crude oil spill occurs in a developed area, oil can migrate into stormwater and sewer collection systems, particularly during rain events, and result in contamination of the infrastructure and associated treatment systems.

Spills in agricultural and other developed areas tend to pool in areas with flatter topography but can spread through ditches, small streams, and groundwater if the water table is reached. If a spill reaches groundwater, constituents in the crude oil may dissolve and migrate farther underground, forming a contaminated plume that follows the general direction of groundwater flow. The contaminated groundwater can intersect with groundwater wells or reach surface water, making water supplies potentially unsafe, depending on the degree of contamination. In karst regions, groundwater may flow more rapidly than in other areas, increasing the risk of contamination.

Without remediation, groundwater contamination can persist for lengthy periods of time. For example, a crude oil spill from a pipeline rupture in 1979 contaminated a shallow aquifer near Bemidji, Minnesota. Despite initial cleanup, the spill continues to be a source of contaminants to a shallow outwash aquifer. This release has been used as a research project to study the fate and transport of crude oil in groundwater. These studies to track the oil have shown that the groundwater contaminant plume has migrated a total distance of approximately 600 feet from the release point in 38 years. This is primarily because the plume is moving as dissolved petroleum constituents in groundwater and as vapors in an unsaturated zone, and that native microbes are converting the oil derivatives into carbon dioxide, methane, and other biodegradation products (U.S. Geological Survey 2017). This has resulted in a steady state system where the plume is no longer expanding appreciably.

10.2.2.4 Review of Observed Impacts from Historical Spills

Immediate and long-term monitoring, experimental studies, and response efforts following various historical spills provide an overview of potential spill-related impacts. Over 20 historical spills and associated reports and literature were evaluated (Enbridge 2016d). The impacts discussed below were observed from spills including, but not limited to, the following:

- **Bemidji, Minnesota** – August 20, 1979: the Enbridge Line 6 crude oil pipeline burst and released approximately 10,700 bbl of light crude oil.
- **Cass Lake, Minnesota** – Roughly 25 miles from the Bemidji spill site; an estimated 1,150 bbl of crude oil were released to the water table at a crude oil pipeline pumping station. The long-term leak was discovered in 2002. The leak onset is not known precisely, but occurred sometime after pipeline construction in 1971.
- **Wabamun Lake, Alberta, Canada** – August 2005: a train derailment resulted in the release of 4,500 bbl of heavy, high-viscosity fuel oil.
- **Marshall, Michigan** – June 2010: rupture of Enbridge Line 6B released 20,000 bbl of heavy crude oil with 30 percent diluent (combined Western Canadian Select and Cold Lake Blend dilbit).
- **Red Deer River, Alberta** – June 2012: exceptionally high river flows eroded and ruptured a Plains Midstream Canada pipeline adjacent to Jackson Creek, a tributary of the Red Deer River, releasing 2,900 bbl of light crude oil.
- **Asher Creek**, **Missouri** – August 1979: a release of 9,500 bbl of crude oil occurred from a burst pipeline.
- **Pine River, British Columbia, Canada** – August 2000: a rupture of a Pembina Pipeline Corporation pipeline resulted in approximately 2,800 bbl of sour light crude discharging into the Pine River.
- **Fort McMurray, Alberta** – June 2013: a break in the Enbridge Line 37 pipeline released approximately 1,300 bbl of light crude oil.

- **Moose Jaw, Saskatchewan, Canada** – January 1974: a crude oil pipeline break released 15,725 bbl of heavy crude oil.
- **Cayuga Inlet, New York** – November 1997: a train derailment resulted in 167 bbl of spilled diesel fuel.
- **Grand Rapids, Minnesota –** March 1991: a Lakehead Pipeline Company pipeline ruptured and released 40,000 bbl of crude oil into the Prairie River during winter months.
- **Rainbow Pipeline, Alberta** – April 2011**:** release of 28,300 bbl of sweet crude oil occurred from a Plains Midstream Canada pipeline into a muskeg area.
- **Glenavon, Saskatchewan** – April 2007: a release from Enbridge Line 3 of 6,200 bbl of heavy crude oil occurred.
- **Ashland Oil Facility**, **West Elizabeth, Pennsylvania** – January 1988: a spill tank failure at the facility released nearly 24,000 bbl of diesel fuel into the Monongahela River.
- **Burnaby, British Columbia** – July 2007: rupture of the Trans Mountain Pipeline sprayed dilbit 40 to 50 feet in the air for 25 minutes.

The subsequent sections (10.2.2.4.1 through 10.2.2.4.17) describe observed impacts from these spills and others with respect to environmental receptors, including elements of the physical, biological, and human environment. Physical receptors include air quality, groundwater, lakes, rivers, sediment, shorelines and riparian banks, wetlands, and soils. Biological receptors include terrestrial plants, benthos, fish, aquatic plants, amphibians and reptiles, birds, and semi-aquatic mammals. Human receptors include human health and land resource uses.

10.2.2.4.1 Air Quality

Previous spills highlight the rate, timing, and magnitude of evaporation following crude oil releases. In general, the greatest evaporation rates, and thus greatest potential for air quality impacts, occurred immediately after the release and declined with time. Most or all of the evaporation commonly occurred within the first few days to weeks of the release. In the case of the Exxon Valdez spill in Alaska on March 24, 1989, volatile compounds (e.g., BTEX) evaporated within the first few hours of the spill, and less volatile compounds (i.e., those with longer hydrocarbon chains) evaporated over the first two weeks (Hanna and Drivas 1993). Similar evaporation rates were observed for other spills, including the Silvertip Pipeline Spill in Laurel, Montana, in 2011, where all volatile compounds had evaporated within 4 days of the release. Laboratory experiments following the 2010 Marshall, Michigan, spill showed that 75 to 85 percent of volatiles from dilbit evaporated within 6 hours, with additional loss occurring over the following few days (Zhou et al. 2015).

The spill volume and original concentration of volatile compounds within the crude oil were most likely to affect the local air concentrations of volatile compounds during the period immediately following the spills. Environment Canada found that evaporation rates of volatile compounds were largely a function of volume released, and had little relation to spill area, spill thickness, or wind speed. Light, medium, and heavy crude oils respectively lost 75, 40, and 5 percent by volume over the first few days following a release (Fingas 1999). In contrast, evaporation of less volatile compounds can be increased by wind and higher temperatures. In the case of the Wabamun Lake spill, the amount of evaporation was negligible over a few days.

Following the Marshall, Michigan, spill, Enbridge conducted extensive air quality monitoring for about a month after the spill in nearby residential areas. During the voluntary evacuation period (July 29 to August 17, 2010) and in the residential areas in the immediate release vicinity, 62 of 1,619 measurements exceeded the screening level for benzene and 70 of 1,747 samples exceeded the screening level for hydrogen sulfide. During the post-evacuation period (August 18 to December 31), 17 of 3,095 measurements exceeded the screening level for benzene and none of 3,270 samples exceeded the screening level for hydrogen sulfide. No samples exceeded screening levels for ozone for the entire monitoring period. The Burnaby, British Columbia, pipeline rupture also occurred in a residential area, and nearby residents were evacuated after reporting various acute symptoms. After air monitoring revealed rapidly declining volatile concentrations, more than half of the 225 evacuees were allowed to return to their homes within the day.

10.2.2.4.2 Groundwater

As discussed in Section 10.2.2.3, spills originating from pipelines have the potential to enter underlying groundwater aquifers and form plumes that migrate along with the natural flow of groundwater. The ultimate fate and transport of these plumes is dictated by many factors including the amount and type of oil released, groundwater flow rate, geological properties of the aquifer, chemical reactions occurring within the plume, and the presence of microbes that degrade contaminants (Enbridge 2016d).

Observations from the Bemidji and Cass Lake spills shed light on the possible groundwater impacts from a pipeline spill. These two spills occurred in northern Minnesota with similar geography and geology to the proposed Project routes.

Immediately following the Bemidji spill, clean-up efforts successfully removed approximately 75 percent of the released oil, with the remainder ultimately migrating downward to the underlying aquifer. The underlying groundwater aquifer is a glacial outwash deposit composed of highly permeable sands and gravels, and extends to a depth of approximately 60 feet below the ground surface (Essaid et al. 2011). The U.S. Geological Survey, Minnesota Pollution Control Agency (Minnesota PCA), Enbridge, and Beltrami County established the National Crude Oil Spill Research Site in Bemidji to evaluate the migration and evolution of the remaining contaminant plume.

Because the pipeline was located approximately 15 feet above the water table, released oil first migrated downward to the water table prior to migrating laterally with groundwater flow. This unsaturated zone above the groundwater table allowed the oil to migrate downward until encountering the groundwater table, where downward migration significantly slowed due to oil and its constituents largely being less dense than water (i.e., they float). However, downward passage of the contaminants through the unsaturated zone did leave crude oil contamination within the pore spaces—roughly 10 to 20 percent of pore spaces were filled with oil. The percentage of pore spaces filled with oil was higher, 30 to 70 percent, near the water table where the light crude oil tended to float.

Oil migrated with groundwater either by infiltrating or dissolving into flowing groundwater. Infiltrated oil, also known as non-aqueous phase liquid (NAPL), generally remains separate from groundwater, but is carried along with groundwater flow. NAPL has migrated roughly 330 feet in the direction of groundwater flow since the spill (USGS 2017). Conversely, dissolved oil constituents have been carried roughly 450 to 600 feet from the source and have stabilized at that distance (Cozzarelli et al. 2001). Both travel distances demonstrate that the contaminant plume has migrated more slowly than uncontaminated groundwater, which migrates 300 feet per year. This disparity in velocity is partially due to degradation of the contaminant plume by biological processes that convert the oil to vapors, mostly carbon dioxide and other hydrocarbon fractions. In addition to loss of oil mass within the migrating plume, the non-dissolved oil near at the spill source also has degraded through time (total loss is roughly 11 percent at present). In general, lighter compounds associated with the crude have degraded faster than heavier compounds (Cozzarelli et al. 2001).

The gradual Cass Lake leak, which contrasts to the single release at the Bemidji site, has implications for the migration and evolution of the contaminant plume. Groundwater tables at the site are roughly 25 to 45 feet below the land surface, and the near-surface aquifer occupies a glacial outwash deposit composed of sands and silt. Groundwater migrates at a rate of approximately 85 feet per year.

Monitoring at the site has revealed the maximum downgradient extent of the plume (dissolved benzene) to be roughly 500 feet (Drennan et al. 2010).

Natural attenuation and biodegradation of the contaminant plume have been primary subjects of research at the Cass Lake site, which provides information on the lifetime of the plume and expected period that it poses a potential risk. In general, the plume is considered to be in a highly degraded state; however, natural degradation progresses at rates that depend on the petroleum constituent being considered. As constituents reach a fully degraded state, they are less able to dissolve in groundwater, and therefore can no longer migrate along with the groundwater. Researchers have attributed the highly degraded state of the Cass Lake plume to three factors: (1) the time since initial release, (2) natural groundwater recharge rates, and (3) the gradual nature of the release (e.g., leak).

10.2.2.4.3 Lakes

A number of previous spills in North America highlight the potential effects of oil on lakes. Crude oil is generally less dense than water, which makes impacts on near-surface water quality and adjacent shorelines most likely, discussed in Section 10.2.2.4.6 below.

Following the Wabamun Lake train derailment, approximately 20 percent of the spilled oil traveled overland into the lake. Windy conditions and waves dispersed the oil rapidly over the lake surface, ultimately causing impacts on downwind shorelines. High winds also caused mixing of oil into the water column, particularly within boomed areas. As a consequence of the heavy oil first traveling overland, organic and soil debris incorporated into the oil, causing the formation of consolidated oil masses (tar balls and logs) in the lake, which behaved in various manners, including floating, submerging, resurfacing, and sinking (Fingas et al. 2006). They also formed large tar mats in nearshore areas. BTEX and PAH concentrations were below laboratory detection limits in lake water within 4 months of the spill.

In the Marshall, Michigan, spill, roughly 8,200 bbl of dilbit initially entered a small creek and tributary of the larger Kalamazoo River, which in turn flowed into Morrow Lake approximately 37 miles downstream (Dollhopf et al. 2014). Because the released crude oil was initially less dense than water, it traveled downstream from the release point as a slick and deposited on the river shoreline and adjacent floodplain wetlands. Flood conditions in the streams caused greater dispersal of oil onto the floodplain, including the delta of Morrow Lake, and further downstream, as well as greater turbulence and mixing with sediment that caused the formation of OPAs. Therefore, oil that reached Morrow Lake was weathered and altered by river transport (Dollhopf et al. 2014). Sampling in these streams and Morrow Lake for nearly 2 years after the spill revealed few petroleum-related compounds in excess of health screening levels, most of which were longer-lived PAHs.

Following the Red Deer River spill, floodwaters carried the released crude oil roughly 25 miles downstream to Gleniffer Lake reservoir, and then an additional 5 miles downstream. Response efforts included containment booms in the lake. BTEX compounds were initially detected in the lake above Canadian water quality guidelines for aquatic life, but these lighter weight compounds evaporated quickly. PAHs were present for up to 4 days but also diminished through time. Drinking water system intakes within Gleniffer Lake were a primary concern, but monitoring revealed no exceedance of drinking water standards. The relatively minor impacts on the lake have been attributed to the relatively long distance traveled by the oil in streams before reaching the lake. In addition, the lighter weight crude contributed to a high degree of weathering.

10.2.2.4.4 Rivers

Pipeline releases have the potential to enter streams and rivers, which then can transport released crude oil downstream, affecting water quality, sediments, adjacent shorelines, and other features. In addition to the volume and type of release, the nature and extent of impacts can depend on factors like stream size (width and depth), type, and flow conditions at the time of the release (Enbridge 2016d).

The subsequent discussion focuses on a series of documented oil spills to shed light on the nature of impacts on streams under a range of conditions.

Following the Asher Creek spill, responders installed six surface skimming siphoning dams along the creek to collect and retain floating oil. Upstream of dams, oil infiltrated the streambed, and given the relatively low stream flow at the time of the release, dilution of the released oil was minor. However, scouring floods during the following winter helped dissipate the oil. Oil sheens were observed after disturbing the stream substrate for as many as 453 days following the release at select sites. However, most of the downstream area did not have observable oil impacts for much of the 532-day study.

In the Pine River spill, the generally fast-flowing nature of the river effectively dispersed the released oil, though some oil accumulated in slow-velocity areas (Lee et al. 2015). Accumulation in slow-velocity areas, river margins, and off-channel features was also a common observation following the Red Deer River, Alberta, and Marshall, Michigan, spills. Petroleum was ultimately dispersed at least 50 miles downstream along Pine River. High flows from heavy rainfall in the subsequent months scoured and remobilized oil and oil-contaminated debris. Response efforts involved removal of oil-contaminated sediments and log jams. Three weeks after the spill, petroleum contamination was still detectable at groundwater intakes, but concentrations were below applicable water quality guidelines. The rapid declines in hydrocarbon concentrations were attributed to the lightweight crude and its tendency to degrade and weather rapidly.

The Marshall, Michigan, spill resulted in oil impacts on multiple streams. The receiving streams, Talmadge Creek and Kalamazoo River, have extensive floodplain features including wetlands, forests, and ponds, which ultimately acted as depositional areas for oil (Dollhopf and Durno 2011). Response efforts involved removal of affected riparian vegetation and sediment. OPAs formed extensively as a result of the heavyweight crude and turbulence along the river present during the flood flows and passage over two dams. Water quality sampling revealed petroleum concentrations below water quality criteria within a month or two following the spill, depending on the location.

10.2.2.4.5 Sediment

Sediments along banks and shorelines can be affected by floating oil, whereas oil submergence is a key process required for impacts on sediments in non-nearshore environments. The type of waterbody can affect the nature and mobility of the sediment being considered. Sediment in lakes is generally more stationary and finer grained, and resides in a depositional environment, whereas sediments found in stream and riverbeds are often transported by floods and therefore are less stationary by nature.

The Marshall, Pine River, and Asher Creek spills affected stream sediments. In the Marshall and Pine River spills, affected sediments were most prevalent in slow-moving water depositional areas such as eddies and back channels. However, in the Asher Creek spill, depositional areas, and thus sediment impacts, were concentrated by the low flows and resulting deposition at the time of the spill (Crunkilton and Duchrow 1990). In the roughly 3-year monitoring period following the Marshall spill, petroleum concentrations within sediments in these depositional areas declined, though there were some detections and exceedances of screening criteria, primarily of more persistent PAHs (Fitzpatrick et al. 2015). These declining concentrations were likely due to flushing by floods and weathering of petroleum-related compounds. In Pine River, petroleum was detected in downstream water quality samples taken 2 years after the release, suggesting the petroleum was leaching from sediment (De Pennart et al. 2004). In Wabamun Lake, PAHs were detected in sediment sources 2 years following the spill events and were at even lower concentrations 5 years after the spill (Anderson 2006).

10.2.2.4.6 Shorelines and Riparian Banks

Shorelines and riparian banks represent the interface between surface water and terrestrial environments. These areas have diverse land cover and vegetation in response to disturbing scour and sediment transport from stream flow and wave action (Enbridge 2016d). They also have potential to be affected by spills, particularly from oil that enters and is mobilized in lakes and streams. The effect of oil on shorelines and riparian banks is influenced by various factors, including the oil type, waterbody type, substrate type, frequency and intensity of scour (by waves or current), vegetation characteristics, and seasonal timing of the spill.

The tendency for oil to attach to and affect banks depends to a large degree on the oil type, which is demonstrated by differences in oil dispersal between a light crude oil spill in Grapevine Creek (Kern County, California) and heavy fuel oil release in the Patuxent River (Chalk Point, Maryland). Within 2 days of the Grapevine spill, over 90 percent of its toxic compounds had been degraded (Mancini et al. 1995). In comparison, only 39 percent of the oil spilled at Chalk Point had degraded within 5 days (NOAA 2002).

Observations from previous spills also demonstrate the effect of vegetation type and extent on the oil trapping capacity of shorelines. Vegetation can absorb oil and effectively protect bank sediments from oil, as was the case in the 1988 Shell oil release in Martinez, California, and the M/T Westchester oil release into the Mississippi River (2000). Vegetation can also act to absorb and hold oil on the banks, thereby increasing the length of time that oil has an effect on shorelines and banks. For example, in the Buzzards Bay spill in Massachusetts (1969), areas with marshy vegetation retained oil residues, whereas un-vegetated areas did not (Peacock et al. 2005).

10.2.2.4.7 Wetlands

Oil releases into wetlands have the potential to affect vegetation communities or cause soil contamination such that typical hydrologic conditions are interrupted. The effects of released petroleum products on wetlands have been extensively studied at a number of release sites and via case studies.

Crude oil type, plant recovery, contaminated soil effects on plant growth, and sensitivity to oil releases influence the impacts of oil on wetlands.

A 30,000-bbl spill of crude oil into a Louisiana Cypress swamp had the greatest impact on floating vascular plants, whereas highly shaded plants and perennials in sunlit areas were minimally affected (Baca et al. 1985). A 160-bbl diesel fuel spill on Mount Baker, Washington, severely reduced vegetation cover from nearly complete coverage to no coverage, with the exception of one particularly resistant species. Snow cover at the time of the spill helped to reduce the effects by absorbing the diesel (Belsky 1982). Subsequent spring snowmelt carried the stored diesel fuel away from the wetland.

Topography on the site also helped to divert fuel away from sensitive plants. The spill site was covered by roughly 12 percent plants 9 years after the spill.

Hutchinson and Freedman (1978) studied effects of the type and timing of releases and found that intensive releases were generally more damaging than spray releases, and that releases during winter months tended to be less damaging than summer releases. A study of plant recovery following a release (Racine 1994) found that understory vegetation was nearly complete within 20 years, but areas with pooled oil had little recovery. Leck and Simpson (1992) found that contaminated soil reduced plant survival and growth from seeds, and diminished growth of plant seedlings in tidal freshwater marshes. Lin and Mendelssohn (1996) found that organic matter in soils made the wetland and plants particularly sensitive to crude oil.

10.2.2.4.8 Soils

Petroleum releases to the ground surface can have harmful effects on soil and important resident microorganisms (Enbridge 2016d). Response efforts often involve scraping or excavating the land surface to remove contamination.

A series of oil releases in north-central Alberta near Great Slave Lake happened in close proximity to one another and within a relatively short time span (1970 to 1972). The combined volume of 60,000 bbl of oil represents one of the largest spills in Canadian history, and the area has been studied extensively as a result (Wang et al. 1998). Clean-up efforts following the releases included burning, tilling, and fertilizer application. Researchers returned 25 years later to evaluate conditions and the effectiveness of the employed remediation techniques. This research revealed high oil concentrations to depths of over a foot and low contamination at approximately 3-foot depths. The state of oil contamination became less weathered with depth. Weathering rates were therefore greatest near the surface.

A wide range of soil remediation techniques have been employed in response to previous spills. The effectivity of burning and fertilizer application at reducing oil contamination was tested following the Moose Jaw, Saskatchewan, spill. Response efforts included fertilizer application with positive results: oil concentrations decreased during the fertilizer application period, with the greatest decrease in the year with the largest fertilizer application rate (De Jong 1980). Burning of dispersed oil contamination had mixed results. A direct effect was a reduction in habitat, and the burning may have been associated with the soil becoming highly water repellent (also an effect of the oil; Nieber 2013). In the case of the Glenavon spill, which discharged heavy crude oil to a slough, remediation efforts included recovery of oil from surface water, containment berm construction, removal of oil-contaminated vegetation, and removal of sediment and soil.

Bioremediation was a subject of study at the Fort McMurray spill site, as well as at a series of experimental release sites. At Fort McMurray, contaminated soils had sufficient bacterial populations to promote biodegradation, though they were more effective at dissolving lighter oil constituents. This study showed that existing microbial communities adjust to the presence of oil, with some natural communities being diminished and others increasing in abundance (Hemmings et al. 2015). The microbe communities with increased abundance are able to metabolize petroleum hydrocarbons present in soil, and thus help to degrade contamination.

10.2.2.4.9 Terrestrial Vegetation

Numerous studies examining the impacts of crude oil on vegetation have been completed in northern latitudes that have general applicability to Minnesota climate and vegetation types. An experimental application of oil onto terrestrial vegetation by Wein and Bliss (1973;) in Northwest Territories revealed that oil-contaminated deciduous plants showed effects within hours of oil application, whereas evergreen vegetation took weeks to show stress. Regrowth in oil-exposed plants was less robust than would typically occur. Plants in oil-saturated soil showed no regrowth. After a growing season, recovery varied between 20 and 55 percent, depending on the oil treatment rate. A similar study in the Northwest Territories involving light-crude application revealed changes in species composition and diminished vegetation cover in the test area after 10 years (Robson et al. 2004). A test release of heavy crude in Caribou-Poker Creek Watershed (Alaska, 1976) showed that mosses and lichens died shortly after the release, but particular grass species persisted and thrived with lesser competition in the years following the spill (Collins et al. 1994). After 15 years, roughly half of black spruce trees had died in a plot with winter oil application, and roughly one-third had died in the plot experiencing summer application.

Previous spill incidents also shed light on the various impacts of oil contamination on vegetation. The Moose Jaw, Saskatchewan, spill directly affected wheat crops, causing reduced yields with greater oil contamination until 1 percent oil concentration in soil, at which point no plant growth occurred (De Jong 1980). Over the 4 years following the release, crop yields in oil-contaminated sites generally improved but had not improved to the production level of uncontaminated areas. Response to the Bemidji spill involved capture and recovery of spilled oil and burning of oil-soaked vegetation (Nieber 2013). The burning caused surface soils to become highly water-repellent, which has contributed to a slow vegetation recovery over at least 30 years. Following the Fort McMurray spill, emergency response efforts removed 93 percent of the oil; however, over the subsequent year, impacts on birch, black spruce, and reedgrass were observed (Hemmings et al. 2015).

10.2.2.4.10 Benthos

Effects of oil spills on benthos tend to be minimized due to the tendency of oil to float on water; however, oil that enters the water column through processes like mixing and dissolution can have negative effects. Benthos are commonly used as an indicator of waterbody health, which makes them a common focus in post-spill monitoring programs.

Various spills reveal approximate response and recovery times of benthic communities to oil releases. The Asher Creek spill illustrates the response of benthos to a spill with heavy impacts on a stream.

Immediately following the spill event, benthic populations within the affected area were 0.1 percent of typical populations, with a complete loss of mayflies and stoneflies. By 9 months following the release, the mayfly and stonefly populations had recovered to levels observed in unaffected areas upstream of the spill (Crunkilton and Duchrow 1990). By 18 months, the mayfly and stonefly populations had recovered to levels observed in healthy Missouri streams. In a similar 18-month timeframe at a separate Missouri pipeline spill (Gasconade River, 1988, intermediate weight sweet crude), macroinvertebrate communities had not fully recovered in their diversity and abundance due to residual hydrocarbon contamination, which was particularly concentrated in sloughs (Poulton et al. 1997). Greater recovery had occurred in riffle habitats where more frequent bed scour helped to flush oil contamination from sediments. Following another spill in the Chariton River (Missouri, 1990, 2,600 bbl of light crude from rupture of an Amoco Pipeline), benthic communities were nearing recovery by approximately a year post-release with reductions in abundance and the number of species present continuing (Poulton et al. 1998). Immediate responses of benthic communities to the Pine River spill extended 75 miles downstream from the release site. Within approximately a year, monitoring found that these communities had recovered in much of the affected area (Lee et al. 2015).

A number of spills also reveal the extent and habitat types where benthic communities have greatest impacts from oil releases. Monitoring following the Cayuga Inlet diesel spill focused on impacts and recovery times at varying distances downstream from the release site (Lytle and Peckarsky 2001). Benthic communities had detectable, immediate responses as far as 3 miles downstream of the release site, with expectedly greater effects closer to the release site. Within approximately a year, benthic communities in the study site nearest to the release site (0.4 mile downstream) had nearly recovered, with the only lingering effect being related to a change in species composition. Benthic organisms in the Wabamun Lake spill were most affected in sandy sediments lacking organic material (Lee et al. 2015).

Benthic communities in sandy sediments were also most affected in depositional sandy areas affected by the Marshall, Michigan, spill. Scientists concluded that recovery of benthic communities was complete 3 years following that release.

10.2.2.4.11 Fish

Freshwater fish are important components of aquatic ecosystems and food webs, as well as major economic resources in recreation and commercial fishing industries. Fish can be affected by oil releases through multiple exposure pathways and at multiple life stages, and the toxicity effects can be either acute, chronic, or indirectly related to contamination of habitat features (Enbridge 2016d).

Information on fish mortality immediately following spills is the most readily available for the spill events reviewed. The Marshall, Michigan, spill resulted in 42 dead fish immediately after the spill, which was considered negligible (USFWS 2015). Though scientists and local officials debated the exact cause, roughly 100 dead fish were found following the crude oil release to Wabamun Lake (Birtwell 2008). The Pine River spill resulted in 1,637 observed dead fish immediately following the spill. These fish tended to be larger, bottom-feeding fish, with a small proportion (<15 percent) being surface feeders. Fish mortality was noted up to 30 miles downstream of the release.

Given the difficulty in observing all dead fish, the estimate of total fish mortality within the 30-mile stretch of river ranged from 25,000 to 250,000 in Pine River (Goldberg 2011). However, fish were reported to be returning to the affected area within 11 days. Large fish kills were also noted in response to the Cayuga Inlet and Asher Creek spills—up to 92 percent mortality was estimated for Cayuga Inlet (Lytle and Pekarsky 2001) and 42,000 dead fish were identified along a 5-mile section of Asher Creek (Crunkilton and Duchrow 1990).

Longer term effects of spills include habitat degradation and sublethal effects, including deformities. Longer term effects of the Marshall spill included declines in abundance and diversity of fish in Talmadge Creek for the year following the release. Recovery occurred shortly thereafter, but changes in fish community composition also occurred in response to habitat changes in the following 3 years (USFWS et al. 2015). Sublethal effects on fish were present for 27 miles downstream of the release site, as revealed by a fish health study 2 months following the spill (Papoulias et al. 2014). Fish consumption advisories were set forth for 2 years as a result of crude oil exposure. In Wabamun Lake, important juvenile and spawning habitat for various species were significantly affected by oil contamination, and in the 2 years following the spill, increases in fish deformities were attributed to the spill. Ten years following the spill, introduced walleye populations were present and increasingly healthy in the lake (Birtwell 2008).

10.2.2.4.12 Aquatic Plants

Aquatic plants grow in standing water and provide important services including food to aquatic ecosystems and humans, habitat areas, water quality benefits, and aesthetic and economic value. Aquatic plants can either be non-vascular (like algae, without roots) or vascular. Aquatic vascular plants can either have submerged or floating leaves. They tend to grow near shorelines in lakes to take advantage of light, and in quiet water zones of streams that experience infrequent scour.

Multiple studies found that that blue-green algae grew in response to released oil (Snow and Rosenberg 1975; Snow and Scott 1975). Effects from releases can vary by season—for instance, phytoplankton may be most affected by spills late in the growing season (Hellebust et al. 1975). Phytoplankton, in general, had varying responses to crude oil according to experiments by Kauss et al. (1973), which showed a range in growth response from inhibition to acceleration. Vascular plants tended to be diminished in abundance, but recovered in marshy areas over the course of 3 to 4 years (Burk 1977). Other conditions, like the presence of ultraviolet light, increased the effect of crude oil constituents on vascular plants (Ren et al. 1994). Increasing concentrations of oil also have increasingly harmful effects on vascular plants (Akapo et al. 2011; Lopes and Piedade 2014).

10.2.2.4.13 Amphibians and Reptiles

Amphibians are common along waterbodies in Minnesota and are important components of the aquatic ecosystem that have high potential to be affected by oil releases. Seasonal timing of spills can influence the ability of responders to clean-up released oil and reduce exposure of amphibians. For example, much of the oil released in the Grand Rapids, Minnesota, spill collected on the ice surface, which aided clean-up efforts. As a result, impacts on fish and wildlife were reported as minimal. A cracked pipeline near Tinicum, Pennsylvania, released 4,575 bbl of crude oil onto an ice-covered impoundment.

During clean-up efforts, the ice began to break up and resulted in exposure of turtles to oil (Saba and Spotila 2003). After cleaning and monitoring of the turtles, only one died after a month.

In streams, flow conditions at the time of release also can affect the distribution of oil and the extent and magnitude of effects on reptiles and amphibians. The Marshall, Michigan, spill occurred at a time of receding flood flows in the Kalamazoo River. As a result, oil was distributed into and trapped within floodplain depressions, resulting in a substantial effect on amphibians and reptiles. Over 100 reptiles died, and nearly 4,000 turtles and 73 amphibians were captured and treated for oil effects (USFWS et al. 2015). Flood conditions can also help to distribute and dilute the effects of oil, thereby minimizing the effects on amphibians and reptiles. This was the case in the 2011 Yellowstone River release, which, as a result of high stream flow, affected areas 72 miles downstream but only affected two amphibians and one lizard (EPA 2011). The Rainbow Pipeline release also resulted in oil pooling in depressions, which resulted in at least 12 amphibians being killed (Energy Resources Conservation Board 2013).

The Red Deer River spill, Fort McMurray spill, and 2015 Yellowstone River spill of Bakken crude from the Bridger Pipeline (Montana Department of Environmental Quality 2015a) resulted in no documented impacts on reptiles or amphibians.

10.2.2.4.14 Birds

Numerous bird species spend their time near or within waterbodies and can be highly susceptible to oil spill impacts. The Ashland Oil Facility spill had significant effects on birds. The spill response involved efforts to clean birds that had been affected by the spilled diesel; however, these efforts were hindered by winter conditions. Partial ice coverage in particular limited the ability of responders to reach the areas with the greatest concentrations of birds. Ultimately, between 2,000 and 4,000 birds were killed as a result of the spill (Miklaucic and Saseen 1989).

The Grand Rapids, Minnesota, spill also occurred in winter conditions with frozen waterbodies, but the result was very different from the Ashland Oil Facility spill (NOAA 1992). A portion of the spilled oil spread onto the frozen surface of the Prairie River, which ultimately aided response personnel in clean-up efforts. Responders used vacuum trucks and squeegees to remove pooled oil from the ice surface.

Workers also allowed oil into the flowing river to take advantage of oil collection booms in the river. There were no reports of oiled birds, which was partially a result of the effective cleanup aided by the ice coverage at the time of the spill.

The Marshall, Michigan, spill affected roughly 400 birds, 52 of which died shortly after the spill (USFWS et al. 2015). An additional 144 birds affected by released oil were captured and rehabilitated, and roughly 140 birds were observed with oil effects but were not captured. Affected birds were generally waterfowl, including Canadian geese, mallard ducks, and great blue herons. For comparison, of the birds affected by the Rainbow Pipeline release, approximately one-third were waterfowl and two-thirds were shorebirds and songbirds. Impacts on birds may be minimal if response and containment efforts are successful. Responders to the Red Deer River spill, for example, successfully contained a large proportion of the light crude oil using booms. As a result, oiling of only two birds was documented (AER 2014).

10.2.2.4.15 Semi-Aquatic Mammals

Semi-aquatic mammals are those specially adapted to live near water and inhabit aquatic environments. While most mammals are terrestrial, the semi-aquatic variety are generally most prone to impacts from oil spills (Enbridge 2016d). Semi-aquatic mammals can vary in their dependence on aquatic environments. For instance, moose are considered semi-aquatic, but are considered to have the least dependence on aquatic environments. Other common semi-aquatic mammals include beaver and muskrat, mink, otter, and shrews. In general, species most dependent on aquatic environments (e.g., beaver and muskrat) are most likely to be affected by spilled oil distributed through surface waterbodies.

Historical spills have had relatively minor documented impacts on mammals. Following the Ashland Oil Facility spill, there were no reported incidents of oiled mammals even though the spill area was typically inhabited by beaver, mink, and river otter (Miklaucic and Saseen 1989). Similarly, there were no reports of oiled mammals following the Grand Rapids, Minnesota, spill (NOAA 1992). The lack of effects on these species was, in part, a result of the frozen surface water conditions during the spill. The Glenavon spill also did not have documented direct impacts on mammals (SLR Consulting 2008).

A number of the spills have had documented impacts on semi-aquatic mammals, including the Marshall, Rainbow Pipeline, and Red Deer River spills. The Marshall spill reportedly killed 40 mammals, and an additional 23 were captured and rehabilitated, though it was expected that additional mammals were affected but not observed during monitoring efforts (USFWS et al. 2015). Of the affected mammals, the primary species included muskrat (45 percent), raccoon (13 percent), and beaver (13 percent). The Rainbow Pipeline spill, which affected approximately 20 acres, resulted in mortality of 11 beavers and several small rodents. The Red Deer River spill had relatively few reports of wildlife impacts but did have a documented effect on two beavers (Energy Resources Conservation Board 2013).

10.2.2.4.16 Human Health

Oil spill impacts on humans are usually short term (acute), resulting from direct exposure to spilled oil or its byproducts, either by contact with skin, ingestion, or inhalation. The historical spills discussed below have either directly affected humans, or resulted in regulatory restrictions to reduce potential for exposure.

Regulatory restrictions can involve limitations on fish consumption, closing of groundwater wells, or other measures to limit human exposure risk. Responses to the Pine River spill included restrictions on fishing within the river, temporary closure of water intakes, and permanent closure of water supply groundwater wells in the vicinity of the river (Goldberg 2011). Closure of groundwater wells often depends, in part, on groundwater studies evaluating movement of the contamination plumes. For example, Cass Lake studies revealed that the plume was unlikely to affect water supply wells based on a detailed study on the direction and rate of contaminant movement (Drennan et al. 2010). Officials made a similar no-effect determination for a spill near Laurel, Montana (1,500 bbl medium crude, 2011), after installation of groundwater monitoring wells. Sampling from these and over 300 private wells revealed no detections of petroleum (Montana Department of Environmental Quality 2015b).

As a result of the oil spray into the air following the Burnaby, British Columbia, pipeline rupture, high volatile compound levels were present immediately after the incident but declined quickly. The spray covered five people and 44 residences in oil (eight residences with heavy coverage). Residents in heavily oiled houses were evacuated and placed in longer-term housing during clean-up efforts, and roughly half the 250 evacuated individuals returned to their homes within the day. Health effects in residents included headaches (15 percent), respiratory irritation (8 percent) nausea (6 percent), dizziness (3 percent), and eye irritation (3 percent) (Eykelbosh 2014).

The Marshall, Michigan, spill involved public health responses to air quality, surface water and fish, and possible groundwater impacts (Michigan Department of Community Health 2012, 2013, 2014a, 2014b, 2015). Public health was of concern because 40,000 people lived within a mile of the affected release area. Though no residents were located in the area with the highest impacts on air, nearby residences did relocate as a result of odors. Impacts on surface waters caused officials to issue an advisory against swimming and fishing. Extensive monitoring of contamination in surface water and fish tissue ultimately led officials to reopen most of the affected streams and rivers to recreational use roughly 2 years after the event. The fish consumption advisory was also lifted at that time. Though concern for impact on drinking water sources was relatively minimal, officials also issued a precautionary bottled water advisory. After sampling of over 150 private wells revealed no samples exceeding screening levels, the precaution was lifted. Multiple public health assessments were completed in response to the event, some of which included door-to-door surveys, monitoring of local health-care trends, and assessments of risk from sediment, groundwater, and inhalation. All assessments resulted in conclusions of low risk to residents.

Though rare, loss of life has occurred for individuals engaged in land or resource use along pipelines (Enbridge 2016d). These instances tend to be associated with pipelines carrying more refined fuels with greater flammability. The victims tend to be construction or repair workers working directly on the pipeline, though victims may also include the general public. Repair of an Enbridge pipeline near Clearbrook, Minnesota, resulted in the deaths of two pipeline workers in 2010 when leaking oil ignited (Bloomberg News 2010). When a bulldozer struck a crude oil pipeline in Lufkin, Texas (2005), oil ignited and injured the operator (Propublica 2015). In California (2004), five deaths and four injuries occurred when contractors struck a gasoline pipeline (Office of State Fire Marshall 2004).

10.2.2.4.17 Land and Resource Use

The effects of oil on land and resource use can vary from permanent or temporary suspension of use to evacuation and loss of life (Enbridge 2016d). Examples of land uses potentially affected by oil spills include agriculture, aquaculture resources (including wild rice harvest), fisheries, forest resources, and recreation.

Oil spills commonly affect recreational use along waterbodies with beaches and fisheries. An example includes a release of heavy crude (1996) from a Chevron-owned pipeline, which discharged into Pearl Harbor (Kakesako et al. 1996). Strong odors resulted in closure of the visitor center for 4 days, and the 2- week clean-up efforts resulted in closure to recreational users, harbor vessel traffic, and commercial fisheries. Following a spill of 800 bbl of medium crude oil into Red Butte Creek in Salt Lake City, Utah, recreation activities were restricted near the creek for over 40 days, and direct use of the creek was restricted for 2 years during restoration (O'Donoghue 2012). In response to the Wabamun Lake spill, officials closed portions of the lake for swimming and boating for a year, and put in place fish and waterfowl consumption advisories for 2 years.

Agricultural lands have also been affected by pipeline oil spills. For example, in 2013 a 20,600-bbl leak of crude oil was discharged directly to agricultural fields in North Dakota. The farmer and Tesoro, the owner of the oil, indicated that clean-up activities were likely to take 2 to 3 years, during which time the farmer was to be compensated for losses (Associated Press 2014).

An important resource use consideration along pipelines is use by American Indian tribes. Impacts on these resources have not been well documented in the public record, but often can result in settlements between the responsible parties and tribal groups. The Wabamun Lake CN Rail derailment release resulted in lawsuits filed by the Paul First Nation, which ultimately led to a settlement of $10 million (CBC News 2008). U.S. regulations allow American Indian tribes to be included as trustees in the Natural Resource Damage Assessment (NRDA) process, which occurred after the Marshall, Michigan, spill. The

Nottawaseppi Huron and Match-E-Be-Nash-She-Wish Bands of the Potawatomi Tribe were designated as trustees in the NRDA process (USFWS et al. 2015).

10.2.3 Fire and Explosion Hazards

A complete analysis of the fate and effects of an accidental crude oil release will include the potential for consequential fire and explosion. A crude oil spill leads to the pooling and flow of liquid hydrocarbon onto a land or water surface. Flammable gas mixtures vaporize from the surface of the pool governed by numerous physical processes as shown in Figure 10.2-2 must be understood to account for fire and explosion hazards. One of the most important aspects for fire and explosion hazard representation is representing a realistic source term from a pool which has been formed by liquid escaping containment. The quantities of interest for input into a dispersion model are the rate at which vapor is produced from a pool, the size of the pool (which determines the initial dimensions of the dispersing cloud) and the temperature of the vapor.

The flammability characteristics of crude oil varies significantly by type composition. Table 10.2-7 presents the flash point, the temperature at which a mixture gives off sufficient vapor to ignite in air, for typical crude oils NA. Notice that the flash point changes from transport conditions to weathered conditions evolve such that the highest concern is at the early phase of the release. Table 10.2-7 demonstrates that light and medium crudes have very low temperature flash points, they remain volatile over a normal ambient temperature range. However heavy crudes and Dilbit require higher temperatures to evolve flammable hydrocarbon vapors, above 60°C, after initial weathering. It should also be noted that Dilbit is a proprietary composition, but mainly divides into dilution by natural gas condensate which exhibit fire/explosion concerns.

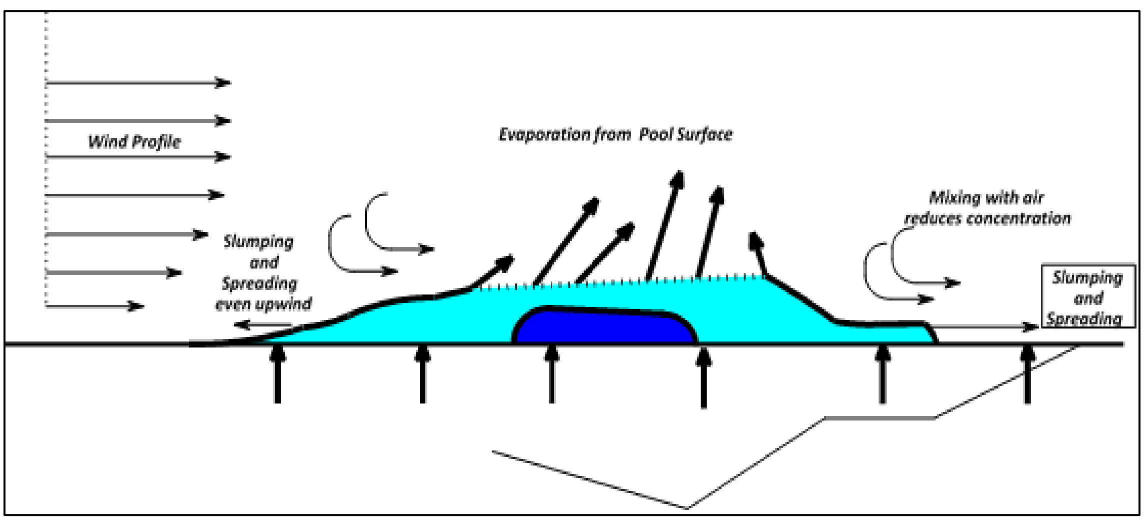


Figure 10.2-2 Hydrocarbon Evaporation Processes

Table 10.2-7. Flash Point Comparison of Typical Crude Oils

Type of Crude Oil	Flash Point Before Release[a]	Flash Point After Initial Weathering (mass % loss in weathering)	Flash Point After Additional Weathering (mass % lost in weathering)
Light Crude[b]	<−30°C	23°C (25%)	95°C (64%)
Medium Crude[c]	−10°C	33°C (10%)	>110°C (32%)
Heavy Crude[d]	−3°C	67°C (10%)	>95°C (19%)
Diluted Bitumen[e]	<−35°C	>60°C (15%)	>70°C (30%)
Bitumen	>100°C	>100°C (1%)	>110°C (2%)

Source: Hollebone, B. 2015[a] Flashpoint in degrees Centigrade (°C).

[b] Scotia Light.

[c] West Texas Intermediate.

[d] Sockeye Sour.

[e] Cold Lake Blend.

If the vapors do not ignite immediately, the vapor cloud will drift and disperse downwind decreasing in concentration as the vapors mix with air. When the vapor to oxygen ratio decreases from its initial rich concentration to within the flammability range, it can ignite. Ignition of a flammable vapor cloud in an open space leads to a flash fire, with impacts to people and structures inside and slightly beyond its volume. However, if the flammable vapor cloud ignites within an area that is both confined (walls, floor, ceilings, decks) and congested (objects densely occupying volume; such as cars, trees, industrial equipment) then a vapor cloud explosion can occur. Depending on the combination of fuel, confinement and congestion, the combustion could either be subsonic, (deflagration) or supersonic (detonation). A vapor cloud explosion, like a fire, can lead to effects on people and property. If the explosion occurs proximate to additional stored flammable materials, this can lead to escalation, the situation wherein additional fuel is additive to the initial release inventory.

The timing and location of the ignition determines the physical effect resulting from the hydrocarbon vapors, and includes these types of hazards

- **Pool Fire.** This is a fire that burns from a pool of vaporizing fuel. The primary concern associated with pool fires is hazards associated with increased temperatures from thermal radiation (heat). For crude-by-rail trains, a pool fire could occur if there is an incident leading to a release of crude oil that forms a pool and then catches fire. . For the pool fire, the flame width is essentially the diameter of the pool which also sets the flame height

- **Vapor Cloud Fire (Flash Fire).** A rapidly moving flame front characterized by combustion. Flash fires occur in an environment where fuel and air become mixed in adequate concentrations to combust.

- **Vapor Cloud Explosion.** A vapor cloud explosion is the result of a flammable material that is released into the atmosphere, at which point the resulting vapor cloud is ignited. The primary concern from a vapor cloud explosion is overpressure (pressure caused by a shockwave). For crude-by-rail trains, such an explosion could occur if oil was released during an incident and evaporated into the air, forming a vapor cloud. This requires that there be no immediate ignition source.

All of these physical effects have been analyzed within the petrochemical industry for many years, the methods and computational models are available for such analyses (e.g. pool spread, dispersion, fire, and explosion).

Each of these processes shown in Figure 10.2-2 must be understood to account for fire and explosion hazards. One of the most important aspects for fire and explosion hazard representation is representing a realistic source term from a pool which has been formed by liquid escaping containment. The quantities of interest for input into a dispersion model are the rate at which vapor is produced from a pool, the size of the pool (which determines the initial dimensions of the dispersing cloud) and the temperature of the vapor.

10.3 CRUDE OIL TRAJECTORY AND FATE MODELING

Enbridge commissioned a modeling analysis on behalf of and with input from the Minnesota Department of Commerce, Energy Environmental Review Analysis Staff, the Minnesota Department of Natural Resources, and the Minnesota Pollution Control Agency, for seven hypothetical crude oil releases from pipeline locations along the Applicant's preferred route and route alternatives(Stantec et al. 2017). This study is relevant to the behavior of crude oil after a release, as discussed in Section 10.2, and the exposure assessment in Section 10.4. This computer modeling involves simulating the chemical and physical behavior of hypothetical oil spills in the selected environments under specified conditions, including weathering processes.

The rupture study (Stantec et al. 2017) focused on providing information about potential pipeline rupture events only. Hence this work is at the opposite extreme from the pinhole release study (Stantec and Barr Engineering 2017), evaluating the largest possible breach size -- the full diameter of the pipeline. In the case of the Line 3 Project, this is 36 inches in diameter, an area over 300,000 times larger than a pinhole. The probability analysis approach taken in the rupture study used a combination of statistical and mechanistic modeling. A modeling approach was taken to represent each pipeline failure mechanism (threat) individually and to combine them into an overall probabilistic failure rate estimate. Statistical evaluation of PHMSA Hazardous Liquids Database, 2010–2015 was used for estimating the failure probabilities due to; manufacturing defects, construction defects and incorrect operations. Mechanistic reliability models were used for estimating the failure probabilities due to; external corrosion, internal corrosion, and third party damage.

The rupture study was used to develop specific failure probabilities for seven sites selected for in-depth analysis based on (1) their distribution across the Applicant's preferred route and route alternatives,[21] and (2) how well they represented the diversity of characteristics that were identified as significant during public scoping (Figure 10.3-1). The sites were selected jointly by agency staff and the consulting team as documented in the rupture study.

Stantec et al. conducted a failure probability analysis for these seven sites—six at pipeline water crossings and one in an upland location adjacent to a small creek (2017). As part of that analysis, they

21 Stantec et al. only evaluated the Applicant's preferred route and route alternatives. The CN Alternatives, including system alternative SA-04, transportation by rail and truck, and continued use of existing Line 3 were not evaluated during their study (Stantec et al. 2017).

assessed potential causes of pipeline failures or threats. The threat components resulting in pipeline failure were evaluated based on current materials and technologies characteristic of a modern replacement pipeline. The results of these studies were applied to the failure probability analysis in this section, as well as the exposure assessment in Section 10.4.

The spill model study (Stantec et al. 2017) is available online on the DOC-EERA Project website (https://mn.gov/commerce/energyfacilities/line3/), on the Project eDockets site (Line 3 Route Permit PUC eDockets), and by CD included with hard copies.

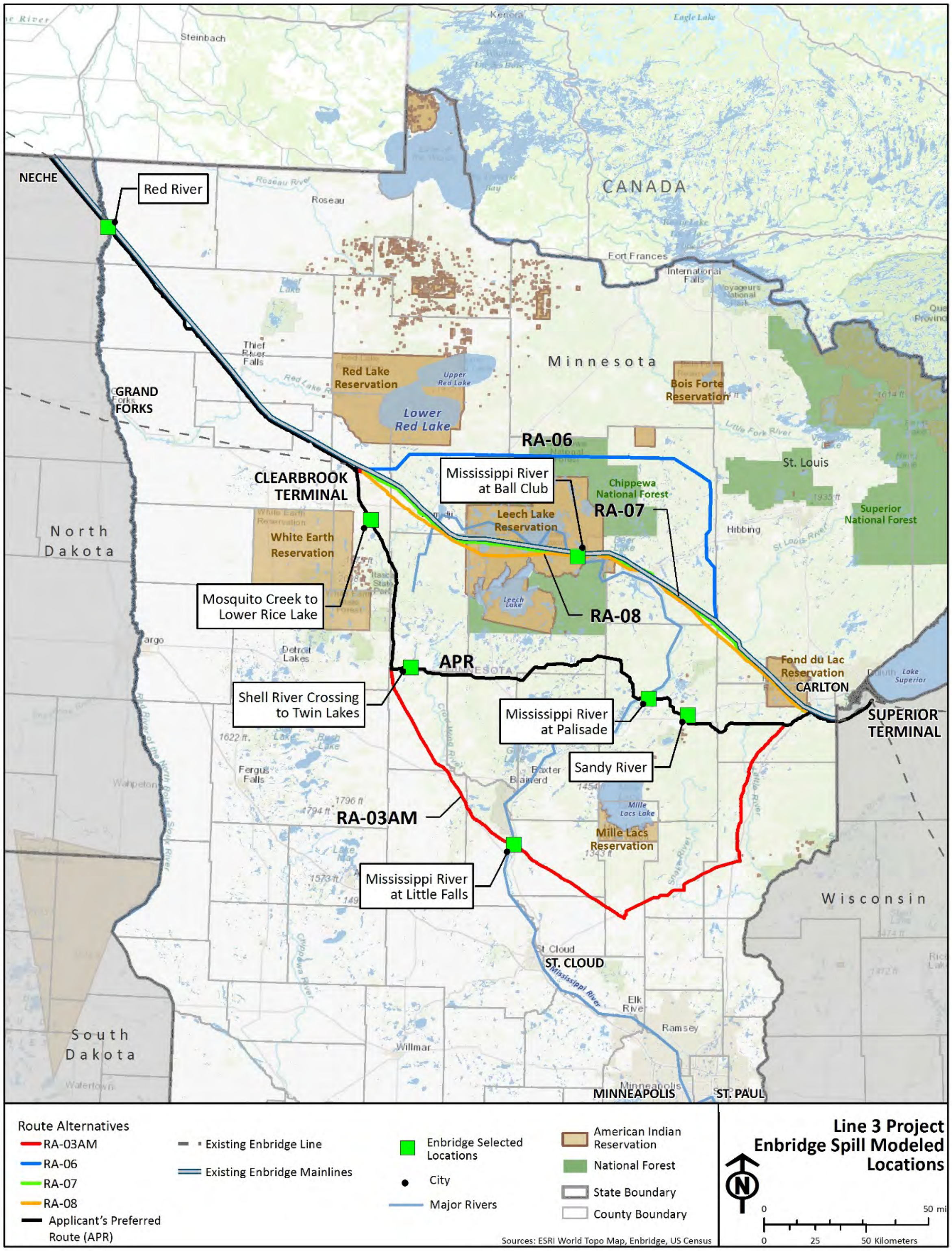


Figure 10.3-1. Seven Enbridge Spill Sites Modeled in Stantec et al. 2017 Study

10.3.1 Description of the Models Used

Stantec et al. (2017) used two different models to evaluate the trajectory and fate of crude oil releases at seven study sites: OILMAP Land is a two-dimensional predictive modeling tool for predicting the trajectory and fate of released crude oil in the horizontal downslope and downstream direction (Figures 10.3-2 and 10.3-3). SIMAP is a considerably more complex model that incorporates a third dimension, vertical movement in the water column, which provides the ability to model the transport of crude oil in the water column and potential sinking and submergence in turbulent waters after contact with in river sediments (Figure 10.3-4) (Stantec et al. 2017). The models can also be used to determine potential environmental damages based on the concentrations, dose exposures, and properties of the oils as related to toxicity, adherence, and persistence.

Both of these models have been used extensively in the US and internationally to meet regulatory requirements and other recommendations and guidelines. These models are used frequently by government, industry, and academia. Spill modeling currently provides the most comprehensive, accurate, and practical means to evaluate the outcomes of hypothetical spills.

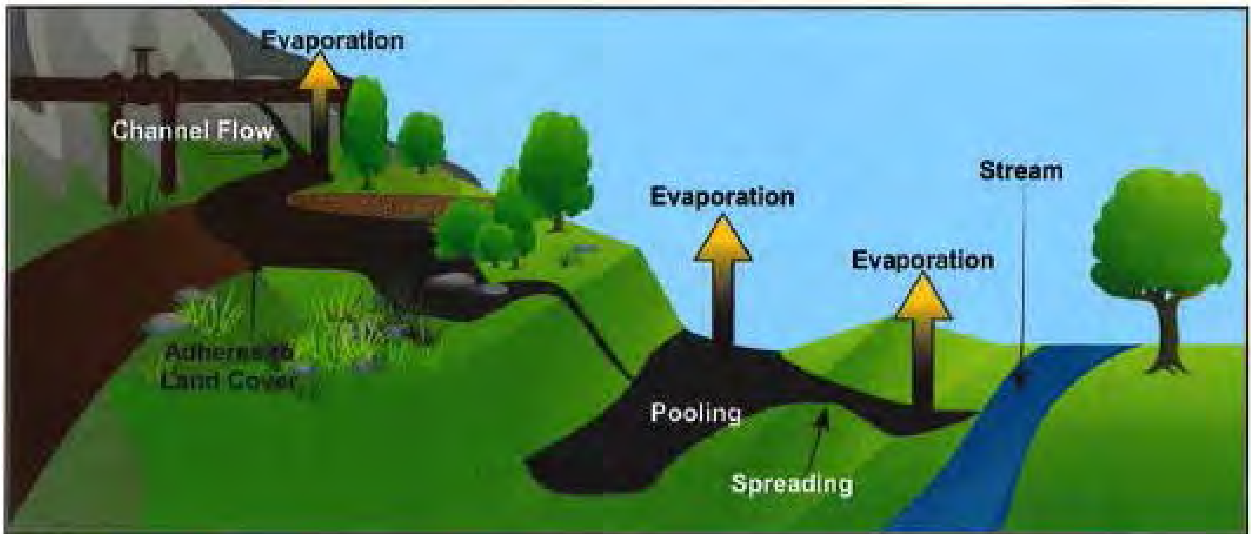
The SIMAP modeling system was developed by RPS (formerly Applied Science Associates, ASA). It originated from the oil fate and biological effects sub-models in the Natural Resource Damage Assessment (NRDA) Models for Coastal and Marine Environments (NRDAM/CME) and Great Lakes Environments (NRDAM/GLE), which ASA developed in the early 1990s for the U.S. Department of the Interior for use in “Type A” NRDA regulations under the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA). The most recent version of the type A models, the NRDAM/CME (Version 2.4, April 1996) was published as part of the CERCLA type A NRDA Final Rule (Federal Register, May 7, 1996, Vol. 61, No. 89, p. 20559-20614). The technical documentation for the NRDAM/CME is in French et al. (1996). This technical development involved several in-depth peer reviews, as described in the Final Rule. (The model is described in greater detail in Stantec et al. 2017).

SIMAP was used as part of the Natural Resource Damage Assessment studies conducted for NOAA in the aftermath of the Deepwater Horizon spill (French McCay et al. 2016). These spill models have been validated against actual spills (French and Hines 1997; French et al. 1997; French McCay 2004).

Detailed descriptions of the algorithms and assumptions in the model are provided in French McCay 2002, 2003, 2004, and 2009. The model has been validated with more than 20 case histories, including the Exxon Valdez and other large releases (French and Rines 1997; French McCay 2003 and 2004; French McCay and Rowe 2004), as well as test releases designed to verify the model (French et al. 1997).

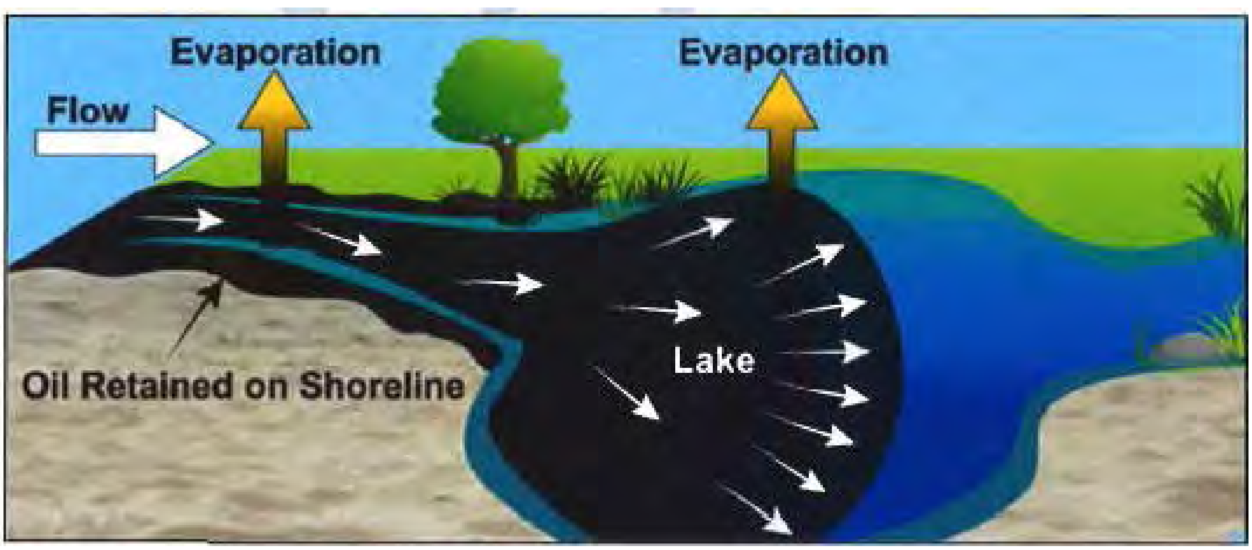
OILMAP Land was selected for modeling releases at less turbulent aquatic systems (Sites 1 through 5), and SIMAP was employed for higher flow, more turbulent large rivers (Sites 6 and 7) where entrainment of crude oil droplets would be more likely to occur with vertical mixing and movement within the water column and potential deposition in bottom sediments.

OILMAP Land takes into account the overland flow of the oil when the hypothetical release occurs on land. The retention of oil in puddles and adhesion to substrates is considered and calculated based on topography, types of land cover (e.g., bare rock, evergreen forest, wetland), and oil type. In addition, the weathering (evaporation) of the oil is included. The encounter of oil with surface water during different seasons is incorporated into the model as well. In streams, OILMAP factors in the adherence of different oil types to various shoreline substrates (e.g., sand/gravel, marsh, rock , as well as the formation of tar bodies that may lead to oil submergence in turbulent waters) (Stantec et al. 2017).



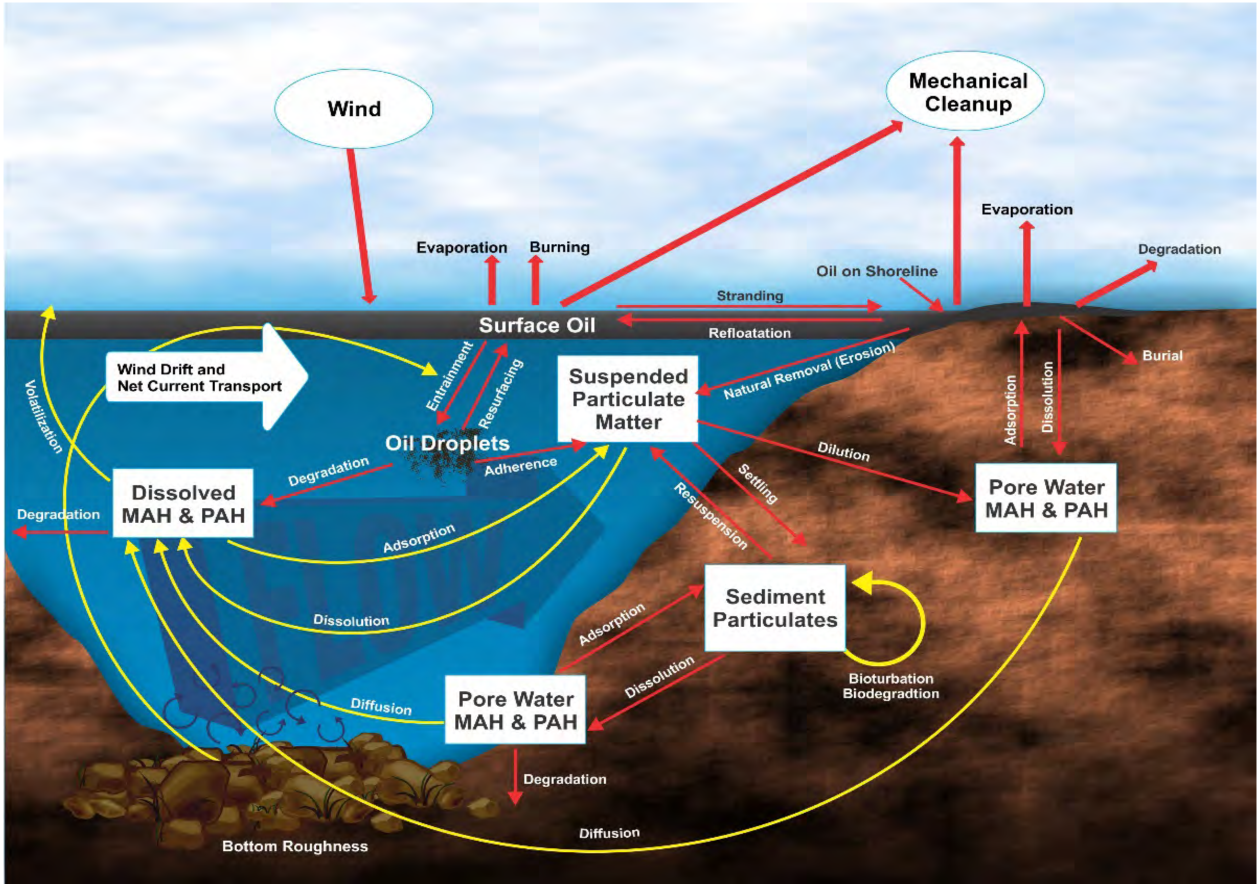
Source: Stantec et al. 2017.

Figure 10.3-2. Conceptual Diagram of Land Transport Model in OILMAP Land



Source: Stantec et al. 2017.

Figure 10.3-3. Conceptual Diagram of Downstream Transport Model in OILMAP Land



Source: Stantec et al. 2017.
MAH = monocyclic aromatic hydrocarbon, PAH = polycyclic aromatic hydrocarbon

Figure 10.3-4. Crude Oil Behavior in Aquatic Systems Simulated by SIMAP

The modeling is very specific to the conditions that would be encountered in the event of an actual spill. OILMAP and SIMAP incorporate data on the specific topographical, geographical, hydrodynamic (river currents and flow rates), weather conditions, habitats, ice conditions, and shoreline types at the selected sites.

Several release scenarios were modeled for each of the seven sites. Unmitigated releases, characterized by no emergency response for the first 24 hours, were simulated to provide a conservative, "worst-case" scenario at the hypothetical release locations[22] (Stantec et al. 2017). Two different crude oil types, a light Bakken crude oil and heavier Cold Lake Blend dilbit, were evaluated under three flow conditions (spring high flow, summer and fall average/moderate flow, and winter low flow) at the seven sites at different time intervals (6, 12, 18, and 24 hours). The spill volumes were estimated based on a 13-minute (10 minutes for response and 3 minutes of pumping out during valve closure) shutdown response and gravitational drainage of oil in the line based on distance between shut off valves and topography.

22 Another conservative assumption is that crude oil would travel unimpeded during the entire 24-hour modeled run for each release scenario.

10.3.2 Purpose of Spill Modeling

The modeling of hypothetical worst-case discharge spill scenarios was to provide insight into the behavior of different types of oils in the environments that are typical of Minnesota to help in the consideration of potential contingency planning requirements and to evaluate the range of potential environmental impacts. It was not practical to model hypothetical incidents along the entire 365-mile long Applicant's proposed route of Line 3 and the various lengths of all its alternative routes, nor to incorporate every conceivable contingency and circumstance. The purpose of the modeling was not to predict the outcomes of all the potential types of spills that might hypothetically occur from the Line 3 alternatives.

In reality, each spill is a unique event. Even with the same spill volume and oil type spilled at the same location, there can be varying outcomes depending on the weather, decisions made in the response operations, and other chance events. For example, for the 2000 PEPCO pipeline spill of 3,300 bbl of heavy oil in Chalk Point, Maryland, it was shown, through modeling, that if particular boom had not failed during the response and the directions of response officials had been followed, 57 percent of the oiled wetlands might have been spared impact (Etkin et al. 2006). In other spills, the weather has affected oil behavior. For example, in the 2010 Kalamazoo pipeline spill, heavy rain and flooding had a significant impact on the spread of the oil. Storms and other weather events could potentially affect the ability of responders to operate effectively or to carry out certain response strategies.

The modeling for Line 3 alternatives represent a reasonable and practical selection of spill outcomes that were meant to represent worst-case conditions to the extent possible.

10.3.3 Selection of Representative Sites for Modeling

Modeling of hypothetical spills from Line 3 was conducted to simulate the behavior, trajectory (path), fate, and effects of the spilled oil and determine the potential impacts from large spills. Since it was not feasible to model spills and all potential spill locations along the various Line 3 routes, it was necessary to select a reasonable number of sites that would adequately represent the variety of conditions present along the entire length of the Line 3 Applicant Preferred Route (APR) and various Route Alternatives (RA), as shown in Figure 10.3-1.

10.3.3.1 Site Selection Process

The Applicant's proposed Line 3 pipeline covers diverse landscape and habitat types, including grasslands, agricultural lands, forests, streams, rivers, lakes, and wetlands, along its over 340-mile path across the width of the state of Minnesota. There are regional and seasonal differences in climatic and environmental factors, including temperature, wind speed, precipitation (rain and snow), ice conditions, river flow, and terrain that could have a significant effect on the transport of oil over land and in water, as well as the adherence and retention of oil in various shoreline and land substrates. These factors needed to be taken into account in the site selection process.

The selection process involved a series of meetings with Minnesota Department of Commerce Energy Environmental Review and Analysis (DOC-EERA) and state and federal agencies to define not only the selection of sites, but also the overall modeling approach. The modeling approach was based on a number of "conservative" choices. A conservative modeling approach:[23]

- Tends to maximize predicted effects and improves the understanding of worst-case outcomes in oil trajectories, behavior, and associated effects;
- Allows for the model to bound upper and lower limits, reducing the number of scenarios required, while still maintaining the integrity and likelihood [plausibility] of the model and scenario; and
- Aids pipeline engineers and emergency response planners to better understand and prepare for a potential worst-case scenario.

A primary consideration for selecting sites for modeling was the understanding that in the event of a full-bore rupture incident, crude oil releases to land often result in oil contamination of only small areas of land (i.e., a few acres). On land, crude oil will pool and collect in depressions and adhere to vegetation and soil. In contrast, if crude oil was accidentally released into water, it can travel over larger distances due to water movement and its behavior in water, thereby potentially exposing a larger area to contact with crude oil. The effects of a release of crude oil on land are not inconsequential. However, the selection of locations for the hypothetical releases of crude oil that would result in oil entering watercourses (rivers or lakes) was in keeping with a conservative approach with respect to the fate, transport, and potential effects of released oil. Modeling scenarios therefore focused on locations where the hypothetical release of oil would either occur directly into a watercourse or would travel overland before eventually reaching a watercourse.

Issues and concerns that were raised as a result of the regulatory review process were used to identify the type and range of conditions that would need to be considered in the assessment of large crude oil releases in the modeling including:[24]

- Sites where the downstream movement of a crude oil release could overlap with and potentially affect a range of human uses (e.g., sources of drinking water, wild rice cultivation, agricultural lands, fishing, recreational uses, urban areas), as well as sensitive ecosystems (wetlands, sensitive fish spawning habitat for species such as walleye and trout, sensitive vegetation communities, forested regions, rare and endangered species).
- The need to assess potential effects of crude oil releases into large watercourses such as the Mississippi River. This reflected concerns for effects on environmental and human receptors, as well as concerns for interaction of the crude oil with suspended sediments in the water column and the potential for the oil-mineral aggregates, which may result in "sinking oil."
- The importance of considering differences in the characteristic of water features, including river width, the length of watercourses before entering larger water bodies, and differences in turbulence (e.g., flat calm water, riffles, rapids, and waterfalls) and other water feature characteristics (e.g., sediment loads, presence of emergent vegetation).

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23 Based on information in Stantec et al. 2017.

24 Stantec et al. 2017.

With these factors in mind, a set of selection criteria for sites were established to address engineering and environmental/socio-economic considerations. The criteria mandated that the sites should:[25]

- Be located so that a hypothetical large release of crude oil could potentially enter a watercourse either directly into a watercourse or through travel overland into a watercourse;
- Be located where shut-off valves would not overly restrict the volume of crude oil that could potentially be released (i.e., hydraulic drain down of pipeline would be a substantial contributor to the oil release volume);
- Include sites along both the preferred and alternate routes for Line 3;
- Be representative of the geographic and environmental conditions and land uses along the proposed right of way (ROW) for Line 3 to aid in the evaluation of the range of potential effects to the natural and human environment along the pipeline;
- Include a range of watercourse types (e.g., size, flow, energy level) and water bodies, including wetlands;
- Support evaluation of potential effects to environmentally sensitive resources (e.g., spawning grounds for fish, wild rice lakes, or other sensitive habitats);
- Represent areas of expressed concern by American Indian tribes, the general public, and/or state and federal agencies; and
- Support evaluation of potential effects to traditional use, other human use or infrastructure (e.g., potable water intakes or treatment facilities)

Working with the state and federal agencies, technical support for DOC-EERA, and Enbridge and their technical support,[26] nearly 1,000 watercourses were considered. There were 274 watercourses transected by the Line 3 APR, and 641 watercourses transected by the various ARs. The final selection of sites was made by summarizing the attributes with respect to six basic criteria:

- Location (within portion of Minnesota crossed by preferred and alternate routes for Line 3);
- Geomorphology;
- Location of sensitive resources or habitats in proximity to the preferred and alternate routes;
- Ecological land classification (province);[27]
- Watercourse characteristics (i.e., flat water, rapids/falls, lake); and
- Potential human uses (i.e., recreational, drinking water, populated area, sensitive ecosystem).

The seven sites selected are described in Table 10.3-1, and characterized by these attributes as in Table 10.3-2. The site locations are shown in Figure 10.3-1.

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[25] Stantec et al. 2017.

[26] Stantec, RPS, and Dynamic Risk.

[27] Based on Minnesota's Ecological Classification System for ecological mapping and landscape classification (MN DNR 1999). Provinces are units of land defined using major climate zones, native vegetation, and biomes such as prairies, deciduous forests, or boreal forests. There are four provinces in Minnesota.

For each of the seven representative locations, the modeling included two oil types (heavy crude and light crude) and three different time periods. The time periods took into account seasonal differences in environmental factors, such as river flow rate, snow/ice coverage, temperature, and wind speed. This created a total of 42 scenarios: 7 locations x 2 oil types x 3 environmental conditions.

10.3.4 Benefits and Limitations of Representative Site Modeling Approach

The representative-site modeling approach, as applied and presented in the EIS has the benefit of providing a means to analyze the potential trajectory (movement), fate (behavior and weathering), and effects of hypothetical spill scenarios under a variety of environmental circumstances. The locations and environmental conditions (as well as the hypothetical volumes of oil in the release scenarios) were selected in a conservative manner to effectively maximize oil transport and impacts to create simulations of worst-case scenarios. The modeling results can be used to qualify and quantify the consequences of a worst-case discharge for risk assessment purposes. The conservatively-developed site approach also fosters the understanding of the potential worst-case circumstances that pipeline engineers and emergency and spill response officials need to factor into planning.

That said, the modeling of representative sites can never comprehensively forecast all conceivable outcomes of hypothetical spill scenarios at the virtually infinite number of unique locations along the along the Line 3 pipeline. Each oil spill incident is a unique event in terms of the specific circumstances that affect the behavior, trajectory, fate, and effects of the oil. Case studies of past spill events in the US and around the world have demonstrated that many different factors determine the outcome of each incident.

The representative sites were selected to favor circumstances that would tend to exacerbate potential impacts and effects of the hypothetical spills along the Line 3 pipeline. In all likelihood, a spill of equivalent volume as the hypothetical scenarios that occurred at another location and time would have an outcome that would be of lesser consequences, or, at most similar consequences to one of the representative scenarios. It is also highly likely that any spill that does occur would be significantly smaller than the release volumes assumed for the hypothetical scenarios. (This is discussed in greater detail in Section 10.3.6 and Appendix S.[28])

A number of public comments have raised the issue of the lack of modeling in specific locations of concern. The potential outcomes of hypothetical spills in many of those locations may be addressed by applying the approach of selecting reasonably similar sites based on Table 10.3.-2.

[28] Etkin 2017.

Table 10.3-1. Description of Representative Release Locations

Site	Overland/Watercourse Factors	Represented Environmental Conditions
Site 1: Mosquito Creek to Lower Rice Lake *47.4604* *-95.3066*	• Potential for overland flow of and downstream transport of oil in very small watercourse. • Release point in relatively flat, forested region that forms drainage area with gentle slope towards agricultural and grassland habitats. • Swale collects into narrow and seasonal water crossing that ultimately forms Mosquito Creek (channel 3 ft wide). • After 12.5 miles, creek grows to 35 ft in width, before entering Lower Rice Lake (1,600 acres with large areas of wild rice).	• Small quiescent watercourse with wetlands, marsh, and fen. • Agricultural lands, nature preserve, and wild rice representative of lands that may be used as source of food and recreation. • Portions of ecosystem classified as sensitive.
Site 2: Mississippi River at Ball Club *47.2360* *-93.9596*	• Sinuous water channel 80 ft wide. • Flows through relatively well defined channel that with many oxbows. • Banks lined with extensive wetlands and forested areas. • Under high river flows, connects to White Oak Lake, before extending through more sinuous channels and marshy wetlands.	• Quiescent watercourse of intermediate size with wetlands, marsh, and fen. • Lake is approximately 9 miles downstream of hypothetical release location. • Representative of lands where food may be harvested, including fish and wild rice. • Includes upstream portion of Mississippi River and forested land. • Region is used for outdoor recreation, near the populated area of Deer River. • Sensitive ecosystems present.
Site 3: Sandy River *46.6363* *-93.2431*	• Bifurcated channel 30 ft wide. • South channel has natural sinuous feature; northern channel has straight drainage ditch. • Mainly lined by marshy grasses and wetland with some forests. • Flows through Steamboat and Davis lakes to Flowage Lake and eventually Big Sandy Lake (6 and 12 miles downstream) • Known to contain fish spawning habitat.	• Small ditch/creek type watercourse that enters into lakes and ponds after passing through wetlands, marsh, and fen. • Representative of forested and agricultural lands where food may be harvested. • Used for recreation, specifically focused around recreational fishing. • Sensitive ecosystems present.
Site 4: Shell River Crossing to Twin Lakes *46.8196* *-95.0430*	• Straight marshy channel 80 feet wide passes through forested areas and agricultural lands. • Enters Upper Twin Lake before draining into small reach that feeds Lower Twin Lake (0.6 to 1.2 miles downstream) • Houses line lakes, with docks for swimming and boating.	• Medium-width quiescent watercourse that enters directly into lakes after passing through areas with wetlands, marsh, and fen. • Representative of inhabited areas used recreationally. • Sensitive ecosystems present.

Table 10.3-1. Description of Representative Release Locations

Site	Overland/Watercourse Factors	Represented Environmental Conditions
Site 5: Red River *48.70533* *-97.1148*	• Located along border of Minnesota and North Dakota; runs north into Canada. • Downstream from site Red River is large, wide (150–400 ft) river that flows north along well-defined sinuous channel. • Passes communities of Pembina, North Dakota and St. Vincent, Minnesota 32 river miles downstream. • Crosses into Canada 34.5 miles downstream. • Communities of Emerson and West Lyme, Manitoba located on Canadian side of border.	• Large, low-gradient watercourse, with sinuous channel subject to flooding. • Shore predominantly vegetated, often with shrubs and trees above level of ice-scour. • Patches of forest often present where river meanders; • Surrounding land use primarily agricultural. • Known to be major area for recreation use. • Passes through or adjacent to sensitive ecosystems. • River is subject to moderate to extreme flooding, particularly in spring. • Under low or average flow, stream banks are combination of grass and soil; under higher flow river can overtop banks and spread into surrounding farm and grassland.
Site 6: Mississippi River at Palisade *46.6983* *-93.4950*	• At release site, large river 250 ft wide. • Sinuous channel mostly flat water passing through number of oxbows. • Some turbulent waters with presence of flood diversion dam and spillway. • Under high flow rates, small region has very turbulent waters containing rapids from waterfall.	• Large and relatively quiescent watercourse with predominantly forested banks. • Includes midstream portion of Mississippi River and forested lands. • Majority of channel relatively flat water. • Flood diversion channel, with dam and spillway, have potential for localized turbulence that could entrain oil. • Sinuous channel used recreationally. • Sensitive ecosystems present. • Drinking water source to area residences.
Site 7: Mississippi River at Little Falls *46.0483* *-94.3420*	• At release site, large river 820 ft wide, which flows to the south. • Release site 5 miles north of small urban area (Little Falls). • Little Falls Dam has large waterfall that induces large amount of turbulence, which would entrain surface oil into water column, if oil were to travel downstream to dam. • Second dam and waterfall (Blanchard Dam) 8 miles downstream of Little Falls, provides the potential for further entrainment of oil.	• Shore types mainly forested, with some small portions of agricultural lands and urban areas along banks. • Waters used recreationally/ • Sensitive ecosystems present.

Table 10.3-2. Summary of Characteristics of Each Representative Release Location

Representative Release Location		Mississippi River at Ball Club	Mississippi River at Little Falls	Mississippi at Palisade	Mosquito Creek to Lower Rice Lake	Red River	Sandy River	Shell River Crossing to Twin Lakes
EcoProvince		Laurentian Mixed Forest	East Broadleaf Forest	Laurentian Mixed Forest	Laurentian Mixed Forest	Prairie Parkland	Laurentian Mixed Forest	Laurentian Mixed Forest
	Site Features							
Hydrology Features	Ditch/Creek				X		X	
	Watercourse (Stream/River)	X	X	X	X	X	X	X
	Lake/Pond	X			X		X	X
	Flat Water	X		X	X	X	X	X
	Rapids/Falls		X	X				
	Dams		X	X				
	Wetland/Marsh/Fen	X			X		X	X
Watercourse Width	Small (<10 m)				X		X	
	Medium (10–50 m)	X		X				X
	Large (>50 m)		X			X		
Watercourse Features	Agricultural Land		X		X	X	X	X
	Forested Region	X		X			X	X
	Mississippi River	X	X	X				
	Urban Area		X					
	Wild Rice	X			X		X	X
Identified Uses	Recreational	X	X	X	X	X	X	X
	Drinking Water			X		X		
	Populated Area		X			X		
	Sensitive Ecosystem	X	X	X	X	X	X	X
Includes Overland Transport					X			

Source: Stantec et al. 2017.

If an interested party has concerns over potential impacts to a particular watercourse or location not selected for the modeling, the sites in Table 10.3-2 can be used to find an equivalent representative site to the one of concern. In the modeling report,[29] it states:

> "As an example, should an individual near Bemidji be concerned about the possible effects of a release into Lake Irving, they can refer to Table 10.3-2 to find an equivalent site. The Lake Irving location includes a small watercourse (<10 m) that travels a short distance and connects to a lake/pond with recreational use and sensitive ecosystems. Upon comparison, the Shell River representative release location would be a logical substitute. Similarly, if one were to consider another release location that entered a medium watercourse that traveled a longer distance before entering a lake/pond system, they could consider the Sandy River representative release location as an equivalent site."

10.3.4.1 24-Hour Time Frame

The modeling of the 42 hypothetical spill scenarios (7 locations x 2 oil types x 3 seasons) was conducted to determine the trajectory (path) and fate (behavior and weathering) of the oil only over the course of the first 24 hours. According to the modeling study report:[30]

> "The analysis was carried out following a highly conservative assumption that the released crude oil would travel downstream unimpeded for that length of time. This is a conservative assumption because Enbridge would immediately mobilize a response that would contain and collect oil in the event that a release [were] to be detected. The 24-hour time frame is consistent with guidance from the US Environmental Protection Agency (EPA), which stipulates a 27-hour period, representing 24-hours for arrival and 3-hours for deployment.[31] As such, modeled results should not be interpreted as representative of expected effects, but rather as an unlikely, unmitigated worst-case potential outcome."

10.3.4.1.1 Justification for the 24-Hour Time Frame for Spill Modeling

According to the study report,[32] in addition to the referenced EPA guidance, a further justification for the 24-hour time frame is that a similar duration and time steps were used for the ecological and human health risk assessment for Line 3 in Canada that was submitted to the National Energy Board of Canada.[33]

The modeling simulations assumed that the release was "unmitigated," meaning that there were no deflection or blockage of the oil in its movement downstream, nor any reductions in the amount of oil in the water, that might be "mitigated" by the strategic placement of booms and the use of skimming or vacuuming devices, respectively. In an actual spill scenario, the pipeline would be shut-in and emergency responders would be expected to begin to arrive on-scene within a few hours after

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[29] Stantec et al. 2017.

[30] Stantec et al. 2017.

[31] USEPA 2003.

[32] Stantec et al. 2017.

[33] Enbridge 2015.

notification of the incident to begin spill response operations. The former would be meant to stop the flow of oil, which would be the most effective mitigation strategy. The latter would be to take measures to reduce the movement of oil in the water and begin removing oil from the environment.

10.3.4.1.2 Concerns about 24-Hour Time Frame for Modeling

While it is possible to incorporate mitigation measures (spill response into SIMAP modeling),[34] that is usually done to analyze the potential effectiveness of response or compare strategies. The modeling of "unmitigated" responses is standard for most studies associated with EISs and other purposes. The entire "conservative" approach is based on maximizing the effects to examine the worst-case scenarios. Assuming "no response" in the modeling, i.e., not including hypothetical reductions in the amount of oiling through effective recovery methods, is actually in keeping with that.

According to Enbridge's *Line 3 Replacement Project Safety Report*, submitted with its application in April 2015 and its update in January 2017,[35] Enbridge's Controller in the primary incident detection system in the Control Center has 10 minutes to analyze information to initiate a shut-down. However, there is no specific estimate of the time in which the spill response measures would commence or be successfully completed to stop the further flow of oil downstream. However, the response plan would need to comply with EPA regulations.

According to the EPA requirements for inland responses,[36] the "substantial harm planning time" requirement in "all other rivers and canals, inland, and nearshore areas"[37] is 24 hours for arrival and a three-hour time period for deployment.[38] This would be for a Tier 1 response. Tiers 2 and 3 would roll out at 36 and 60 hours, respectively, for a worst-case discharge. The worst-case discharge volumes from Line 3 were calculated as inputs for the modeling.[39] In the Tier 1 response (within 24 hours), the

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34 For example, see Buchholz et al. 2016a, 2016b, 2016c; Etkin et al. 2006, 2008.

35 Enbridge 2015e; Enbridge 2017.

36 40 CFR 112 (Table 3, Appendix C).

37 i.e., Any place that is not in the Great Lakes or a higher-volume port area.

38 The specified time intervals in Table 3 of Appendix C are to be used only to aid in the identification of whether a facility could cause substantial harm to the environment. Once it is determined that a plan must be developed for the facility, the owner or operator shall reference Appendix E to this part to determine appropriate resource levels and response times. The specified time intervals of this appendix include a 3-hour time period for deployment of boom and other response equipment. (40 CFR 112).

39 From 30 CFR 254.47: "For a pipeline facility, the size of your worst case discharge scenario is the volume possible from a pipeline break. You must calculate this volume as follows: (1) Add the pipeline system leak detection time to the shutdown response time. (2) Multiply the time calculated in paragraph (c)(1) of this section by the highest measured oil flow rate over the preceding 12-month period. For new pipelines, you should use the predicted oil flow rate in the calculation. (3) Add to the volume calculated in paragraph (c)(2) of this section the total volume of oil that would leak from the pipeline after it is shut in. Calculate this volume by taking into account the effects of hydrostatic pressure, gravity, frictional wall forces, length of pipeline segment, tie-ins with other pipelines, and other factors."

response equipment that would have arrived would only be required to be capable of recovering 15 percent of the total discharge.[40]

This means, that while the oil spill response plan and associated emergency measures would most likely be well underway in the 24-hour time frame, it is highly unlikely that there would have been significant mitigation of a worst-case discharge release of 10,000 bbl or more, as in some of the hypothetical spill scenarios.

Even in the presence of spill response measures, the movement of oil downstream, particularly in a fast-moving current with a large volume of oil, would continue for some time after the 24- hour period. It is possible that there would be some changes in the movement of the oil with the strategic placement of certain booms to deflect oil, but unless the currents were less than 1.0 knots (0.36 m/s), it would not be possible to completely stop the flow of oil.

This is acknowledged to some extent in the modeling report, though the assumption of the effectiveness of mitigation is stated:[41]

> "Crude oil release simulations that reach the 24 hour time limit may still have oil remaining on the surface of the river or lake that has not adhered to a shoreline or spread to the defined minimum thickness. If there was oil on the water surface after 24 hours, it could (if not mitigated) continue to move downstream, further oiling shorelines until it either evaporated or stranded. The simulations assumed the releases were un-mitigated for the modeled 24 hour period (i.e., no benefits of emergency response operations were incorporated into the model). In a real-life scenario, emergency response procedures would mitigate the effects of the modeled incidents."

10.3.4.1.3 Limitations of the 24-Hour Time Frame for Spill Modeling

Given that the oil is still in the watercourse after 24 hours and that it would most likely still continue to move downstream, stranding in various places depending on the oil type, release site, and environmental conditions, it would be most informative to have modeling results from longer time frames – i.e., until the oil stops moving downstream at significant concentrations. Modeling beyond the first 24 hours would also allow a more accurate assessment of the behavior of the oil with respect to further weathering and interaction with sediments that might affect submergence in the case of the diluted bitumen.

More extended modeling runs of OILMAPL and SIMAP have been conducted in other projects, such as for a study conducted for the Northern Gateway Pipeline in Canada. In that study, modeling runs were conducted with six day to 50 day simulations. The variations in time were based on flow conditions, length of river section modeled, oil parameters, and the mapping of the geography.[42]

40 Planning requirements are not the equivalent of response requirements. In other words, it is not expected that this volume of oil would be recovered in this time, only that the equipment that is on-scene is capable of recovering this amount of liquid (which could be oil and water) in this time.

41 Stantec et al. 2017.

42 Horn and French-McCay 2015.

10.3.4.1.4 Oil Behavior after 24 Hours

Without modeling the trajectory (path) and fate (behavior and weathering) of the two types of oil in each of the seven locations under different seasons using OILMAPLand and SIMAP beyond the 24-hour time frame, it is not possible to predict with any degree of reliability the outcome of the spill scenarios.

Based solely on the properties of the two types of oils selected for modeling (Bakken crude and Cold Lake Blend diluted bitumen),[43] the further weathering of the oils can be simulated past the 24-hour time frame using a different model, the National Oceanic and Atmospheric Administration's (NOAA) Automated Data Inquiry on Oil Spills (ADIOS) 2.[44] Note that this model only addresses the weathering (evaporation) and does not take into account the specific environmental conditions at the seven selected sites beyond a designated temperature, static wind speed, water type (freshwater), and average sediment load. The results of that modeling for five days (120 hours) after the hypothetical releases of the two oil types are shown in Table 10.3-3 through Table 10.3-6. The tables show the amount of oil remaining in the environment after evaporation. There are significant differences in evaporation rates for the two oil types because of their different chemical properties. There is also a somewhat higher percentage of evaporation with smaller quantities of oil and in warmer weather.

For Bakken crude, the evaporation at 24 hours is about 46 percent, meaning 54 percent is still in the environment. At 120 hours (five days), an additional 10 percent has evaporated, leaving 44 percent in the environment. In winter, about 49 percent remains in the environment after five days. Considerable evaporation continues after the first 24 hours. For Cold Lake diluted bitumen, only about 2 percent more oil evaporates after the first 24 hours.

Table 10.3-3. Weathering of Hypothetical Summer Releases of Bakken Crude (ADIOS2)

Site	Percent of Volume Remaining in Environment by Hour						
	1 hour	12 hours	24 hours	48 hours	72 hours	96 hours	120 hour
Site 1	93%	61%	54%	49%	46%	45%	44%
Site 2	94%	62%	54%	49%	46%	45%	44%
Site 3	95%	63%	55%	49%	47%	46%	45%
Site 4	95%	63%	55%	50%	47%	46%	45%
Site 5	95%	63%	55%	49%	47%	46%	45%
Site 6	95%	63%	55%	49%	47%	46%	45%
Site 7	95%	65%	57%	50%	47%	46%	45%

Note:
Bakken crude (°API 42.5; windspeed 5 mph; water temperature 60°F; sediment load 50 g/m^3).

[43] Note that subsequent to the original modeling conducted (as presented in Stantec et al. 2017), the Bakken crude oil was replaced with a "light Canadian crude oil" for which there was no further information. The properties of a light crude oil would differ from that of Bakken crude, as explained further in Section 10.2.1.1.

[44] http://response.restoration.noaa.gov/ADIOS

Table 10.3-4. Weathering of Hypothetical Summer Releases of Cold Lake Diluted Bitumen (ADIOS2)

Site	Percentage of Volume Remaining in Environment by Hour						
	1 hour	12 hours	24 hours	48 hours	72 hours	96 hours	120 hour
Site 1	90%	78%	76%	74%	74%	74%	73%
Site 2	91%	78%	76%	75%	74%	74%	74%
Site 3	92%	78%	76%	74%	74%	74%	74%
Site 4	91%	78%	75%	74%	74%	74%	74%
Site 5	92%	78%	75%	74%	74%	74%	74%
Site 6	91%	78%	75%	74%	74%	74%	74%
Site 7	92%	78%	75%	74%	74%	74%	74%

Note:

Cold Lake blend diluted bitumen (°API 22.6; windspeed 5 mph; water temperature 60°F; sediment load 50 g/m^3).

Table 10.3-5. Weathering of Hypothetical Winter Releases of Bakken Crude (ADIOS2)

Site	Percentage of Spill Volume Remaining in Environment by Hour						
	1 hour	12 hours	24 hours	48 hours	72 hours	96 hours	120 hour
Site 1	96%	66%	58%	53%	51%	49%	48%
Site 2	96%	66%	59%	53%	51%	50%	49%
Site 3	97%	68%	60%	54%	51%	50%	49%
Site 4	97%	67%	59%	53%	51%	50%	49%
Site 5	97%	68%	60%	51%	51%	50%	49%
Site 6	97%	67%	59%	53%	51%	50%	49%
Site 7	97%	68%	60%	54%	51%	50%	49%

Note:

Bakken crude (°API 42.5; windspeed 5 mph; water temperature 38°F; sediment load 50 g/m^3).

Table 10.3-6. Weathering of Hypothetical Winter Releases of Cold Lake Diluted Bitumen (ADIOS2)

Site	Percentage of Spill Volume Remaining in Environment by Hour						
	1 hour	12 hours	24 hours	48 hours	72 hours	96 hours	120 hour
Site 1	92%	79%	77%	76%	75%	75%	75%
Site 2	92%	79%	77%	76%	75%	75%	75%
Site 3	93%	79%	77%	76%	75%	75%	75%
Site 4	93%	79%	77%	76%	75%	75%	75%
Site 5	93%	79%	77%	76%	75%	75%	75%
Site 6	92%	79%	77%	76%	75%	75%	75%

Table 10.3-6. Weathering of Hypothetical Winter Releases of Cold Lake Diluted Bitumen (ADIOS2)

Site	Percentage of Spill Volume Remaining in Environment by Hour						
	1 hour	12 hours	24 hours	48 hours	72 hours	96 hours	120 hour
Site 7	93%	79%	77%	76%	75%	75%	75%

Note:
Cold Lake blend diluted bitumen (°API 22.6; windspeed 5 mph; water temperature 38°F; sediment load 50 g/m^3).

The major changes that would be expected in the hypothetical scenarios after the first 24 hours are:

- Additional evaporation (about 10 percent more) of Bakken crude oil over the course of the next four days;
- Bakken crude would continue to move downriver;
- Additional evaporation (about 2 percent more) of Cold Lake Blend diluted bitumen over the course of the next four days;
- Diluted bitumen would continue to move downriver; and
- Additional time for diluted bitumen in turbulent, sediment-laden waters could increase the amount of submerged oil.

It is important to take into account that these scenarios, as well as the ones that were modeled, involved completely unmitigated releases. In an actual spill situation, the trajectory of the oil would be modified to some extent by spill response measures, such as the placement of boom that would deflect the oil to other locations or possibly block its movement in some cases.

10.3.5 Summary of Results

This section summarizes some of the primary behaviors predicted by the modeling for the three crude oil types, Bakken Crude, Cold Lake Blend (spring summer scenarios), and Cold Lake Winter Blend (winter scenarios). As expected, higher river flows (during spring) typically resulted in greater downstream extents for both crude oil type scenarios (Table 10.3-7). Thick surface oil slicks and evaporative losses of crude oil constituents occurred in low-energy systems. Substantial loss of the spill shoreline oiling was also observed under these conditions, which resulted in the complete loss of the spill volume to surface adhesion, evaporation, and similar factors in less than 24 hours, as noted in Table 10.3-7. Dissolved hydrocarbon concentrations tended to be greater in more turbulent, high-energy systems due to dissolution, aided by dispersion and entrainment. Sediment oiling was also more extensive at these locations due to vertical mixing and interaction with suspended particles, which resulted in deposition on the river bottom. During low-flow conditions (winter), downstream extents were primarily dependent on river flow and oil density.[45]

[45] During low-flow conditions characteristic of winter, lighter Bakken crude more readily rose vertically through the water column and became trapped beneath the ice, effectively removing a portion of the oil mass from further downstream transport. In addition, shoreline oiling was limited during low-flow conditions compared to the other flow conditions when the river surface was free of ice.

These modeling results provide useful context when evaluating the potential effects of crude oil releases on the environment, and were considered during the exposure assessment in Section 10.4. For example, the predicted downstream extents of oil transport from the Stantec et al. modeling, along with the results of other relevant spill studies, were considered during the development of downstream region of interest (ROI) criteria (see Section 10.4.1).

Table 10.3-7. Predicted Downstream Transport Distances of Two Crude Oil Types

Study Site	Predicted Volume Out (bbl)	Approximate River Width (feet)	Maximum Distance Traveled in First 24 Hours (miles)[b,c]	
			Bakken Crude	Cold Lake Blend
Site 1 – Mosquito Creek to Lower Rice Lake	8,265	3–35	10.4[c]	3.5[c]
Site 2 – Mississippi River at Ball Club	10,660	80	23.0	8.1[c]
Site 3 – Sandy River	15,374	30	12.2	8.1[c]
Site 4 – Shell River to Twin Lakes	13,648	95–184	21.9	3.7[c]
Site 5 – Red River	13,856	150–400	40.3	19.2
Site 6 – Mississippi River at Palisades	11,840	250	17.8	17.9
Site 7 – Mississippi River at Little Falls	15,894	820	31.2	32.3

Source: Stantec et al. 2017.

[b] Predicted maximum distance traveled (typically under spring, high-flow conditions) following a 24-hour unmitigated release scenario unless otherwise noted. Potential further migration after 24 hours was not modeled.

[c] Spill volume exhausted prior to 24 hours.

10.3.6 Benchmarking of Volumes of Enbridge Line 3 Hypothetical Spill Scenarios

Hypothetical spill scenarios were modeled in the draft EIS at seven selected sites with the spill volumes in Table 10.3-7. The volumes were benchmarked against spill volumes from past spills throughout the U.S. and in Minnesota for different time periods. (Note that throughout this section, the hypothetical spills are referred to by their site numbers for convenience. The site itself is not pertinent to the benchmarking analysis as the scenario volumes are compared to historical spills throughout the U.S. and throughout the state of Minnesota. The sites themselves are not benchmarked in this analysis in any manner.) The benchmarking of spill volumes does not imply that the impacts, consequences, or behavior of the spills are directly related to those in actual spills based on volume. The outcome of a spill is greatly affected by the oil type, location, and environmental conditions at the time of the spill. Two spills of similar volumes do not necessarily have similar outcomes.

10.3.6.1 Benchmarking of Hypothetical Volumes Against U.S. National Spills

The hypothetical spills in Table 10.3-7 were benchmarked against U.S. pipeline spills (crude and refined) based on data from 1968 through 2015 and on data from 2006 through 2015 (as presented in Section 10.2.6). All of the scenarios exceeded the 99th percentile of pipeline spills regardless of spilled product. In other words, less than 1 percent of historical pipeline spills throughout the U.S. over 48 years were that size or larger.

Table 10.3-8 shows the percentile value for the hypothetical spill scenarios relative only to crude pipeline spills throughout the U.S. for different time periods.

Table 10.3-8. Hypothetical Line 3 Spills Relative to U.S. National Crude Pipeline Incidents

Hypothetical Spill[a]	U.S. 1968-2015		U.S. 2000-2015		U.S. 2006-2015	
	Percentile[b]	% Spills Larger[c]	Percentile	% Spills Larger	Percentile	% Spills Larger
Site 1	98.82	1.18%	99.53	0.47%	99.66	0.34%
Site 2	99.19	0.81%	99.69	0.31%	99.72	0.28%
Site 3	99.52	0.48%	99.80	0.20%	99.83	0.17%
Site 4	99.44	0.56%	99.77	0.23%	99.77	0.23%
Site 5	99.52	0.48%	99.84	0.16%	99.85	0.15%
Site 6	99.27	0.73%	99.73	0.27%	99.72	0.28%
Site 7	99.52	0.48%	99.80	0.20%	99.84	0.16%

[a] The hypothetical spills are referred to by their "site numbers" for convenience. The sites themselves are not benchmarked in any manner in this analysis.

[b] A percentile spill volume is the percentage of spills that are that volume or less. e.g., a 99th percentile spill of 1,100 bbl means that 99 percent of spills are 1,100 bbl or less. Only 1 percent of spills are larger.

[c] The percent of historical crude pipeline spills that were larger than the volume of the hypothetical scenario.

10.3.6.2 Benchmarking of Hypothetical Volumes Against Historical Minnesota Spills

The same analyses were conducted comparing the hypothetical spill scenario volumes to historical crude pipeline spills in Minnesota, as summarized in Table 10.3-9. The data involved spills that occurred from 1968 through the present (end of June 2017). There have been no spills over 6,000 bbl since 2000. For this reason, all of the hypothetical Line 3 spill scenarios would represent the largest spills in this time period.

There have been larger spills prior to 2000. The hypothetical Line 3 scenarios represent the 96th to 99th percentiles. That means that 1 percent to 3.5 percent of crude pipeline spills during 1968 through 2015 were larger. In other words, if these hypothetical incidents had occurred, they would have fallen into the designated percentiles and only the percentage shown would have been larger. If these hypothetical Line 3 spills had occurred in 2000 or later, they would have been the largest crude pipeline spills in that time period.

Table 10.3-9. Hypothetical Line 3 Spills Relative to Minnesota Crude Pipeline Incidents

Hypothetical Spill	Minnesota 1968–2017		Minnesota 2000–2017		Minnesota 2006–2017	
	Percentile	% Spills Larger	Percentile	% Spills Larger	Percentile	% Spills Larger
Site 1	96.45	3.55%	100.00	0.00%	100.00	0.00%

Table 10.3-9. Hypothetical Line 3 Spills Relative to Minnesota Crude Pipeline Incidents

Hypothetical Spill	Minnesota 1968–2017		Minnesota 2000–2017		Minnesota 2006–2017	
	Percentile	% Spills Larger	Percentile	% Spills Larger	Percentile	% Spills Larger
Site 2	97.87	2.13%	100.00	0.00%	100.00	0.00%
Site 3	99.01	0.99%	100.00	0.00%	100.00	0.00%
Site 4	98.87	1.13%	100.00	0.00%	100.00	0.00%
Site 5	99.15	0.85%	100.00	0.00%	100.00	0.00%
Site 6	97.87	2.13%	100.00	0.00%	100.00	0.00%
Site 7	99.08	0.92%	100.00	0.00%	100.00	0.00%

10.3.6.3 Return Period Calculation for Hypothetical Line 3 Scenario Volumes

The return periods for the volumes of the hypothetical Line 3 spills *in the entire U.S.* were calculated based on the national data for the three time periods with the results shown in Table 10.3-10. In other words, spills of this volume would be expected *somewhere in the U.S.* every 2 to 4 years based on the data from the last decade. *This does not indicate that these spills would occur in Minnesota on Line 3 (or any other pipeline in Minnesota).*

Table 10.3-10. Estimated Return Periods for Hypothetical Crude Pipeline Spill Volumes in the U.S.

Hypothetical Spill Volume	U.S. 1968–2015		U.S. 2000–2015		U.S. 2006–2015	
	Frequency per Year	Return Period (Years)	Frequency per Year	Return Period (Years)	Frequency per Year	Return Period (Years)
Site 1	1.58	0.6	0.75	1.3	0.60	1.7
Site 2	1.09	0.9	0.50	2.0	0.50	2.0
Site 3	0.64	1.6	0.32	3.1	0.30	3.3
Site 4	0.75	1.3	0.37	2.7	0.41	2.5
Site 5	0.64	1.6	0.26	3.9	0.27	3.8
Site 6	0.98	1.0	0.43	2.3	0.50	2.0
Site 7	0.64	1.6	0.32	3.1	0.28	3.5

Based on analyses of historical data for Minnesota, the frequency of a spill of large volume in the state is much lower (see Section 10.2.6). As shown in Table 10.3-6, there have been no spills of the magnitude of the volumes for the hypothetical Line 3 scenarios since prior to 2000. The last spill of this volume or greater in Minnesota was in March 1991.

The return period calculation based solely on Minnesota data for the years 1968 through June 2017 is shown in Table 10.3-12. Note that for the 2000–2017 time period, the calculation returns a value of zero for the frequency as there are no historical incidents in this time period. This may be attributed to a very low likelihood or probability of a large spill incident and a short time frame.[46]

The estimated return periods based on the 1968–2017 data are over-estimates with regard to frequency, and, correspondingly, under-estimates for return periods. In other words, the frequencies would be expected to be lower and the return periods would be expected to be longer.

Table 10.3-11. Estimated Return Periods for Hypothetical Crude Pipeline Spill Volumes in Minnesota

Hypothetical Spill Volume	Minnesota 1968-2017	
	Frequency per Year	Return Period (Years)
Site 1	0.101	9.9
Site 2	0.061	16.5
Site 3	0.028	35.5
Site 4	0.032	31.1
Site 5	0.024	41.3
Site 6	0.061	16.5
Site 7	0.026	38.2

An alternative approach to calculating the return period for the Minnesota spills was also taken. The return periods estimated for the U.S. as a whole (in Table 10.3-7) were used to calculate the relative reduction in frequencies for the time periods (1968–2015, to 2000–2015, to 2006–2015) as shown in Table 10.3-12.

Table 10.3-12. Reduction in Frequencies for Hypothetical Crude Pipeline Spill Volumes in the U.S.

Hypothetical Spill Volume	U.S. 1968–2015 Frequency per Year	U.S. 2000–2015		U.S. 2006–2015	
		Frequency per Year	Reduction from 1968–2015	Frequency per Year	Reduction from 1968–2015
Site 1	1.58	0.75	52.5%	0.6	62.0%
Site 2	1.09	0.5	54.1%	0.5	54.1%
Site 3	0.64	0.32	50.0%	0.3	53.1%
Site 4	0.75	0.37	50.7%	0.41	45.3%
Site 5	0.64	0.26	59.4%	0.27	57.8%
Site 6	0.98	0.43	56.1%	0.5	49.0%
Site 7	0.64	0.32	50.0%	0.28	56.3%

46 This would be analogous to rolling dice a limited number of times and never getting a particular result. With more rolls (more time), eventually the number may come up.

The reduction factors in Table 10.3-12 were applied to the frequencies in Table 10.3-11 to derive the extrapolated frequencies and return periods in Table 10.3-13. These results indicate that the expected return period of the hypothetical spills ranges from about once every 21 to 26 years for the lowest volume Spill 1) to once every 99 to 103 years for the highest volume (Spill 5). Note that these return periods do not necessarily correspond to the specific sites (Table 10.3-7) for which these volumes were calculated—only these spill volumes within the state.

It is important to bear in mind that this estimation approach is conservative. That is, it is cautionary by over-estimating the probability of these incidents.

Table 10.3-13. Extrapolated Frequencies/Return Periods for Hypothetical Large Spills in Minnesota

Hypothetical Spill Volume	Minnesota 1968–2017		Minnesota 2000–2017 Extrapolated from U.S. 2000–2015 Reduction		Minnesota 2006–2017 Extrapolated from U.S. 2006–2015 Reduction	
	Frequency per Year	Return Period (Years)	Frequency per Year	Return Period (Years)	Frequency per Year	Return Period (Years)
Site 1	0.101	9.9	0.0479	20.9	0.0384	26.1
Site 2	0.061	16.5	0.0280	35.7	0.0280	35.7
Site 3	0.028	35.5	0.0140	71.4	0.0131	76.2
Site 4	0.032	31.1	0.0158	63.3	0.0175	57.2
Site 5	0.024	41.3	0.0098	102.6	0.0101	98.8
Site 6	0.061	16.5	0.0268	37.4	0.0311	32.1
Site 7	0.026	38.2	0.0130	76.9	0.0114	87.9

10.3.6.4 Return Period Calculation for Smaller Spills

Based on the data in Section 10.2.6, the return periods for smaller spills were calculated, as shown in Table 10.3-14. Since there were no spills in the larger spill categories, the frequencies were zero. However, this is merely be indicative of a lower probability and a return period that exceeds the time period for the data—17.5 years for the 2000–2017 data set, and 7.5 years for the 2010–2017 set.

Table 10.3-14. Frequencies and Return Period by Spill Volumes for Minnesota Crude Pipelines

Spill Volume Category	Based on Minnesota 2000–2017 Data		Based on Minnesota 2010–2017 Data	
	Frequency per Year	Return Period (Years)	Frequency per Year	Return Period (Years)
0.01 – 0.09 bbl	0.29	3.5	3.07	0.3
0.1 -0.9 bbl	1.26	0.8	0.93	1.1
1-9 bbl	2.11	0.5	0.80	1.3
10-99 bbl	0.97	1.0	0.13	7.5
100-999 bbl	0.29	3.5	0.00	0.0
1,000-9,999 bbl	0.29	3.5	0.00	0.0
10,000-90,000 bbl	0.00	0.0	0.00	0.0
TOTAL	**5.20**	**0.2**	**4.93**	**0.2**

10.3.6.5 Summary of Benchmarking Analysis Findings for Selected Spill Models

Using a conservative (cautionary over-estimating) approach, it was estimated that the volumes of spillage approaching the volumes used in the seven hypothetical Line 3 spill scenarios (Table 10.3-7) might be expected once in 26 to 99 years somewhere in the state of Minnesota[47]. *This does not indicate that the incidents would occur at the specific sites selected for modeling.*

10.4 ASSESSMENT OF POTENTIAL CRUDE OIL EXPOSURES AND IMPACTS

This section identifies the resources in the vicinity of the Applicant's preferred route and alternatives (CN Alternatives—Section 10.4.2; route alternatives—Section 10.4.3) that may be exposed to crude oil in the case of a release. The alternatives cross a wide range of habitats and conditions, including a variety of land uses, human uses, and ecosystems. Therefore, each alternative differs in terms **of the resources exposed and the possible impacts that would result in** impacts on resources if a crude oil release were to occur. Resources within specific distances of each alternative were identified to evaluate the potential for **exposure and** impacts due to a spill. For this analysis, ROIs for potential releases were identified (as described in Section 10.4.1) to reflect the potential extent of a large-volume incident that could occur at any point along each route. Alternatives with a higher number of resources within the ROIs would have a greater exposure and potential adverse effects following a release compared to alternatives with fewer resources within the ROIs. **However, the assessment of exposed resources does not predict the outcome of any particular spill because the actual impact of a spill on these resources depends on a number of incident-specific factors like spill size, weather, and seasonality.**

10.4.1 Resources and Regions of Interest for the Comparison of Alternatives

The following three HCAs, as defined by the PHMSA criteria for hazardous liquid pipelines (PHMSA 2011), were considered in the exposure analysis (and provided directly by Enbridge):

47 This is based on existing pipeline data and does not account for better corrosion control, steel and construction standards (thicker steel under water crossings) which would reduce the risk and increase the time expected for a major spill.

- **Populated Areas** include both high-population areas (referred to as “urbanized areas” by the U.S. Census Bureau) and other populated areas (referred to as “designated places” by the U.S. Census Bureau).
- **Unusually Sensitive Ecological Areas** include locations of critically imperiled and imperiled species and ecological communities, federally listed threatened and endangered species, and concentrations of migratory waterbirds. Individual species and habitats are not identified for this analysis; rather it provides a general overview of potential impacts on all unusually sensitive ecological areas should a spill occur.
- **Drinking Water Sources** include those supplied by surface water or wells and where a secondary source of water supply is not available. The land area in which spilled hazardous liquid could affect the water supply is also treated as an HCA. This HCA was derived from state Wellhead Protection Area or Source Water Area.

Areas of interest (AOIs) have been identified by Minnesota Department of Natural Resources (Minnesota DNR) and Minnesota Department of Health (Minnesota DH) as sensitive areas where a crude oil release may have long-term and/or permanent impacts on resources. The following AOI categories and subcategories were considered:

- Drinking Water AOIs
  - Drinking Water Supply Management Areas (DWSMAs) and vulnerability,
  - Wellhead protection areas (WPAs),
  - Hydrogeologic sensitivity,
  - Domestic wells and sensitivity, and
  - Public wells.
- Cultural Resources AOIs
  - Archaeological resources,
  - Historical resources, and
  - Reservations.
- Biological AOIs
  - Aquatic Management Areas,
  - Lakes of Biological Significance,
  - Minnesota Biological Survey Sites of Biodiversity Significance (MBS Sites),
  - Native plant communities,
  - Wetland bank easements,
  - Wild rice lakes,
  - Muskie lakes,
  - Sensitive lakeshore areas,

  - Minnesota Board of Water and Soil Resources (Minnesota BWSR) conservation easements,
  - Marginal cropland – limited,
  - Marginal cropland – perpetual, and Scientific and natural Areas.
- Commodity Production AOIs
  - National forests,
  - Other forest land
  - State forests, and
  - Wild rice harvest areas.
- Recreation and Tourism AOIs
  - State plan/recreational areas,
  - State parks,
  - Wildlife Management Areas (WMAs), and
  - Waterfowl production areas.

These data sets do not predict the outcome of a spill, but rather provide a point of reference that allows a comparison of the type and magnitude of resources that could be exposed along each of the routes should an oil spill occur. These datasets represent the efforts of technical experts to identify appropriate metrics to characterize potential exposure of resources of concern; however, they do not necessarily provide a perfect characterization of potential exposure or tell the full story. Caution should be used in directly comparing these quantitative results across alternatives. For example, the Recreation and Tourism AOIs identify recreational lands but do not incorporate information about the number of recreational users, which is potentially relevant to how the impact of a spill may be experienced.

Despite these limitations, the HCA and AOI datasets listed above are reasonably useful, readily available indicators of resource exposure. Information from PHMSA regarding the drinking water HCA dataset, for example, indicates that the dataset includes groundwater vulnerability factors that could influence the ultimate impact of a spill. Because of this, quantitative comparisons of drinking water exposure can theoretically be made across alternatives using these HCA data.

As part of consultation with Minnesota Department of Health (and with support from Minnesota DNR and Minnesota PCA), appropriate distances for the protection of drinking water supplies, in support of a screening-level GIS approach, were determined based on a consensus of existing information and case studies.

The ROI for comparisons among alternatives encompasses a 2,500-foot-wide distance extending in each direction from the centerline of the alternative (pipeline routes and transportation mode corridor); thus, the total area assessed is a 5,000-foot-wide corridor centered on the pipeline route, rail bed, or roadway. The ROI was identified as the distance that released oil would typically spread on flat ground (calculated to be 1,214 feet from the centerline) plus an additional distance of 1,050 feet for estimated downgradient migration in groundwater (if groundwater were contacted); the estimated total distance of approximately 2,264 feet was rounded up to 2,500 feet. Based on case studies presented above, the 2,500 foot ROI is conservative and does not suggest that any single release will impact resources at these distances. The ROI of groundwater in the Bemidji and Cass lake case studies was less than 1,000 feet.

This ROI was determined to be an appropriate distance, based on a review of existing information and relevant case studies to be applied comprehensively across the HCA and AOI resources listed above, with the exception of certain drinking water resources, which are discussed in more detail in Section 10.4.2.1.1. The numbers and/or acres of HCAs and AOIs within the ROI for each alternative were determined by overlaying GIS layers for each HCA and AOI with the ROI.

10 miles downstream was selected for the ROI, because it was considered to be not overly conservative, and crossing widths for the RAs were unavailable. The Applicant surveyed the streams and rivers for the APR only, so small (less than 30 feet wide) and large (30 feet wide or greater) crossings are only known for this route. It would be biased to only run the two downstream buffers (30 miles for large rivers, and 10 miles for small streams) along the APR. Furthermore, it was determined that it would be overly conservative to run a 30-mile downstream buffer for all water crossings, especially since many of these water bodies are ditches and terminate within a few miles.

In addition to assessing exposure of resources within 2,500 feet on either side of the alternative centerlines for upland areas, a downstream exposure analysis was conducted to identify and enumerate resources that could be at risk of exposure to crude oil if a release occurred at a waterbody crossing. Based on the Stantec et al. trajectory and fate modeling analysis (2017), which modeled spill 24-hour maximum travel distances of 3.5 to 30 miles for dilbit and 10.4 to 40.3 miles for Bakken Crude, and available survey data, a 10-mile-long downstream ROI was applied to all waterbody crossings for this downstream exposure analysis of the Project and its alternatives (Figure 10.4-1).

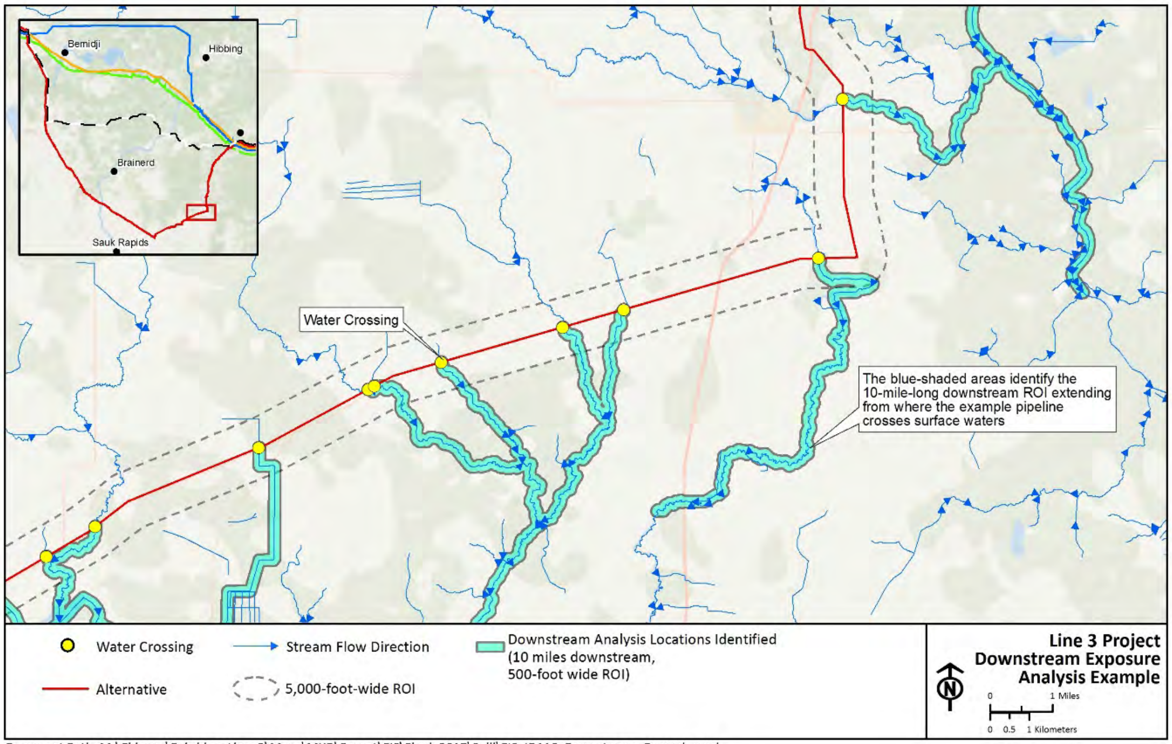

Figure 10.4-1. Example of 10-Mile-Long Downstream Region of Interest for a Pipeline Route Segment

The 10-mile-long downstream ROI was calculated in GIS starting at the point where each waterbody intersects with each alternative. Flow direction was determined using the National Hydrography Dataset flowline direction. River segments were combined and traced downstream for 10 miles. In addition, the 10-mile-long downstream ROI was extended to a width of 500 feet from the centerline of the flow to create a 1,000-foot-wide corridor of potential exposure from a spill up to 10 miles downstream of each waterbody crossing. This ROI was overlaid with HCA- and AOI-specific data layers to determine potential resources that could be exposed should a release occur.

Given the scale of the alternatives, maps of HCAs and AOIs do not include the analysis ROIs. A single map for each HCA or the AOIs is included in the 2,500-foot-wide ROI discussion and referenced in the 10-mile-long, 1,000-foot-wide downstream ROI discussion.

The adoption of 10-mile-long downstream ROIs from watercrossings, as well as a 2,500-foot-wide ROIs across the waterbodies, is generally based on conservative, precautionary assumptions about potential spill impacts (i.e., likely tending to over-estimate impacts). These criteria assume that spilled oil would affect all of these areas by actually contact through overland flow and/or dispersion through substrates adjacent to the streams in sufficient concentrations and for a sufficient length of time to cause impacts through toxicity, absorption, and/or adherence. In reality, the degree to which oil that spilled into a stream or other watercourse would either overflow the banks of the river or penetrate through the substrates along the shorelines would depend on location- and situation-specific factors. These factors would include the water level in the stream and degree of flooding and rainfall that would affect overland flow of oil at the time of the spill, as well as the topography on either side of the stream. Streams would generally form and flow at low points rather than at high points, although it is possible to have a stream in relatively flat terrain. For example, flooding and stream overflow was a significant factor in the behavior of the spilled oil in the 2010 spill in Marshall, Michigan (Kalamazoo River).The effects that might occur would be determined by the sensitivity of the resources and populations at risk, as well as the actual exposure dose. The exposure dose would be determined by both the concentrations of hydrocarbons and the duration of the exposure. For example, oil in the water column (i.e., oil that is dissolved or physically dispersed into the water rather than floating on the surface) does not generally cause biological impacts unless the concentrations are at least one part per billion (ppb). The duration of exposure at this concentration would determine the degree of impacts.

The usual impact thresholds that are used to determine the impacts of oil are as follows:

- Surface concentrations (10 g/m^2 for ecological impacts; 0.01 g/m^2 for socioeconomic impacts);
- Shoreline concentrations (100 g/m^2 for ecological impacts; 1 g/m^2 for socioeconomic impacts); and
- Water column impact (1 ppb for ecological impacts) (French et al. 1996; French McCay 2009).

The reason that the thresholds for socioeconomic impacts are lower than those for ecological impacts is that there has been shown that it would take considerably higher concentrations to cause impacts to biological resources based on toxicity, adherence, or persistence of hydrocarbons than the concentrations that would trigger cleanup responses or affect cultural, social, and economic activities due to cause concern and because of visual or esthetic reasons (French et al. 1996; French McCay 2009).

10.4.2 Exposure Analysis for Comparison of Certificate of Need Alternatives

Areas potentially exposed to oil spills along the CN Alternatives were identified based on the GIS methodology described above. It should be noted that the majority of system alternative SA-04 occurs outside of Minnesota, and because many of the AOIs are Minnesota-specific metrics, there are limited data available in other states, which has likely resulted in an underestimate of acreages of AOIs affected by that route.

10.4.2.1 Region of Interest Analysis

10.4.2.1.1 HCA Comparisons among Applicant’s Preferred Route and Certificate of Need Alternatives

Populated Areas

Oil spills in populated areas have the potential to affect public health, public resources and infrastructure, socioeconomics, and transportation. The acreages of HCA populated areas that could be exposed to crude oil after a release along the CN Alternative routes are listed in Table 10.4-1. The CN Alternative with the greatest acreage of HCA populated area within 2,500 feet on either side of its centerline is existing Line 3 supplemented by truck, followed by existing Line 3 supplemented by rail, transportation by truck, transportation by rail, continued use of existing Line 3, and SA-04. The Applicant’s preferred route has the lowest acreage of affected HCA populated area within the ROI. Potential impacts from a release of crude oil in HCA populated areas are discussed below.

Table 10.4-1. HCA Populated Areas within 2,500 Feet of the Centerlines of the Applicant's Preferred Route and Certificate of Need Alternative Routes (acres)

Applicant's Preferred Route	Continued Use of Existing Line 3	System Alternative SA-04	Transportation by Rail	Transportation by Truck	Existing Line 3 Supplemented by Rail	Existing Line 3 Supplemented by Truck
6,545.2	22,318.7	13,075.3	76,793.4	41,630.0	99,112.1	63,948.7

Source: Enbridge 2016c.

HCA = high consequence area

Public Health

Public health can be affected by oil contamination of air, water, soil, and food resources. Effects from oil exposure can be acute or chronic. Exposure may occur immediately following, or in response to, a spill through dermal contact, ingestion, or inhalation.

For most people, brief dermal contact with a small amount of oil would do no harm; however, some people are more sensitive to chemicals, including those found in crude oil (Centers for Disease Control and Prevention and Agency for Toxic Substances and Disease Registry 2010). Dermal contact with sticky bitumen would increase exposure, although toxicity implications are not clear given limited data (National Academies of Sciences, Engineering, and Medicine 2016). People exposed directly to oil could experience dermatitis; however, the potential for a large proportion of the population to have direct exposure to oil would be small due to restricted access to contaminated areas. Ingestion has the potential to occur through various pathways, including contaminated drinking water sources and fish tissues. In historical studies reviewed by Stantec et al. (2017), groundwater-supply wells were rarely affected, but surface water supply intakes downstream of pipeline ruptures were affected. In some cases, impacts were minimal; in others, water treatment was required. Impacts on water supplies in these case studies were short term. Long-term impacts on water supply could occur under certain circumstances, though protective measures (i.e., using a different water supply) would reduce direct impact on human health. While the general public could be exposed to oil through contamination of aquatic food sources, fisheries are usually closed and monitored for a period after a spill to ensure food safety, reducing this mode of exposure.

People in the immediate area of a spill would experience inhalation exposure and impacts as the oil evaporates. Inhalation of petroleum-related vapors tends to include lighter weight, volatile compounds that evaporate after spills. People such as first responders and residents near an incident site could be exposed to harmful volatile compounds and would likely experience temporary health impacts such as respiratory irritation, headache, or eye irritation. Emergency responders and spill cleanup response crews would experience the greatest exposure, though they would have appropriate protective gear and would have Hazardous Waste Operations and Emergency Response (HAZWOPER) training to reduce risks.

Vulnerable populations, such as children, those with respiratory diseases, and the elderly, could be particularly sensitive to airborne pollutant releases following a spill and would likely experience moderate respiratory impacts depending on their proximity to the incident, current health status, and seasonal/weather conditions in the aftermath of the spill. Overall, air quality effects are predicted to be similar for light and heavy crude oil, as both would be similarly transported downstream during spring and summer conditions. During winter, volatilization, downstream transport, and potential human exposures to crude oil would be more limited due to lower air and water temperatures, the presence of ice on the water surface, and absorption of crude oil into the snow pack.

While acute toxicity and other short-term effects of oil spills have been studied to some extent (as reviewed in IOM 2010), longer-term health effects of oil spills are not well documented. While various of the individual components of crude oil, such as benzene, toluene, ethylbenzene, and xylene (BTEX) are known or suspected carcinogens (International Agency for Research on Cancer 1989), it has not been established that exposure to crude oil in the aftermath of a spill increases the risk of cancer in responders or the public.

<u>Public Resources and Infrastructure</u>

Oil releases have the potential to affect public resources and infrastructure that occur within the ROI as well as emergency response resources. The increased demand on emergency response resources following a large release could divert emergency response personnel from other duties, increasing delays in responding to other service calls.

<u>Socioeconomics and Transportation</u>

Spills can affect local economies through impacts on transportation infrastructure, business operations, property values, or natural resources. Minority and lower income populations could be affected if they are close to the site of a release and not able to easily evacuate.

Increased congestion of roadways could occur as a result of roadway closure and emergency response near the release site. Such disruption could prevent the public from reaching their workplaces. Train lines and highway shipping routes may also be disrupted, resulting in economic impacts over a broader region.

A crude oil spill could require a large response effort including the mobilization of nonlocal response workers who would temporarily relocate to the spill area. A prolonged response effort could affect population and housing. Impacts could include the provision of housing for a number of nonlocal response personnel, leading to an increase in the local population for the duration of the response effort. Potentially negative impacts could include increased traffic and demand for services.

Property value impacts could occur following a spill. The duration of property value effects resulting from contamination has been generally found to be temporary (Jackson 2001). Property values for residents within 1,000 feet of a ruptured petroleum product pipeline have decreased by 0.2 to 4.6 percent within the first 6 months following an event, and the mean sale prices within 100 feet of a ruptured pipeline have remained between 2 and 3 percent lower approximately 5 years following the event (Hansen et al. 2006).

Unusually Sensitive Ecological Areas

HCA unusually sensitive ecological area acres that are within 2,500 feet of the alternative centerlines and would potentially be exposed to a spill are listed in Table 10.4-2. Among the CN Alternatives, existing Line 3 supplemented by rail has the most acres of HCA unusually sensitive ecological areas within 2,500 feet of either side of its centerline, followed by existing Line 3 supplemented by truck, transportation by rail, transportation by truck, continued use of existing Line 3, and SA-04. The Applicant's preferred route has the least acres of HCA unusually sensitive ecological areas within 2,500 feet of either side of its centerline. General impacts on HCA unusually sensitive ecological areas that have the potential to be affected by an oil spill are discussed below.

Table 10.4-2. HCA Unusually Sensitive Ecological Areas within 2,500 Feet of the Centerlines of the Applicant's Preferred Route and Certificate of Need Alternative Routes (acres)

Applicant's Preferred Route	Continued Use of Existing Line 3	System Alternative SA-04	Transportation by Rail	Transportation by Truck	Existing Line 3 Supplemented by Rail	Existing Line 3 Supplemented by Truck
5,774.5	15,067.3	10,530.3	35,919.9	32,400.4	50,987.2	47,467.7

Source: Enbridge 2016c.

HCA = high consequence area

Terrestrial Vegetation and Habitat

Terrestrial vegetation is affected when released oil contaminates adjacent soils or comes into direct contact with plant tissues (McKendrick 1999). Petroleum released to the ground surface can have harmful effects on soil and important resident microorganisms (Stantec et al. 2017). Oil flowing over land can infiltrate into soil, and the extent to which this occurs depends on oil type and volume, topography, soil porosity and permeability, organic matter content, and seasonal conditions. Oil penetrates more readily and deeply into more porous soils like sand and gravel and to a lesser degree into silty or clayey soils. Organic matter in soils or frozen ground can impede infiltration. Though oil can become highly weathered (especially near the surface), it can remain in soil for many years (greater than 25 years; Wang et al. 1998); therefore, remediation techniques often involve excavation and removal of contaminated soil until risk of exposure is acceptably low, which would affect vegetation and availability of terrestrial habitat in the vicinity of a spill.

Plants tend to experience significant damage when oil covers leaves and other sensitive tissue. Herbaceous vegetation is particularly sensitive to oiling (Walker et al. 1978), whereas protective bark makes shrubs and trees more resistant. However, oil reaching root systems can ultimately cause mortality of shrubs and trees (Collins et al. 1994). Spills of light crude oil would be more likely to penetrate soils, spread more quickly, and exhibit higher toxicity to vegetation, especially during the growing season. Spills of heavy crude would be less likely to penetrate soils, would spread more slowly, and would cause more physical damage by coating vegetation. Numerous studies examining the impacts of crude oil on vegetation have been completed in northern latitudes that have applicability to climate and vegetation types that could be affected by this Project. An experimental application of oil onto terrestrial vegetation by Wein and Bliss (1973) in the Northwest Territories of Canada revealed that oil-contaminated deciduous plants showed effects within hours of oil application, whereas evergreen vegetation took weeks to show stress. Regrowth in oil-exposed plants was less robust than would typically occur. Plants in oil-saturated soil showed no regrowth. After a growing season, recovery varied between 20 and 55 percent, depending on the oil treatment rate.

Spills could affect special-status plants that have been documented within the ROI (see Section 5.2.5). Soil impacts that directly affect plant communities include reduced moisture and nutrient availability, impacts on essential microorganisms, and root uptake. Clean-up efforts may also result in removal of oil-saturated plants or trampling damage by workers. Response and containment activities could affect vegetation communities and terrestrial habitat through the removal of contaminated vegetation and soils. In some cases, in situ burning could be used as a response measure and could destroy or damage vegetation. Overall, cleanup activities would benefit vegetation more than no response.

Terrestrial Wildlife

Important wildlife, including amphibians, reptiles, birds, and mammals, which are present in many habitats along the ROIs (see Section 5.2.5), could ingest oil or experience external oiling as a result of a spill. The ability of birds and mammals to maintain proper body temperature can be compromised by external oiling, which can lead to hypothermia and death. Oil that is ingested during preening/grooming of residual external oiling or consumption of oil-contaminated food may result in toxicological effects. Ingestion of oil by wild birds has been associated with severe weight loss, hemolytic anemia, kidney damage, liver damage, foot problems, gut damage, and immunosuppression (Troisi et al. 2006). When oil penetrates into the feathers, it causes marked loss of insulation, waterproofing, and buoyancy in the plumage (Burger and Fry 1993). These alterations increase the risk of hypothermia and impair flight, making birds susceptible to starvation and predation. Exposure to oil could reduce reproductive success because of pathological effects on liver or endocrine systems that interfere with the reproductive process (Tseng 1999). Stress from ingested oil can be additive to ordinary environmental stresses, such as low temperatures and metabolic costs of migration. Oil also could adversely affect food resources, which could decrease survival, future reproduction, and growth of individual receptor species.

Onsite burning to remove oil, if allowed, could create smoke plumes and particulates that could affect birds and mammals through inhalation. Clean-up activities from a spill could also result in direct disturbance and displacement of wildlife, potentially over a relatively large area. Overall, however, clean-up activities would benefit wildlife more than no response, and disturbance effects from containment and clean-up activities are usually short term.

For large spills that are not immediately or successfully cleaned up, the potential for contamination would persist for a longer time and increase the likelihood of terrestrial wildlife being exposed to the weathered oil. Clean-up success could vary, depending on the environment; but over time, remaining oil would gradually degrade. Toxic products could remain in soil, plant tissues, or prey items after cleanup and continue to bio-accumulate up the food chain.

Wetlands

Wetlands are sensitive to oil spills, with potentially immediate effects following exposure (Overstreet and Galt 1995). A crude spill could affect wetland resources directly through contamination with oil or indirectly from response vehicles, equipment, and operations that could affect wetland hydrology, vegetation, and soils. The nature and extent of impacts relates to the oil spill type and volume, surface topography, wetland type, and wetland hydrology. Unless the water is deep enough that submergence of oil poses an issue, dilbit and commonly transported crude oils pose many similar challenges following release in wetlands, but there are three factors specific to dilbit: (1) the amount of residual oil would be large compared to that produced by spills of conventional crude oils; (2) the increased level of adhesion of bitumen may complicate operations in a wetland environment; and (3) dilbit residues may persist longer in wetlands than in other environments because of their greater resistance to biodegradation (National Academies of Sciences, Engineering, and Medicine 2016).

Various wetland plant species respond differently to oil spills; plants are more sensitive to oiling during the growing season than during other periods (Zhu et al. 2004). Sediment type also plays an important role. In general, oil remains longer in soils with higher organic matter and, therefore, has greater impact on resident plants. Lin and Mendelssohn (1996) found that organic matter in soils made wetlands and plants particularly sensitive to crude oil. Some wetland sediment can act as a reservoir, absorbing oil and later releasing it into adjacent coastal habitats, causing chronic impacts on biota (Zhu et al. 2004). Hutchinson and Freedman (1978) found that intensive releases of oil were generally more damaging than spray releases, and that releases during winter months tended to be less damaging than summer releases. A study of plant recovery following a release in Alaska (Racine 1994) found that understory revegetation was nearly complete within 20 years, but areas with pooled oil had little recovery. Leck and Simpson (1992) found that contaminated soil reduced plant survival and growth from seeds, and diminished growth of plant seedlings in tidal freshwater marshes.

The type of wetland and the corresponding hydrology affect the persistence and concentration of spilled oil. Generally, marshes and swamps near larger bodies of water have water flow that helps to flush and disperse oil. Released oil also has potential to alter oxygen and microbial levels as well as overall chemistry in wetlands (Leck and Simpson 1992; Mendelssohn et al. 2012). Changes to hydrology and vegetation would likely be temporary, but soil compaction and/or contaminated soil removal could result in persistent hydrologic impacts on wetlands.

<u>Aquatic Environment</u>

Crude oil exposure can result in adverse effects on aquatic receptors such as benthic invertebrates, fish, and aquatic plants (emergent, floating, and submerged). Receptors present in waterbodies during and following a release would be most vulnerable to crude oil exposures and potential adverse effects.

Effects on aquatic receptors depend not only on the physical and chemical characteristics of different crude oils, but also on the site-specific environmental conditions at the time of the initial release and the spatial and temporal extent of the oiling, including lateral and downstream migration. For instance, low-energy environments promote greater concentration of oiling effects, resulting in greater toxicity within a relatively small area. Conversely, greater dispersal (e.g., from a high-energy environment or wind) would result in a broader impact, but with lower impacts on individual organisms (i.e., greater prevalence of sublethal effects). Higher, flood flows tend to disperse oil onto floodplains, where oil could become trapped in floodplain depressions and wetlands. Floods also have greater concentrations of suspended sediment, which promotes formation of tarballs. During low-flow conditions, oil tends to have greater contact with the streambed and therefore may more readily contaminate bed sediments.

The season during which the spill occurs would also affect the extent of effects on aquatic receptors. If a spill were to occur in the winter during full ice coverage, oil discharged on the surface of the ice would have a smaller impact on water, shoreline, sediments, and aquatic biota as it would not enter the aquatic system. The presence of full ice coverage could also facilitate clean-up efforts, though partial ice coverage can have the opposite effect (Miklaucic and Saseen 1989). Additionally, snow can increase oil absorption and reduce oil dispersion. If a spill were to occur when there is open water (e.g., spring, summer, and fall), oil would be more likely to enter the aquatic system. The duration of water quality and toxicity impacts on aquatic receptors within a given waterbody would depend on oil dispersal area, oil type and quantity spilled, and the degree of entrainment within bed substrates. Contaminated substrates can be scoured and mobilized well after the release to cause lingering water quality impacts and toxicity to biota.

Impacts on aquatic habitats and species would result from oil contamination within the area of surface spreading and lateral and vertical movement through the water column. Habitat degradation associated with a spill would result from the physical presence of floating and/or partially submerged (depending on its relative density) crude oil, the presence of toxic water-soluble or suspended fractions of crude oil and petroleum derivatives, and reduced dissolved oxygen concentration. The oil could come into contact with shorelines and aquatic vegetation. Lighter crudes generally have lower impacts on shorelines than heavy crudes due to differences in persistence and adhesion. Flow, scour, and depositional conditions influence effects of oils in a similar manner as discussed with respect to bed sediments. Shoreline substrates also affect the retention of oil, with impermeable materials (e.g., bedrock) absorbing less oil than sands and gravels with greater permeability. Riparian vegetation, particularly dense vegetation, tends to protect shorelines from oiling effects (Fraser et al. 1989). However, vegetation can have a trapping effect if oil initially penetrates vegetation or enters the shoreline area from land (Baca et al. 1983).

Effects on biota can be lethal or sublethal. Exposures of light crude oil can have unique effects on different categories of aquatic receptors in the freshwater environment. Light crude oil contains more soluble compounds, which can dissolve in the water column immediately following a release (and prior to significant volatilization from the water surface) and result in elevated hydrocarbon concentrations that are potentially toxic to receptors such as invertebrates and fish. Exposures and acute toxicity to fish and invertebrates can occur in high-energy aquatic systems where light crude oil can be entrained in droplets and move throughout the water column. Sublethal and lethal effects on fish are more likely for light than heavy crude oils.

Mortality may occur as a result of direct oiling or exposure to high concentrations of oil. Sensitivity to spill effects also depends on mobility and dependence of a given species on aquatic habitats. Benthic macroinvertebrates are commonly filter feeders and immobile, meaning they can be greatly affected by oiling effects. Semi-aquatic mammals are capable of moving away from the spill site, have greater flexibility in their habitat and food sources, and would therefore generally have lower relative sensitivity to spills in aquatic environments. The magnitude of impacts also depends on the relative location of the organism within the water column. Biota dwelling at depth may be less exposed to oiling effects. Conversely, species that primarily inhabit the near-surface water column and adjacent shorelines have a greater likelihood of direct oiling effects and toxicity (Dicks 1998). Impacts on fish would depend on life stage. Some fish may not be affected at all, or, in the case of fish in larval or spawning stages, impacts may be quite detrimental (NOAA 2011) due to smothering of eggs and/or larvae. Larval/juvenile fish are generally more sensitive to toxicity than adults (Hose et al. 1996). Increased mortality of larval/juvenile fish would be expected because they are often found at the water’s surface, where contact with oil is most likely, and because they are relatively immobile, whereas adult fish would be able to swim away from the spill.

Fish that have been exposed to oil may suffer from changes in heart and respiratory rate, enlarged livers, reduced growth, fin erosion, deformities, and a variety of effects at biochemical and cellular levels (USFWS 2010). Oil may also affect the reproductive capacity of fish and may result in deformed fry (United Nations Environment Programme 2011). Indirect effects on fish from an oil spill include interference with movements to feeding or spawning areas; localized reduction in food resources; and effects from consumption of contaminated prey (Brannon et al. 1986; Morrow 1974; Purdy 1989). Floating oil can contaminate plankton, which includes algae, fish eggs, and the larvae of various fish and invertebrates. Fish that feed on these organisms can subsequently become contaminated (USFWS 2010).

Floating plants are particularly vulnerable to crude oil released to the water surface, while submerged vegetation is less sensitive, especially to temporary dissolved hydrocarbon exposures. Vegetation can absorb oil and effectively protect bank sediments from oil, as was the case in the 1988 Shell oil release in Martinez, California (Fraser et al. 1989), and the 2000 M/T Westchester oil release into the Mississippi River (Michel et al. 2002). Vegetation can also absorb and hold oil on the banks, thereby increasing the length of time that oil has an effect on shorelines and banks. For example, after an oil spill in Buzzards Bay, Massachusetts, in 1969, areas with marshy vegetation retained oil residues, whereas un-vegetated areas did not (Peacock et al. 2005). Damages to aquatic plants can have impacts on the aquatic habitat in terms of both biological health and productivity as well as physical integrity (e.g., loss of plants that reduce the potential for riverbank erosion).

Immediate response would minimize a spill’s spatial extent and the duration that oil would be in the water, and would thus decrease the potential for crude oil settling and adhering to streambed sediments, shoreline areas, and other aquatic habitats. However, spill response and clean-up activities could result in damage and disturbance to aquatic vegetation and habitats and displace aquatic species that are present.

Drinking Water Sources

The alternative with the greatest acreage of HCA drinking water sources within 2,500 feet of either side of its centerline is existing Line 3 supplemented by truck, followed by transportation by truck, existing Line 3 supplemented by rail, transportation by rail, system alternative SA-04, and continued use of existing Line 3. The Applicant’s preferred route would have the least acres of HCA drinking water sources within the 2,500-foot-wide ROI (Table 10.4-3). Figure 10.4-2 shows HCA drinking water sources along the Applicant’s preferred route and CN Alternative routes.

Table 10.4-3. HCA Drinking Water Sources within 2,500 Feet of the Centerlines of the Applicant’s Preferred Route and Certificate of Need Alternative Routes (acres)

Applicant’s Preferred Route	Continued Use of Existing Line 3	System Alternative SA-04	Transportation by Rail	Transportation by Truck	Existing Line 3 Supplemented by Rail	Existing Line 3 Supplemented by Truck
1,614.6	3,975.2	11,058.9	27,347.8	29,524.1	31,323.0	33,499.3

Source: Enbridge 2016c.

HCA = high consequence area

Drinking water sources can be affected when groundwater and/or surface water become contaminated. Released crude oil can enter underlying groundwater aquifers and form plumes that migrate with the natural flow of groundwater. The migration of the contaminated plumes could result in contamination of nearby drinking water supply wells and other local wells. The ultimate fate and transport of these contaminated plumes is dictated by the amount and type of oil released, groundwater flow rate, geological properties of the aquifer, chemical reactions occurring within the plume, and the presence of microbes that degrade contaminants (Stantec et al. 2017). In general, these processes tend to limit the length of groundwater plumes to 600 feet or less.

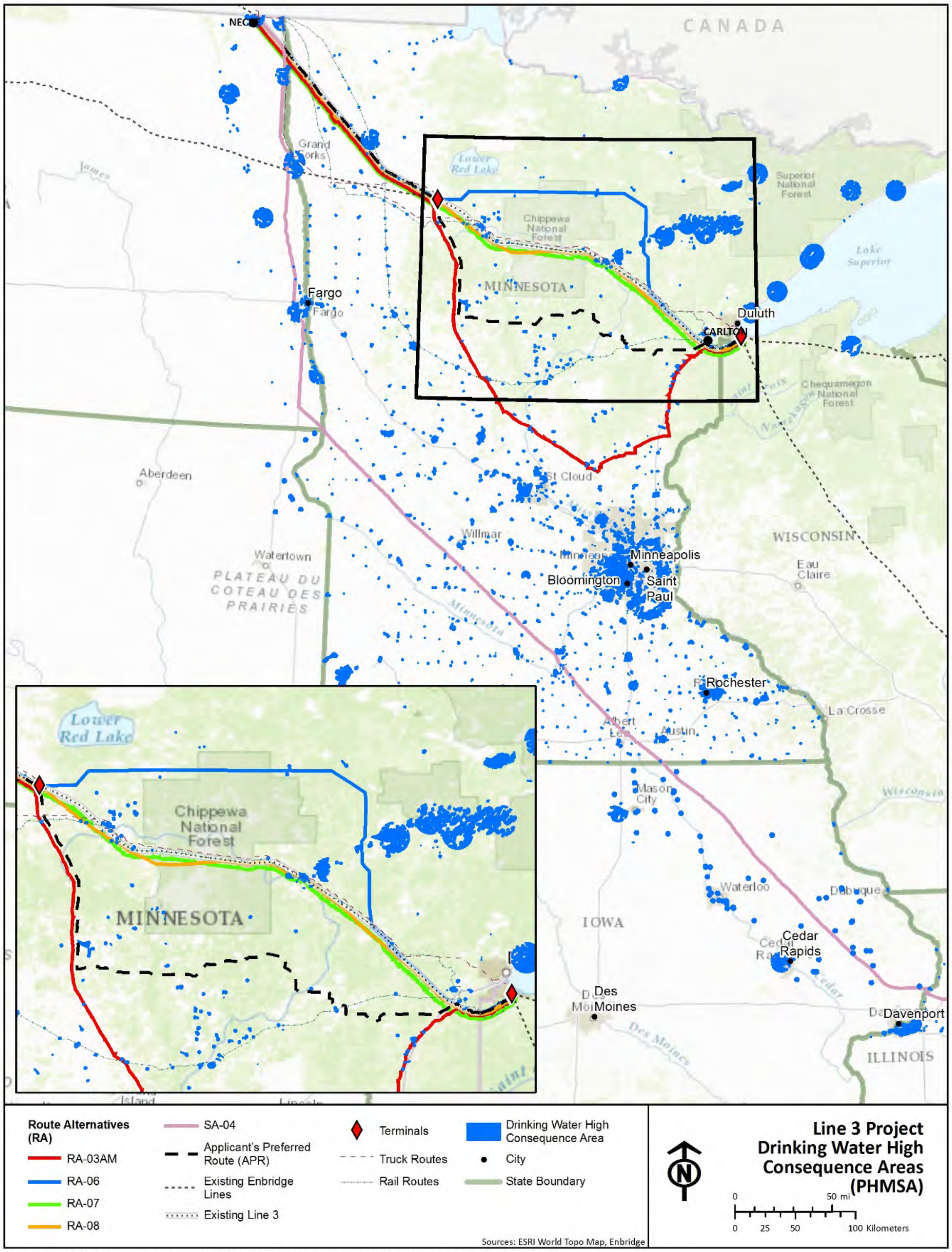

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Figure 10.4-2. High Consequence Area Drinking Water Sources along the Applicant's Preferred Route and Certificate of Need Alternative Routes

A significant proportion of crude oil released in the subsurface could accumulate at the water table. A smaller portion, particularly lighter compounds with greater water solubility, would dissolve into the groundwater (O'Reilly et al. 2001). Contaminated groundwater plumes typically have a central zone of high contamination, with decreasing contamination toward the plume margins. Migration of crude oil constituents depends on groundwater flow rates, aquifer properties, and the constituent being considered. Lighter compounds (e.g., BTEX) are generally more mobile, spreading farther and faster, whereas heavier compounds (e.g., PAHs) are more likely to adhere to soils and sediments. As a contaminant plume migrates, it also is weathered and degraded by processes of evaporation volatilization, adsorption, dissolution, dispersion, and biodegradation. These processes of natural attenuation typically cause a plume to stabilize at a maximum distance in the hundreds of feet from the original spill source, and ultimately decline in size (Connor et al. 2015). If a contaminant plume intersects groundwater discharge points like surface waterbodies, or intersected groundwater extraction points, or water supply wells, contaminants can reach these receptors. Remediation techniques such as groundwater pumping and treatment, air injection to increase volatilization (evaporation), point-of-use treatment (carbon filtration), and bioremediation can be employed to mitigate the contaminant plume and reduce spreading.

Water supplies in the vicinity of an oil spill are often temporarily shut off to prevent contamination, and total petroleum hydrocarbons in drinking water are detectable by human taste and odor at concentrations below levels of concern for acute human health effects. As a result, even short-term human exposure to total petroleum hydrocarbons in drinking water is highly unlikely (World Health Organization 2004).

10.4.2.1.2 Areas of Interest Comparisons for the Applicant's Preferred Route and Certificate of Need Alternatives

Drinking Water Areas of Interest

In addition to the HCA drinking water sources, Minnesota DH identified other drinking water resources that may be susceptible to exposures of crude oil. Potential impacts on drinking water resources from a crude spill would be the same as those described above for HCA drinking water sources.

<u>Drinking Water Supply Management Areas and Vulnerability</u>

Data characterizing DWSMAs are not available outside of Minnesota; therefore, this metric has not been analyzed for the CN Alternatives. An analysis of DWSMA data is included in Section 10.4.3.1.2 for the route alternatives.

<u>Wellhead Protection Areas</u>

WPAs are Minnesota DH-approved surface and subsurface areas surrounding public water supply wells or well fields that supply a public water system and through which potential contaminants would be likely to move toward and reach the well or well field (Minnesota DH 2014). Among the alternatives, the most WPA acres are within 2,500 feet of either side of the centerline of existing Line 3 supplemented by truck, followed by existing Line 3 supplemented by rail, transportation by truck, system alternative SA-04, transportation by rail, and continued use of existing Line 3. The fewest WPA acres are within 2,500 feet of either side of the centerline for the Applicant's preferred route (Table 10.4-4 and Figure 10.4-3).

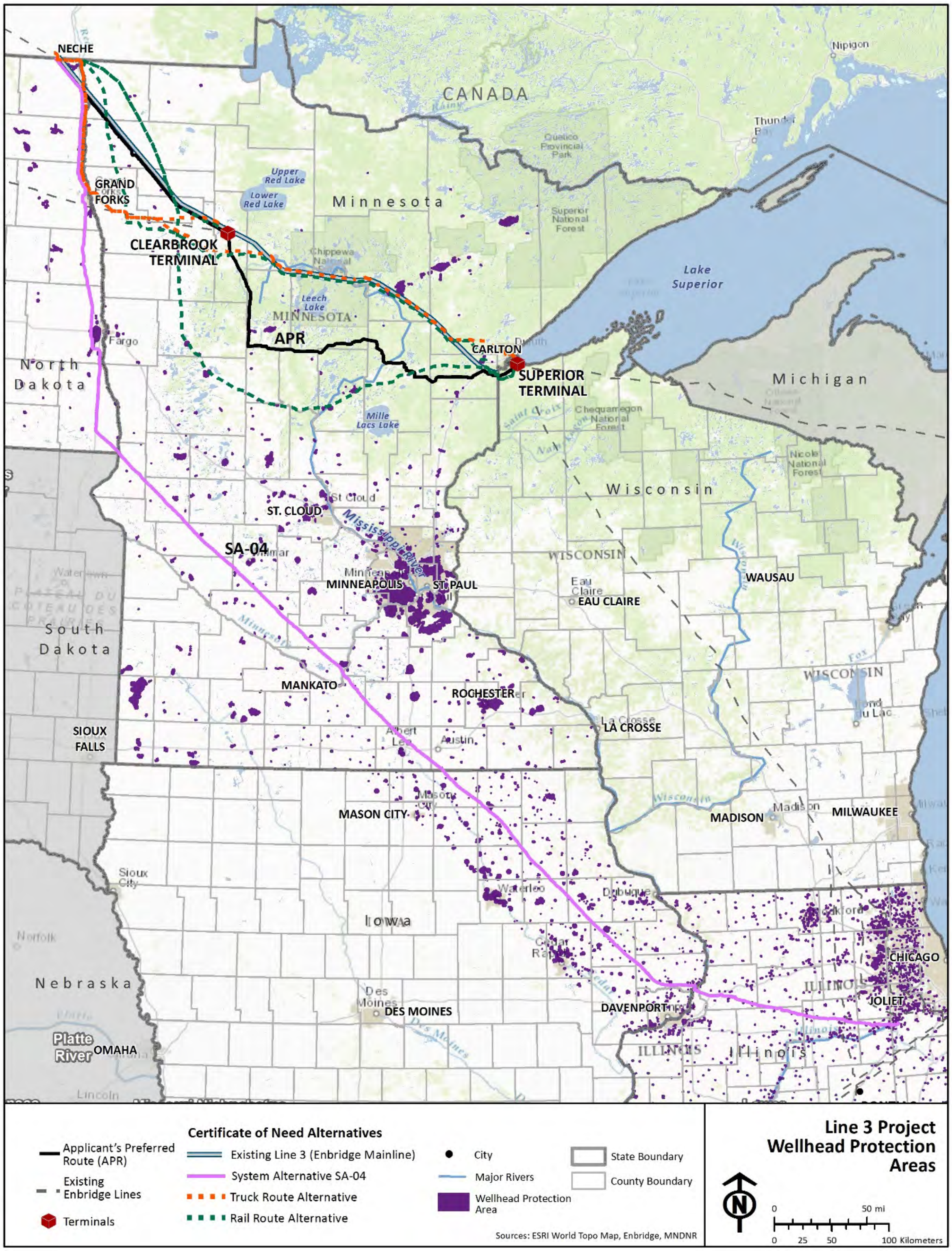

Figure 10.4-3. Wellhead Protection Areas along the Applicant's Preferred Route and Certificate of Need Alternative Routes

Table 10.4-4. Wellhead Protection Areas within 2,500 Feet of the Centerlines of the Applicant's Preferred Route and Certificate of Need Alternative Routes (acres)

Applicant's Preferred Route	Continued Use of Existing Line 3	System Alternative SA-04	Transportation by Rail	Transportation by Truck	Existing Line 3 Supplemented by Rail	Existing Line 3 Supplemented by Truck
189.7	1,391.3	3,579.7	6,863.3	5,591.7	8,254.6	6,983.0

Sources: Iowa DNR 2017; Konczyk 2017, pers. comm.; Minnesota DH 2016; North Dakota Department of Health 2017.

Note:

Wisconsin well data were not available.

Domestic Wells and Associated Geological Sensitivity Ratings

Domestic (private) drinking water wells and their geological sensitivity were identified within the 2,500-foot-wide ROI for the Applicant's preferred route and the CN Alternatives. These wells are potentially at risk from released oil plumes. The alternative with the highest number of domestic drinking water wells within 2,500 feet of either side of its centerline is existing Line 3 supplemented by rail, followed by existing Line 3 supplemented by truck, system alternative SA-04, transportation by rail, the Applicant's preferred route and continued use of existing Line 3 (which have the same number of wells), and transportation by truck (Table 10.4-5).

Table 10.4-5. Numbers of Domestic Wells within 2,500 Feet of the Centerlines of the Applicant's Preferred Route and Certificate of Need Alternative Routes

Applicant's Preferred Route	Continued Use of Existing Line 3	System Alternative SA-04[a]	Transportation by Rail	Transportation by Truck	Existing Line 3 Supplemented by Rail	Existing Line 3 Supplemented by Truck
618	618	920	1,374	608	1,992	1,226

Sources: Iowa DNR 2017; Konczyk 2017, pers. comm.; Minnesota DH 2017, pers. comm.; North Dakota Department of Health 2017.

[a] In Illinois, 509 wells within 2,500 feet of either side of the centerline for system alternative SA-04 have not been field verified; only 16 have been field verified as non-community water supply wells. Information regarding the other 493 wells is not available; therefore, they are not included in the total for SA-04.

Note:

Wisconsin well data were not available.

Public Drinking Water Supplies

Public water supply wells were identified within the 2,500-foot-wide ROI for the Applicant's preferred route and the CN Alternatives. The alternative with the highest number of public water supply wells within 2,500 feet of either side of the centerline is existing Line 3 supplemented by truck, followed by existing Line 3 supplemented by rail, continued use of existing Line 3, SA-04, the Applicant's preferred route, transportation by truck, and transportation by rail (Table 10.4-6).

Table 10.4-6. Numbers of Public Water Supply Wells within 2,500 Feet of the Centerlines of the Applicant's Preferred Route and Certificate of Need Alternative Routes

Applicant's Preferred Route	Continued Use of Existing Line 3	System Alternative SA-04[a]	Transportation by Rail	Transportation by Truck	Existing Line 3 Supplemented by Rail	Existing Line 3 Supplemented by Truck
20	72	26	2	4	74	76

Sources: Minnesota DH 2017, pers. comm.; Iowa DNR 2017; Konczyk 2017, pers. comm.; North Dakota Department of Health 2017.

[a] In Illinois, 509 wells within 2,500 feet of either side of the alternative centerline for system alternative SA-04 have not been field verified; only 1 is listed as a community water supply well. Information regarding the other 508 wells is not available; therefore, they are not included in the total for SA-04.

Note:

Wisconsin well data were not available.

Cultural Resources Areas of Interest

A crude oil release along the Applicant's preferred route and the CN Alternative routes has the potential to result in exposure of reservation lands (Table 10.4-7). Reservations contain cultural resources, which include both archaeological and historic resources. These lands also may support natural resources that are treated in the same manner as cultural resources (see Section 9.4.4.1.1). For instance, wild rice lakes are considered to be traditional cultural properties (see Section 9.4.1).

Table 10.4-7. Reservation Lands within 2,500 Feet of the Centerlines of the Applicant's Preferred Route and Certificate of Need Alternative Routes (acres)

Applicant's Preferred Route	Continued Use of Existing Line 3	System Alternative SA-04	Transportation by Rail	Transportation by Truck	Existing Line 3 Supplemented by Rail	Existing Line 3 Supplemented by Truck
48.0	33,737.6	6,738.1	31,854.3	30,280.4	65,591.9	64,018.0

Source: ESRI 2017; Minnesota Department of Transportation 2003.

Within 2,500 feet of the centerline of the routes, existing Line 3 supplemented by rail crosses the greatest acreage of reservation lands, followed by existing Line 3 supplemented by truck, the continued use of existing Line 3, transportation by rail, transportation by truck, system alternative SA-04, and the Applicant’s preferred route.

Direct impacts on tribal resources could occur by direct damage to archaeological and historic resources or secondary damage during clean-up activities. Impacts on reservations would be similar to those described for terrestrial and aquatic habitats under HCA unusually sensitive ecological areas. Temporary access limitations are possible, especially during response efforts. In general, tribal resources related and/or in close proximity to surface waters have the most potential to be affected by oil releases. Surface water-related resources of particular concern are fisheries and wild rice harvest areas.

Biological Areas of Interest

Various biological AOIs were identified within 2,500 feet of either side of the centerlines for the Applicant’s preferred route and CN Alternative routes (Table 10.4-8 and Figure 10.4-4). The most biological AOI acres are contained within the 2,500-foot-wide ROI of existing Line 3 supplemented by rail and existing Line 3 supplemented by truck, followed by the Applicant’s preferred route, continued use of existing Line 3, transportation by rail, and transportation by truck. The ROI of SA-04 does not contain any of the Minnesota recorded biological AOIs; however, the biological AOIs evaluated are Minnesota-specific and comparable data were not available from other states.

Point data identifying locations of calcareous fens in Minnesota within the ROI indicate that the most calcareous fens occur along existing Line 3 supplemented by rail (average of 9), followed by continued use of existing Line 3 and the Applicant’s preferred route (five each), and SA-04 (1). Trout streams and lakes were not analyzed for the CN Alternatives as comparable data for SA-04 are not available, and therefore a comparative analysis across all routes could not be conducted.

The alternatives overlap with marginal cropland in limited or preputial conservation easements, as identified by the Minnesota Board of Water and Soil Resources. These former agriculture areas have been taken out of production, typically funded by forgiveness of public debt or similar mechanism, to allow for soil and natural habitat restoration. Among the CN Alternatives, existing Line 3 supplemented by rail has the greatest number of marginal cropland acres within 2,500 feet of either side of its centerline, while system alternative SA-04 has no marginal cropland within this distance (Table 10.4-8). Existing Line 3 supplemented by rail encompasses 90 acres of limited marginal cropland, and is followed by transportation by rail, existing Line 3 supplemented by truck, continued use of existing Line 3, the Applicant’s preferred route, and transportation by truck. A spill into marginal croplands could affect the publically funded habitat restoration by killing new growth and contaminating soils. The cleanup process may also cause compaction and loss of topsoil, further reducing the quality of the marginal cropland. Impacts on biological AOIs would be similar to those described above for HCA unusually sensitive ecological areas. Wild rice is considered an aquatic grass, and effects on it from a crude oil spill would be similar to those described above for wetland vegetation. Given the high organic matter found in wetland soils, plants found in this environment are particularly sensitive to crude oil (Lin and Mendelssohn 1996).

Table 10.4-8. Biological Areas of Interest within 2,500 Feet of the Centerlines of the Applicant's Preferred Route and Certificate of Need Alternative Routes (acres)

Area of Interest	Applicant's Preferred Route	Continued Use of Existing Line 3	System Alternative SA-04[a]	Transportation by Rail	Transportation by Truck	Existing Line 3 Supplemented by Rail	Existing Line 3 Supplemented by Truck
Aquatic Management Area	125.0	227.5	0	228.6	93.9	456.0	321.4
Scientific and Natural Area	0	7.5	0	186.7	0	380.8	7.5
Minnesota BWSR conservation easement	15.8	167.1	0	736.0	33.0	903.1	200.1
Lakes of Biological Significance	406.7	2,209.8	0	1,951.5	2,617.9	4,161.4	4,827.8
Marginal Cropland – Limited	15.6	16.1	0	73.9	5.4	90	21.5
Marginal Cropland - Perpetual	0	0	0	13.5	0	13.5	0
MBS Sites	28,046.8	12,992.6	0	18,309.7	6,285.4	31,302.3	19,278.1
Muskie lakes	41.4	976.6	0	1,060.9	1,882.1	2,037.5	2,858.8
Native plant communities	38,173.8	40,195.4	0	33,852.4	35,643.9	74,047.8	75,839.3
Sensitive lakeshore areas	300.5	1,329.8	0	743.4	1,387.9	2,073.2	2,717.7
Wetland bank easement	0	70.6	0	120.3	33.6	190.9	104.2
Wild rice lakes	675.4	1,240.4	0	1,474.1	1,661.0	1,240.4	2,901.4
TOTAL	**67,801.0**	**59,433.4**	**0.0**	**58,751.0**	**49,644.1**	**116,896.9**	**109,077.8**

Sources: Enbridge 2016c; Minnesota DNR 2016.

[a] The ROI of SA-04 does not contain any of the Minnesota recorded biological areas of interest (AOIs); however, the biological AOIs evaluated are Minnesota-specific and comparable data were not available from other states.

MBS Sites = Minnesota Biological Survey Sites of Biodiversity Significance, Minnesota BWSR = Minnesota Board of Water and Soil Resources

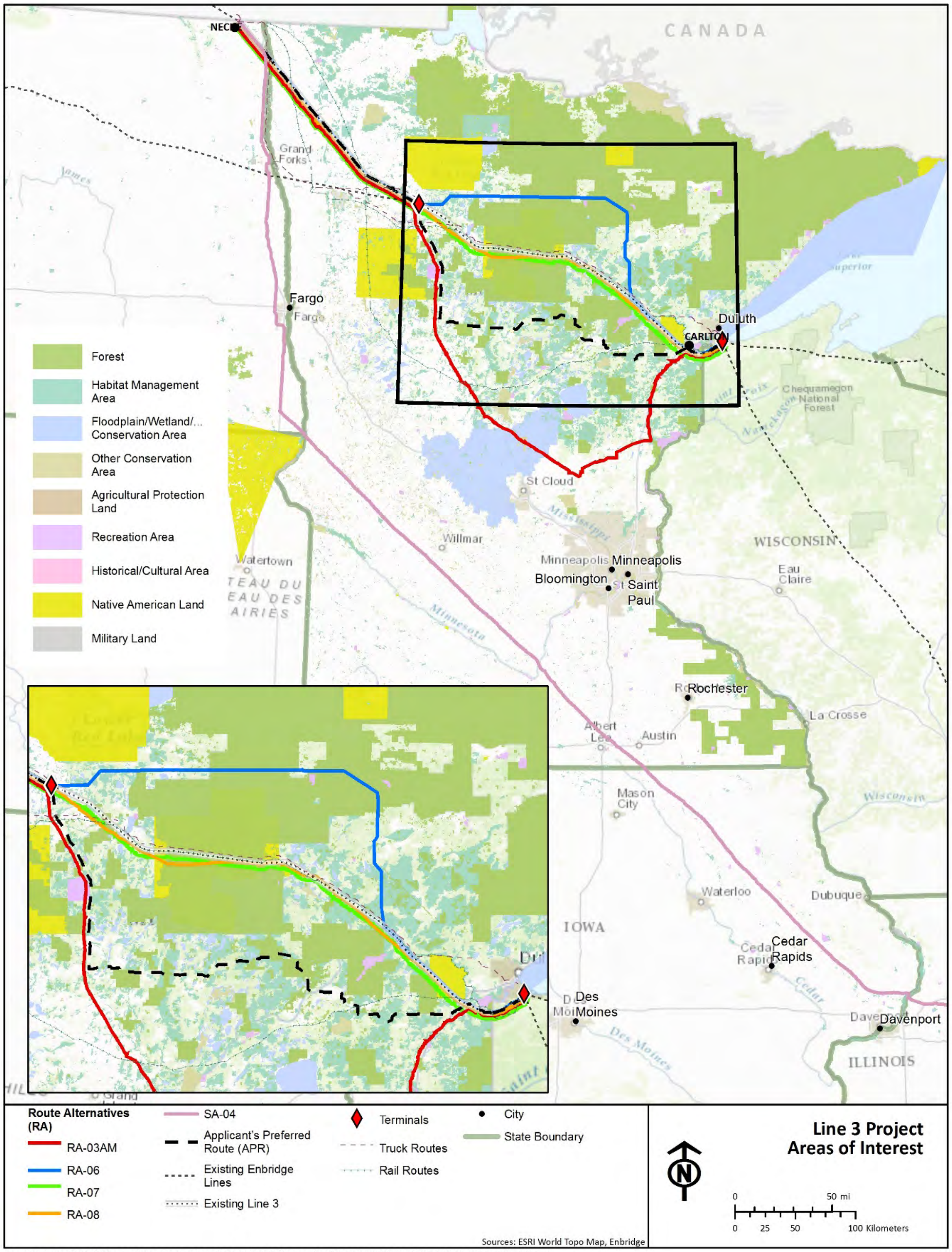

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Figure 10.4-4. Areas of Interest along the Applicant's Preferred Route and Certificate of Need Alternative Routes

Contaminated soil reduces plant survival and growth from seeds and results in diminished growth of plant seedlings (Leck and Simpson 1992). A study of plant recovery following a release (Racine 1994) found that understory revegetation was nearly complete within 20 years, but areas with pooled oil had little recovery. If a spill were to occur, plants would be more sensitive to oiling during the growing season than during other periods (Zhu et al. 2004).

Commodity Production Areas of Interest

The 2,500-foot-wide ROI of all alternatives overlaps with various government managed areas of commodity production. Among the CN Alternatives, existing Line 3 supplemented by truck would affect the greatest state, national, and other forest acres, followed by existing Line 3 supplemented by rail (Table 10.4-9). In contrast, system alternative SA-04 has the lowest state, national, or other forest acreage within 2,500 feet of either side of its centerline. The Applicant's preferred route has no national forests within this ROI, but it has 31,764.3 acres of state forest and 3,349.5 acres of other forest land within the ROI. Impacts on forested land from a crude spill would be similar to those described under HCA unusually sensitive ecological areas for terrestrial vegetation and habitat.

Table 10.4-9. Commodity Production Areas of Interest within 2,500 Feet of the Centerlines of the Applicant's Preferred Route and Certificate of Need Alternative Routes (acres)

Area of Interest	Applicant's Preferred Route	Continued Use of Existing Line 3	System Alternative SA-04	Transportation by Rail	Transportation by Truck	Existing Line 3 Supplemented by Rail	Existing Line 3 Supplemented by Truck
National forests	0	21,055.0	145.9	10,149.0	20,018.2	31,203.9	41,073.1
Other forest land	3,349.5	2,827.2	45.7	2,735.5	2,954.0	5,562.7	5,781.2
State forests	31,764.3	27,806.9	0	17,505.5	25,451.2	45,312.4	53,258.1
Harvested Wild Rice Lakes	181.6	241.9	0	384.7	328.5	345.1	430.1
TOTAL	**35,295.4**	**51,931.0**	**191.6**	**30,774.7**	**48,751.9**	**82,424.1**	**100,542.5**

Source: Enbridge 2016c; Minnesota DNR 2016.

Of the wild rice lake listed in Table 10.4-8, with the exception of SA-04, all CN alternatives are located within 2,500 feet of waterbodies used for harvesting wild rice (Figure 10.4-5), as documented 2006 rice harvester survey (Minnesota DNR 2007). Among the CN Alternatives, existing Line 3 supplemented by rail has the greatest number of harvested wild rice lake acres within 2,500 feet of either side of its centerline, followed by existing Line 3 supplemented by truck, continued use of existing Line 3, and the Applicant's preferred route (Table 10.4-9). It should be noted that many rice lakes are undergoing habitat restoration and areas of harvested wild rice may have expanded since 2006. In addition to effects from oiling, wild rice is a delicate crop that is subject to shattering, or having the seed fall to the ground in the wind, making the crop susceptible to failure if disturbed. If crude oil did reach a wild rice lake pre-harvest, not only would the plant itself be exposed to contamination, but the clean-up efforts would affect the year's harvest.

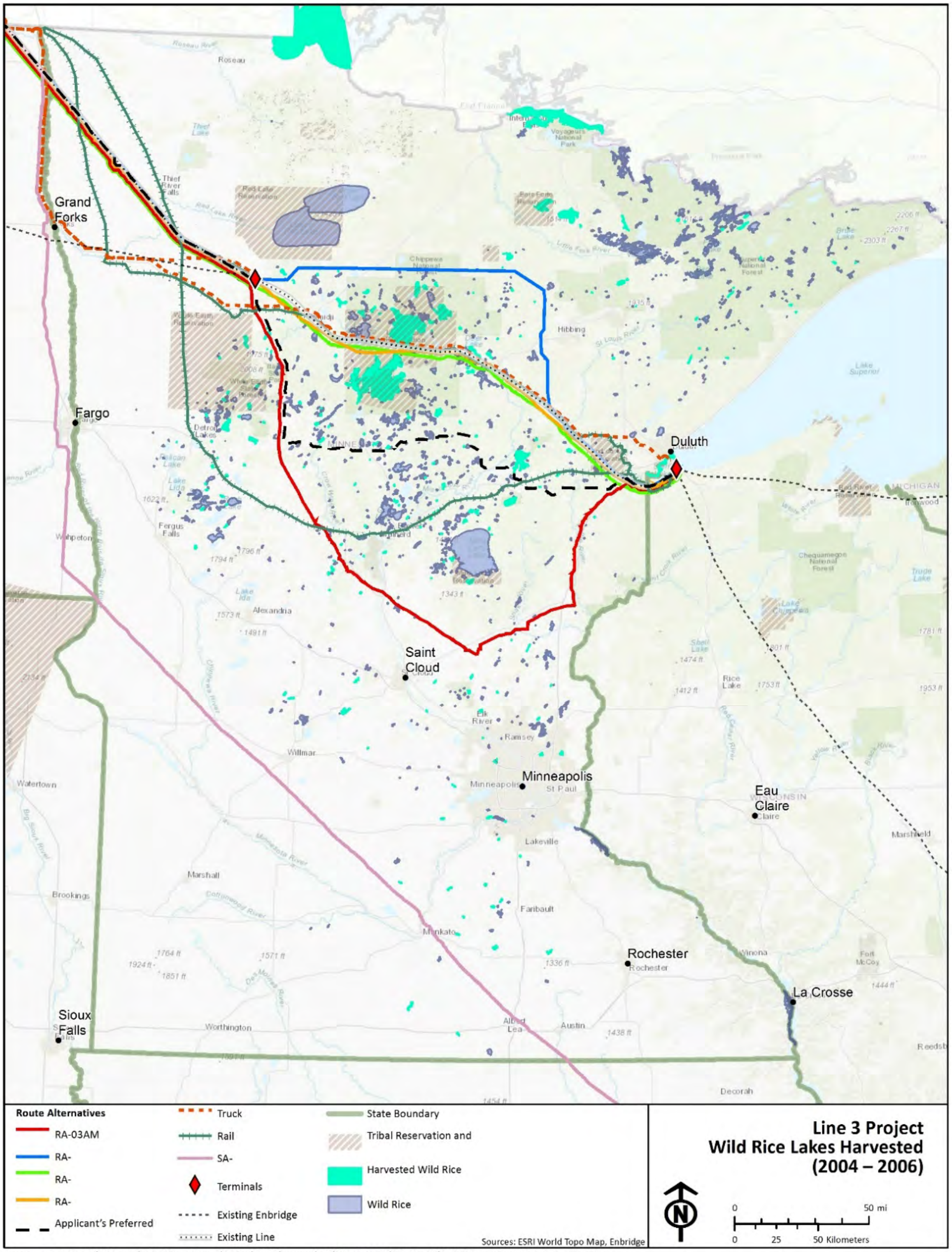

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Figure 10.4-5. Wild Rice Harvested along the Applicant's Preferred Route and Certificate of Need Alternative Routes

The market value of wild rice is variable and dependent on source, means of cultivation and harvesting (e.g. traditional hand-harvested versus use of a combine), etc. Limited information pertaining to commodity values of Minnesota wild rice, both generally and traditionally hand-harvested, is available. According to a report on wild rice prepared by the Minnesota Department of Natural Resources, the price paid for unprocessed rice from the Leech Lake Band of Ojibwe (LLBO) reservation between 1990 and 2007 was between $1.00 and $1.50 per pound (Minnesota DNR 2008). Data gathered from the 2006 rice harvester survey estimated a total harvest estimate of almost 700,000 pounds of natural wild rice in 2006, based on 1,625 state issued licenses and an estimated 430 pounds harvested per license (Minnesota DNR 2007). Some tribal areas allow harvesting of wild rice by non-band members, but require an on-reservation license for state residents wishing to harvest. Approximately 70 percent of the 2004 to 2006 harvesters surveyed operated only under a state license. Tribal members are more frequently required to obtain multiple licenses based on where they plan to harvest, including off-reservation permit for treaty ceded lands and tribal licenses for reservation lakes, in addition to state license for other areas.

Based on the 2015 Annual Report of the LLBO, the LLBO Department/Division of Resource Management purchased over 89,000 pounds of wild rice from LLBO Band members, resulting in $178,000 injected into the local economy (LLBO 2015). While the Applicant's preferred route would not cross any American Indian reservations, areas of wild rice on American Indian reservations are located within the 10-mile downstream ROI for potential spills.

Using the resulting rudimentary assumption that the average price for traditionally harvested unprocessed wild rice is $2.00 per pound, and a yield assumption of approximately 300 pounds per acre, the approximate annual market values of unprocessed wild rice within the construction work area and permanent right-of-way of the Applicant's preferred route are $3,000 and $2,000, respectively. These estimates assume that the entire waterbody acreage contains harvestable wild rice. The estimates do not consider the economic value of other activities, such as finishing/processing for consumption.

Recreation and Tourism Areas of Interest

Existing Line 3 supplemented by rail and transportation by rail contain the most recreation and tourism AOI acres within 2,500 feet of either side of their centerlines. These are followed by the Applicant's preferred route, existing Line 3 supplemented by truck, transportation by truck, continued use of existing Line 3, and system alternative SA-04 (Table 10.4-10).

Impacts on land, water, and natural resources can, in turn, affect recreational and land use. Impacts on parks and recreation areas may be environmental, cultural, or visual in nature. Specific recreational resources of concern include trails, state parks, hunting and fishing areas, and lakes, which may be closed to the public following a spill and during response activities. Other areas affected by oil spills could include residential, commercial, industrial, agriculture, and forestry lands, and associated uses and business operations.

Table 10.4-10. Recreation and Tourism Areas of Interest within 2,500 Feet of the Centerlines of the Applicant's Preferred Route and Certificate of Need Alternatives (acres)

Area of Interest	Applicant's Preferred Route	Continued Use of Existing Line 3	System Alternative SA-04	Transportation by Rail	Transportation by Truck	Existing Line 3 Supplemented by Rail	Existing Line 3 Supplemented by Truck
State plan/ recreational areas	317.7	0	0	2,079.3	485.6	2,079.3	485.6
State parks	629.9	0	790.5	3,910.3	0	3,910.3	0
Wildlife Management Areas	1,299.3	16.4	105.5	3,352.1	820.55	3,368.5	836.9
Waterfowl production areas	92.0	185.80	0	632.0	485.0	817.8	670.7
TOTAL	**2,338.9**	**202.2**	**896.0**	**9,763.0**	**1,641.3**	**9,965.2**	**1,843.4**

Sources: Enbridge 2016c; Minnesota DNR 2016.

The tourism industry is a major source of direct and indirect employment and wages. It includes fishing, land and water touring, and retail and service firms, including lodging providers, restaurants, automobile service stations, and other businesses. A crude oil spill could lead to both temporary and long-term closures and restricted access for recreation resources including boat launch restrictions, fishing restrictions, and waterway closures. A large spill could also lead to closure or restricted access to roads, bike paths, trails, scenic overlooks, and other recreation resources. Depending on the location and extent of the spill, these resources could be inaccessible to the public for days to several weeks or longer during cleaning efforts. Longer-term impacts on fishing could result if aquatic resources were fouled or there was a reduction in the amount and/or quality of fish available for harvest. Impacts on vegetation and scenic views, both of which are draws for recreationists, could last longer. Economic damages could persist if a diminished public perception of an area occurred (Chang et al. 2014).

10.4.2.2 Downstream Exposure Analysis for Spills

10.4.2.2.1 High Consequence Area Downstream Exposure Comparisons

Populated Areas

Existing Line 3 supplemented by truck has the most HCA populated areas acres within 10 miles downstream of its waterbody crossings, followed by SA-04, existing Line 3 supplemented by rail, transportation by truck, transportation by rail, the Applicant's preferred route, and continued use of existing Line 3 (Table 10.4-11). Potential effects on HCA populated areas from a crude oil spill would be the same as described in Section 10.4.2.1.1.

Table 10.4-11. HCA Populated Areas within the 10-Mile-Long Downstream ROI for the Applicant's Preferred Route and Certificate of Need Alternative Routes (acres)

Applicant's Preferred Route	Continued Use of Existing Line 3	System Alternative SA-04	Transportation by Rail	Transportation by Truck	Existing Line 3 Supplemented by Rail	Existing Line 3 Supplemented by Truck
4,414.6	3,379.2	12,053.4	15,614.9	10,558.3	18,994.1	13,937.5

Source: Enbridge 2016c.

HCA = high consequence area, ROI = region of interest

Unusually Sensitive Ecological Areas

Existing Line 3 supplemented by rail has the most HCA unusually sensitive ecological area acres within 10 miles downstream of its waterbody crossings, followed by existing Line 3 supplemented by truck, transportation by rail, transportation by truck, SA-04, continued use of existing Line 3, and the Applicant's preferred route (Table 10.4-12). Potential effects on HCA unusually sensitive ecological areas from a crude oil spill would be the same as described in Section 10.4.2.1.1.

Table 10.4-12. Unusually Sensitive Ecological Area HCAs within the 10-Mile-Long Downstream ROI for the Applicant's Preferred Route and Certificate of Need Alternative Routes (acres)

Applicant's Preferred Route	Continued Use of Existing Line 3	System Alternative SA-04	Transportation by Rail	Transportation by Truck	Existing Line 3 Supplemented by Rail	Existing Line 3 Supplemented by Truck
4,453.3	5,932.6	9,848.1	20,518.7	12,078.1	26,451.3	18,010.7

Source: Enbridge 2016c.

HCA = high consequence area, ROI = region of interest

Drinking Water Sources

SA-04 has the greatest acreage of HCA drinking water sources within the 10-mile-long downstream ROI for its waterbody crossings, followed by existing Line 3 supplemented by truck, transportation by truck, existing Line 3 supplemented by rail, transportation by rail, the Applicant's preferred route, and continued use of existing Line 3 (Table 10.4-13). Potential effects on HCA drinking water sources from a crude oil spill would be the same as those described in Section 10.4.2.1.1.

Table 10.4-13. HCA Drinking Water Sources within the 10-Mile-Long Downstream ROI for the Applicant's Preferred Route and Certificate of Need Alternative Routes (acres)

Applicant's Preferred Route	Continued Use of Existing Line 3	System Alternative SA-04	Transportation by Rail	Transportation by Truck	Existing Line 3 Supplemented by Rail	Existing Line 3 Supplemented by Truck
829.3	546.7	13,409.8	8,263.2	17,186.1	8,809.9	17,732.8

Source: Enbridge 2016c.

HCA = high consequence area, ROI = region of interest

10.4.2.2.2 Areas of Interest Downstream Exposure Comparisons

Drinking Water Areas of Interest

Drinking Water Supply Management Areas and Vulnerability

Data characterizing DWSMAs are specific to Minnesota; therefore, this metric was not analyzed for the CN Alternatives. An analysis of DWSMA data is included in Section 10.4.3.1.2 for the route alternatives.

Wellhead Protection Areas

SA-04 has the greatest number of WPA acres within the 10-mile-long downstream ROI (11,906 acres), while the Applicant's preferred route has the least (approximately 130 acres). Existing Line 3 supplemented by truck would affect significantly more acres than the existing Line 3 supplemented by rail, 6,258 acres vs. 687 acres, respectively (Table 10.4-14). Potential effects on WPAs from a crude oil spill would be the same as described in Section 10.4.2.1.2.

Table 10.4-14. Wellhead Protection Areas within the 10-Mile-Long Downstream ROI for the Applicant's Preferred Route and Certificate of Need Alternative Routes (acres)

Applicant's Preferred Route	Continued Use of Existing Line 3	System Alternative SA-04	Transportation by Rail	Transportation by Truck	Existing Line 3 Supplemented by Rail	Existing Line 3 Supplemented by Truck
130.0	208.6	11,906.4	1,025.5	11,656.2	1,234.1	11,864.8

Sources: Iowa DNR 2017; Konczyk 2017, pers. comm.; Minnesota DH 2016; North Dakota Department of Health 2017.

Note:

Wisconsin well data were not available.

ROI = region of interest

Domestic Wells

The geographic scope of the alternatives required domestic wells data to be compiled from multiple state databases. However, the 10-mile-long downstream ROI was limited to capturing domestic wells within 1 mile of the route (or 1 mile downstream in most cases). However, because the same reduced area of analysis was applied for all alternatives, the results are considered useful for comparison purposes.

Domestic water wells within 1 mile of each alternative centerline and 500 feet from either side of the flowing waterbody were identified and are presented below in Table 10.4-15. Existing Line 3 supplemented by rail has the highest number of wells within the downstream ROI, followed by transportation by rail, SA-04, existing Line 3 supplemented by truck, transportation by truck, the Applicant's preferred route, and continued use of existing Line 3. Potential effects on domestic wells from a crude oil spill would be the same as those described in Section 10.4.2.1.2.

Table 10.4-15. Number of Domestic Wells within the 1-Mile Downstream ROI for the Applicant's Preferred Route and Certificate of Need Alternative Routes

Applicant's Preferred Route	Continued Use of Existing Line 3	System Alternative SA-04	Transportation by Rail	Transportation by Truck	Existing Line 3 Supplemented by Rail	Existing Line 3 Supplemented by Truck
146	39	228	367	184	406	223

Sources: Iowa DNR 2017; Konczyk 2017, pers. comm.; Minnesota DH 2017, pers. comm.; North Dakota Department of Health 2017.

Note:

Wisconsin well data were not available.

ROI = region of interest

Public Water Drinking Supplies

Comparable public water wells data were not obtained for all CN Alternatives, so no meaningful analysis can be done. An analysis of public water wells is included in Section 10.4.3 for the route alternatives.

Cultural Resources Areas of Interest

Within the 10-mile-long downstream ROI, existing Line 3 supplemented by rail overlaps with the most acreage of reservation land, followed by transportation by rail, existing Line 3 supplemented by truck, continued use of existing Line 3, and SA-04 (Table 10.4-16). The Applicant's preferred route does not overlap with any reservation lands within the 10-mile-long downstream ROI. Potential effects on cultural resource AOIs from a crude oil spill would be the same as those described in Section 10.4.2.1.2.

Table 10.4-16. Reservation Lands within the 10-Mile-Long Downstream ROI for the Applicant's Preferred Route and Certificate of Need Alternative Routes (acres)

Applicant's Preferred Route	Continued Use of Existing Line 3	System Alternative SA-04	Transportation by Rail	Transportation by Truck	Existing Line 3 Supplemented by Rail	Existing Line 3 Supplemented by Truck
0	10,400	4,868.3	23,502.5	9,956.2	33,902.0	20,356.0

Sources: Enbridge 2016c; Minnesota DNR 2016.

ROI = region of interest

Biological Areas of Interest

Biological AOIs were identified within the 10-mile-long downstream ROIs of the CN Alternatives and the Applicant's preferred route (Table 10.4-17). SA-04 overlaps the fewest AOIs (three), and all other alternatives overlap all AOIs to a varying degree. Overall, existing Line 3 supplemented by rail or truck contains the greatest acreage of AOIs within 10 miles, with the exception of Scientific and Natural Areas—the Applicant's preferred route has the greatest acreage of Scientific and Natural Areas within the 10-mile-long downstream ROI. The Applicant's preferred route would cross the greatest acreage of marginal cropland among all routes (44.1 acres). The existing Line 3 supplemented by rail and truck alternatives both overlap approximately twice the total acreage of biological AOIs than the continued use of existing Line 3 or the Applicant's preferred route. SA-04 has significantly less acreage within the ROI than all other routes given it only crosses three AOI types (Minnesota BWSR conservation easement, MBS Sites, and native plant communities).

Point data identifying locations of calcareous fens in Minnesota within the 10-mile-long downstream ROI indicate limited fen crossings. The Applicant's preferred route would cross the most calcareous fens (two), followed by existing Line 3 supplemented by rail (one). Continued use of existing Line 3 and SA-04 would not cross any calcareous fens.

Potential effects on biological AOIs from a crude oil spill would be the same as those described in Section 10.4.2.1.2.

Table 10.4-17. Biological Areas of Interest within the 10-Mile-Long Downstream ROI for the Applicant's Preferred Route and Certificate of Need Alternative Routes (acres)

Area of Interest	Applicant's Preferred Route	Continued Use of Existing Line 3	System Alternative SA-04	Transportation by Rail	Transportation by Truck	Existing Line 3 Supplemented by Rail	Existing Line 3 Supplemented by Truck
Aquatic Management Area	209.8	320.0	0	196.3	183.5	516.4	503.5
Scientific and Natural Area	342.9	192.7	0	63.4	0	256.1	192.7
Minnesota BWSR conservation easement	262.0	260.7	29.8	158.2	90.9	418.8	351.5
Lakes of Biological Significance	3,608.9	3,400.1	0	3,659.1	4,559.4	7,059.2	7,959.5
Marginal Cropland[a]	44.2	10	0	0	0	10	0
MBS Sites	11,589.4	8,001.2	120.6	11,117.4	5,740.2	19,118.6	13,741.5
Muskie lakes	676.0	2,107.0	0	1,990.8	3,526.5	4,097.8	5,633.5
Native plant communities	14,015.3	22,744.8	219.0	16,735.5	19,166.4	39,480.3	41,911.3
Sensitive lakeshore areas	441.9	513.4	0	305.3	373.6	818.7	887.0
Wetland bank easement	38.5	30.3	0	49.7	21.9	80.0	52.2
Wild rice lakes	3,396.3	2,956.4	0	3,298.6	3,899.3	6,255.0	6,855.7
TOTAL	**34,625.2**	**40,536.6**	**369.4**	**37,574.3**	**37,561.7**	**78,110.9**	**78,088.4**

Sources: Enbridge 2016c; Minnesota DNR 2016.

[a] Perpetual and limited.

MBS Sites = Minnesota Biological Survey Sites of Biodiversity Significance, Minnesota BWSR = Minnesota Board of Water and Soil Resources, ROI = region of interest

Commodity Production Areas of Interest

The route for the existing Line 3 supplemented by truck contains the most commodity production AOI acres within the 10-mile-long downstream ROI. It is followed by the routes of existing Line 3 supplemented by rail, continued use of existing Line 3, and the Applicant's preferred route. SA-04 would not contain commodity production AOIs within the 10-mile-long downstream ROI (Table 10.4-18).

Table 10.4-18. Commodity Production Areas of Interest within the 10-Mile-Long Downstream ROI for the Applicant's Preferred Route and Certificate of Need Alternative Routes (acres)

Area of Interest	Applicant's Preferred Route	Continued Use of Existing Line 3	System Alternative SA-04	Transportation by Rail	Transportation by Truck	Existing Line 3 Supplemented by Rail	Existing Line 3 Supplemented by Truck
National/ state forests	12054.9	8,496.3	0	20,762.9	16,965.6	29,259.2	31,384.8
Other forested land	1,910.9	2,207.8	0	3,222.6	2,451.7	5,430.4	4,659.5
Harvested wild rice lakes	982.3	773.7	0	1,603.6	914.2	1,612.6	935.3
TOTAL	**14,948.1**	**11,477.8**	**0.0**	**25,589.1**	**20,331.5**	**36,302.2**	**36,979.6**

Sources: Enbridge 2016c; Minnesota DNR 2016.
ROI = region of interest

The 10-mile-long downstream ROI from SA-04 would not cross any national or state forests, while continued use of existing Line 3, the Applicant's preferred route, and existing Line 3 supplemented by rail and truck would. Existing Line 3 supplemented by truck would cross approximately 1.4 times more acreage than existing Line 3 supplemented by rail. The Applicant's preferred route and continued use of existing Line 3 would cross similar acreages of "Other forested land"; inclusion of the rail or truck supplementation would increase the acreage, with the truck route doubling the potential area exposed. Potential effects on commodity production AOIs from a crude oil spill would be the same as those described in Section 10.4.2.1.2.

Recreation and Tourism Areas of Interest

Existing Line 3 supplemented by rail and truck contain the most recreation and tourism AOI acres within the 10-mile-long downstream ROI. These are followed by continued use of existing Line 3, transportation by rail, the Applicant's preferred route, system alternative SA-04, and transportation by truck (Table 10.4-19). Potential effects on recreation and tourism AOIs from a crude oil spill would be the same as those described in Section 10.4.2.1.2.

Table 10.4-19. Recreation and Tourism Areas of Interest within the 10-Mile-Long Downstream Region of Interest for the Applicant's Preferred Route and Certificate of Need Alternative Routes (acres)

Area of Interest	Applicant's Preferred Route	Continued Use of Existing Line 3	System Alternative SA-04	Transportation by Rail	Transportation by Truck	Existing Line 3 Supplemented by Rail	Existing Line 3 Supplemented by Truck
State plan/ recreational areas	180.7	543.7	41.6	0	108.2	543.7	597.8
State parks	0.2	941.3	0	7,497.2	0	8,438.5	941.3
Wildlife Management Areas	1,240.8	3.0	0	3,288.3	699.1	3,291.3	702.1
Waterfowl production areas	11.5	182.2	0	0	0	182.2	182.2
TOTAL	**1,433.2**	**1,670.2**	**41.6**	**10,785.5**	**807.3**	**12,455.7**	**2,423.4**

Sources: Enbridge 2016c; Minnesota DNR 2016.

10.4.3 Exposure Analysis for Comparison of Applicant's Preferred Route and Route Alternatives

The resource tables in this section can be used to broadly understand the tradeoffs in type, number, or geographic distribution of resources exposed, but they are not a prediction of what impacts would actually occur in the event of a large oil spill. In part, this is because there are so many incident-specific factors involved. The extent of the release, weather, time of year, water levels, human error, and even what type of wildlife is present at the time a spill occurs all affect its probability and outcome.

In addition, the proposed project in this case includes both the construction of a new pipeline and the abandonment of an old one. Therefore, should a route permit be approved, the extent and type of resources at risk due to an accidental release could change in the old corridor as well as in the new corridor, depending on the route alternative selected.

In the case of RA-07 and RA-08, Enbridge would construct the new pipeline within their existing mainline corridor. Enbridge would have either to remove the existing Line 3 or possibly abandon it in place. Construction along either of these routes would therefore incrementally reduce existing risk to resources along the mainline corridor by taking existing Line 3 out of service, but would also introduce incremental new risk to the resources by putting the new Line 3 into service. It is difficult to estimate the change in the probability of a large release from a new Line 3 compared to leaving the existing Line 3 in service, but construction along either of these routes would not completely eliminate the risk

of a new Line 3. Therefore, although construction along either RA-07 or RA-08 would not cause any notable change in the existing type, number, or geographic distribution of resources exposed, it would perpetuate the existing exposure of these resources, as shown in the tables in this section.

In the case of the Applicant's proposed route, RA-06, or RA-03AM, Enbridge would construct the new Line 3 outside of the existing mainline corridor. Enbridge would remove existing Line 3 from service, resulting in a shift in the type, number, or geographic distribution of resources exposed. The EIS did not attempt to quantify the incremental change in the probability of a significant spill due to placement of the new Line 3 in a new corridor versus placement in the mainline corridor. However, construction along any of these three alternative routes would incrementally reduce existing risk to the resources along the mainline corridor by taking existing Line 3 out of service, but it would introduce incremental new risk to the resources along a new route. Since these alternatives eliminate the risk of an accidental release from the existing Line 3 in the mainline corridor but introduce new risk a new corridor, construction of the new Line 3 along any of these three routes would change the type, number, and/or geographic distribution of resources exposed.

The comparison of the exposure due to an oil spill for the Applicant's preferred route and the route alternatives assessed the presence of HCA and AOI resources along the routes from where the Applicant's preferred route diverges from the other routes at the Clearbrook terminal to where all the Applicant's preferred route and the route alternatives remerge at Carlton. The analysis was completed for this portion of the Applicant's preferred route and route alternatives to identify the extent of HCA and AOI resources that theoretically could be exposed if a spill were to occur. The types of impacts on the identified resources from a crude oil spill would be the same as those described in Section 10.4.2 and are not repeated here.

10.4.3.1 Region of Interest Analysis

10.4.3.1.1 HCA Comparisons among Applicant's Preferred Route and Route Alternatives

Populated Areas

Between Clearbrook and Carlton, the RA-07 route has the greatest number of HCA populated areas acres within 2,500 feet of either side of its centerline, and the Applicant's preferred route has the least (Table 10.4-20). RA-06 has 1.3 times more HCA populated areas acres than the Applicant's preferred route, RA-03AM has 4.7 times more, RA-08 has 7.5 times more, and RA-07 has almost 10 times more.

Table 10.4-20. Populated HCAs within 2,500 Feet of the Centerlines of the Applicant's Preferred Route and Route Alternatives in Minnesota (acres)

Segment	Applicant's Preferred Route	Route Alternative RA-03AM	Route Alternative RA-06	Route Alternative RA-07	Route Alternative RA-08
Clearbrook to Carlton	1,759.5	8,264.9	2,271.8	17,427.4	13,261.2

Source: Enbridge 2016c.

HCA = high consequence area

Unusually Sensitive Ecological Areas

From Clearbrook to Carlton, RA-07 has the greatest number of HCA unusually sensitive ecological area acres within 2,500 feet of either side of its centerline (14,801 acres), and RA-03AM has the least (2,650acres) (Table 10.4-21). Compared to the Applicant's preferred route, RA-03AM has half as many HCA unusually sensitive ecological area acres, RA-06 has 1.4 times more, and RA-07 and RA-08 have about 2.5 times more.

Table 10.4-21. Unusually Sensitive Ecological HCAs within 2,500 Feet of the Centerlines of the Applicant's Preferred Route and Route Alternatives in Minnesota (acres)

Segment	Applicant's Preferred Route	Route Alternative RA-03AM	Route Alternative RA-06	Route Alternative RA-07	Route Alternative RA-08
Clearbrook to Carlton	5,508.4	2,650.5	7,577.4	14,801.2	14,002.3

Source: Enbridge 2016c.

HCA = high consequence area

Drinking Water Sources

The RA-07 route has the greatest number of HCA drinking water sources acres within 2,500 feet of either side of its centerline from Clearbrook to Carlton, and the Applicant's preferred route has the least (Table 10.4-22). Figure 10.4-6 shows HCA drinking water sources along all route options.

Table 10.4-22. Drinking Water Sources HCAs within 2,500 Feet of the Centerlines of the Applicant's Preferred Route and Route Alternatives in Minnesota (acres)

Segment	Applicant's Preferred Route	Route Alternative RA-03AM	Route Alternative RA-06	Route Alternative RA-07	Route Alternative RA-08
Clearbrook to Carlton	83.4	1,322.5	168.2	2,395.3	2,105.6

Source: Enbridge 2016c.

HCA = high consequence area

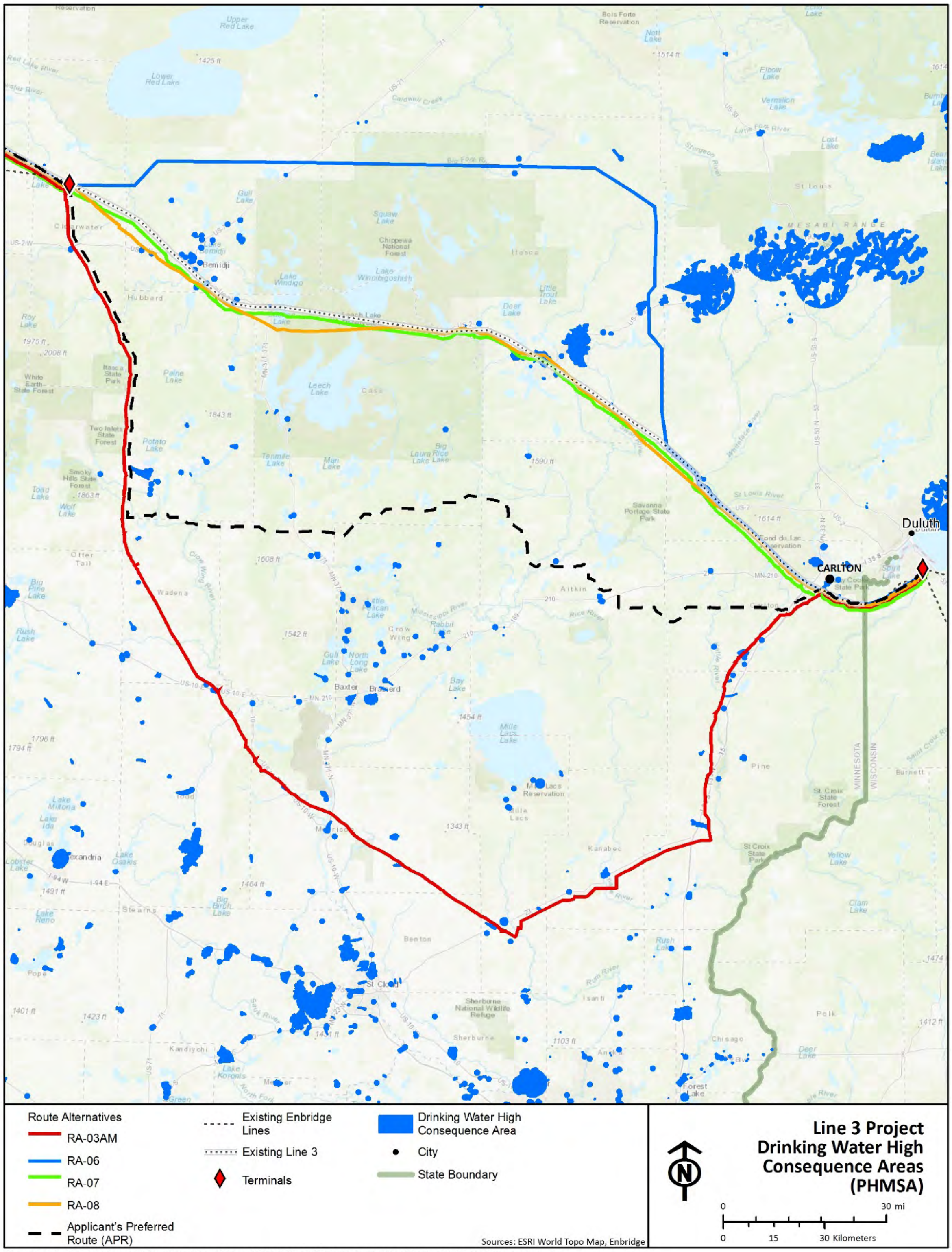

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Figure 10.4-6. High Consequence Area Drinking Water Sources between Clearbrook and Carlton

10.4.3.1.2 AOI Comparisons between Applicant's Preferred Route and Route Alternatives

Drinking Water Areas of Interest

In addition to the HCA drinking water sources, Minnesota DH identified additional drinking water resources that may be susceptible to exposures of crude oil. As part of consultation with Minnesota DH (and with support from Minnesota DNR and Minnesota PCA), appropriate ROI distances for the protection of drinking water supplies were determined based on a consensus of existing information and case studies.

<u>Drinking Water Supply Management Areas and Vulnerability</u>

Minnesota Department of Health DWSMAs are approved surface and subsurface area surrounding a public water supply well that completely contains the scientifically calculated wellhead protection area and is managed by the entity identified in a wellhead protection plan. The boundaries of the drinking water supply management area are delineated by identifiable physical features, landmarks or political and administrative boundaries. DWSMA vulnerability is defined as "an assessment of the likelihood for a potential contaminant source within the drinking water supply management area to contaminate a public water supply well, based on geologic sensitivity and the chemical and isotopic composition of the ground water" (Minnesota DH 2015).

The numbers and acres of DWSMAs were determined, as well as the vulnerability of the DWSMAs within 1 mile of the centerline of each route. From Clearbrook to Carlton, RA-03AM has the greatest number of DWSMAs (11) within 1 mile, the most DWSMA acres, and the most acres of High and Very High vulnerability (Table 10.4-23). The Applicant's preferred route has the fewest number of DWSMAs (one) within 1 mile, fewest DWSMA acres, and fewest acres of High vulnerability; there are no Very High vulnerability areas within 1 mile of that route. Figure 10.4-7 shows the DWSMAs and their vulnerability ranking within 1 mile of the route centerlines.

<u>Wellhead Protection Areas</u>

A 1-mile-wide ROI was established for this drinking water resource. Minnesota WPAs are shown in Figure 10.4-8. The numbers and areas of WPAs within a 1-mile-wide ROI of each route are listed in Table 10.4-24. From Clearbrook to Carlton, RA-03AM has the greatest number of WPAs (11) and the most WPA acres. The Applicant's preferred route has the fewest number of WPAs (one) and the fewest WPA acres.

Table 10.4-23. Drinking Water Supply Management Areas with Vulnerability within 1 Mile of the Applicant's Preferred Route and Route Alternatives in Minnesota

Route	Number of DWSMAs	DWSMA Vulnerability (acres)					
		Very Low	Low	Moderate	High	Very High	Total
Applicant's preferred route	1	0	0	0	790.6	0	790.6
Route alternative RA-03AM	11	0	941.6	2,098.1	2,471.0	166.0	5,676.7
Route alternative RA-06	3	0	350.8	651.2	0	109.0	1,111.0
Route alternative RA-07	4	0	523.4	394.6	2,272.5	0	3,190.5
Route alternative RA-08	3	0	208.9	428.5	2,338.0	0	2,975.4

Source: Minnesota DH 2016.

DWSMA = drinking water special management area

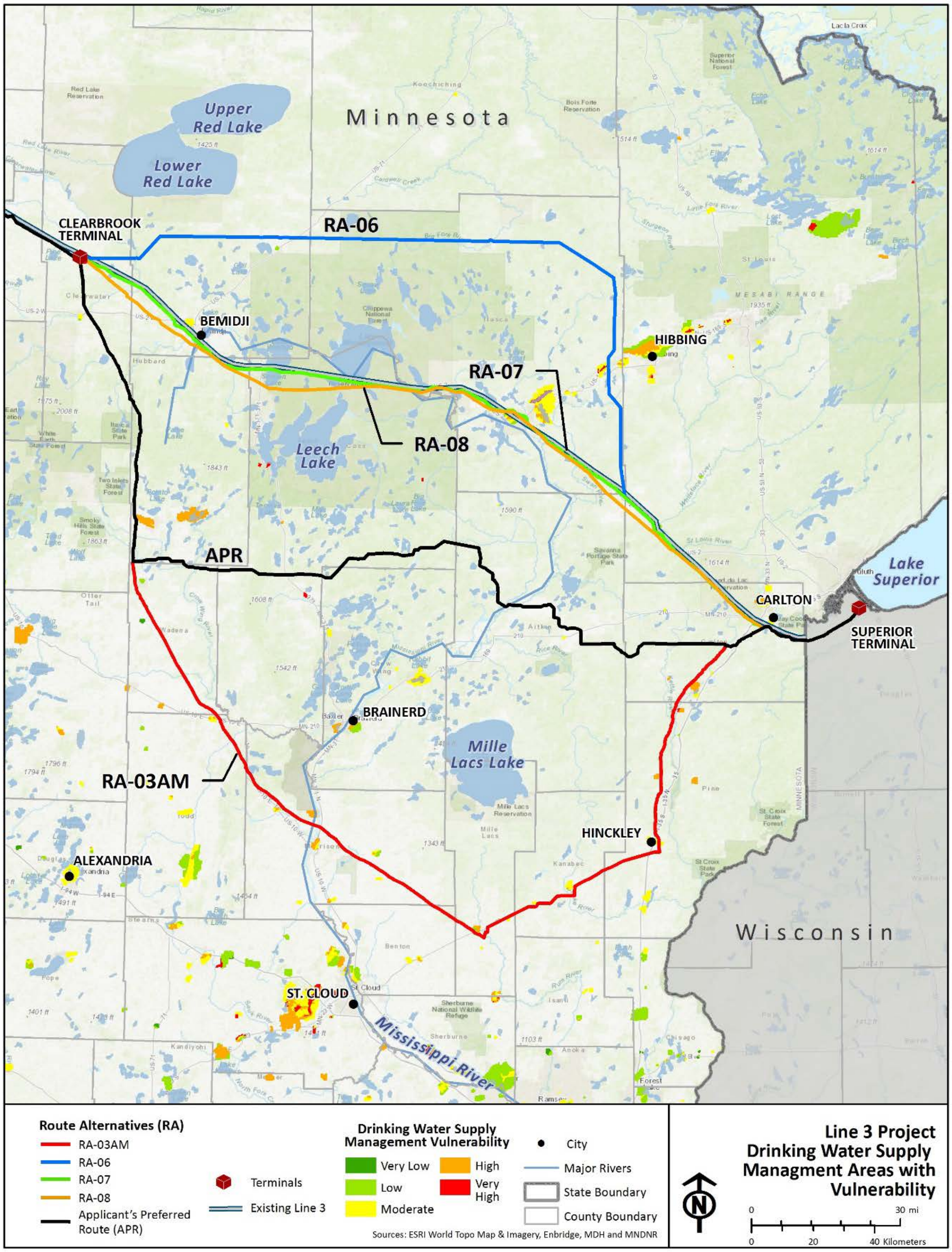

Figure 10.4-7. Drinking Water Supply Management Areas with Vulnerability between Clearbrook and Carlton

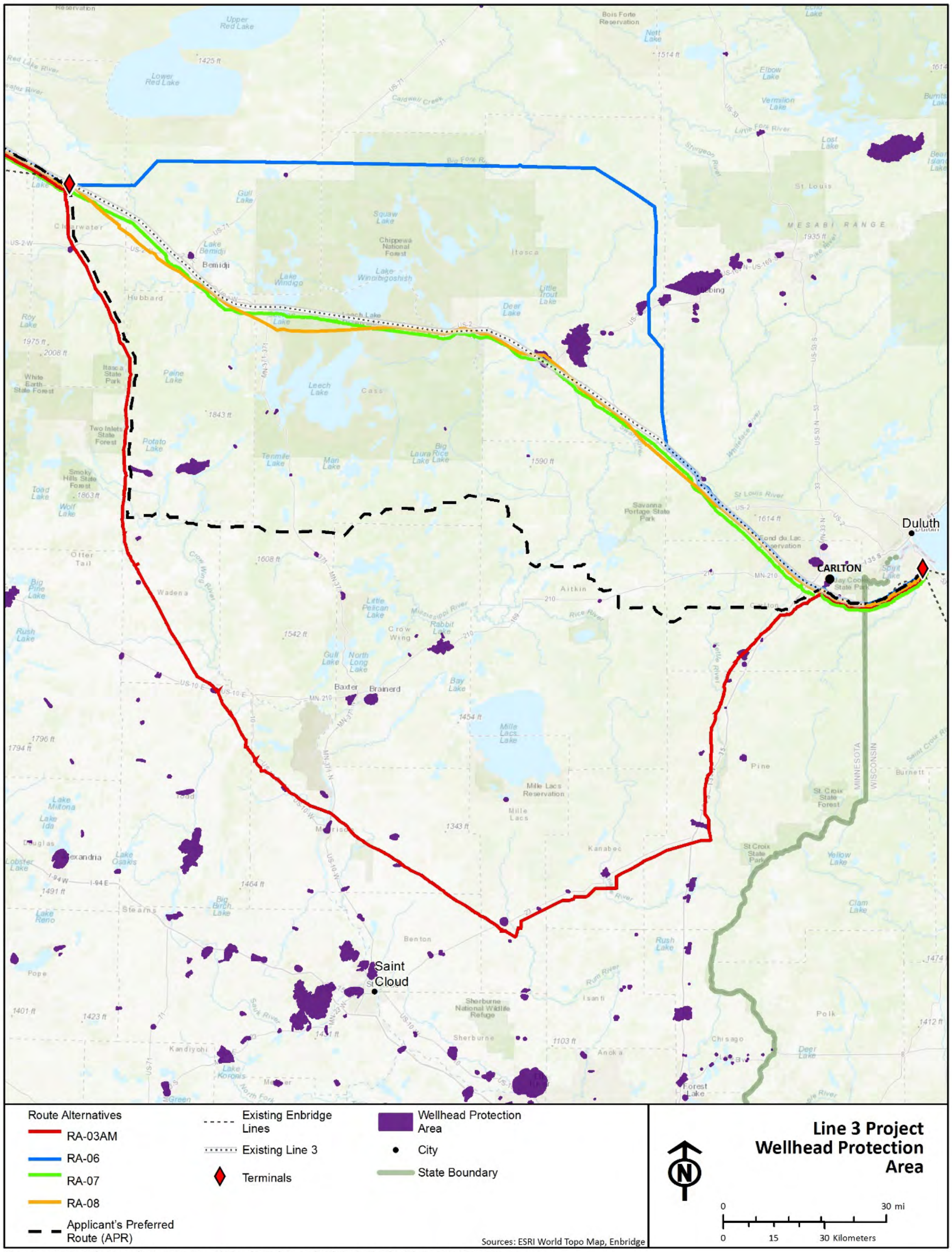

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Figure 10.4-8. Wellhead Protection Areas between Clearbrook and Carlton

Table 10.4-24. Wellhead Protection Areas within 1 Mile of the Applicant's Preferred Route and Route Alternatives in Minnesota

Segment	Applicant's Preferred Route		Route Alternatives							
			RA-03AM		RA-06		RA-07		RA-08	
	Acres	No.	Acres	No.	Acres	No.	Acres	No.	Acres	No.
Clearbrook to Carlton	219.5	1	3,159.1	11	653.6	2	2,646.5	7	2,626.8	8

Source: Minnesota DH 2016.

Hydrogeologic Sensitivity of Near-Surface Materials

The hydrogeologic sensitivity of near-surface materials close to a pipeline is an important factor in influencing the potential migration of a plume should a crude oil release occur. Hydrogeologic sensitivity is a qualitative measure of the ability of near-surface materials to transmit contaminants vertically to the water table and is ranked as follows by Minnesota DH:

- Low: fine-grained materials such as clays and clay-silt mixtures;
- Moderate: clay-silt-sand mixtures, sandy or silty tills, and colluvium;
- High: sands and sandy mixtures; and
- Very High: gravels, or coarse sands mixed with gravel.

Areas of hydrogeologic sensitivity within 0.5 mile of each route are depicted on Figure 10.4-9 and listed in Table 10.4-25. RA-03AM has the greatest number of acres with Very High and High hydrogeologic sensitivity, followed by the Applicant's preferred route, RA-07, RA-08, and RA-06.

Table 10.4-25. Hydrogeologic Sensitivity of Near-Surface Materials within 0.5 Mile of the Applicant's Preferred Route and Route Alternatives in Minnesota (acres)

Route	Not Evaluated	Low	Moderate	High	Very High	Total
Applicant's Preferred Route	223.9	29,427.9	31,222.4	80,661.7	1,143.8	142,679.7
Route Alternative RA-03AM	467.7	16,431.8	28,539.7	109,134.8	31,402.0	185,975.9
Route Alternative RA-06	3,618.1	44,841.4	69,391.8	9,935.2	3,993.2	131,779.6
Route Alternative RA-07	1,323.1	22,960.6	27,083.6	52,506.8	3,612.8	107,486.8
Route Alternative RA-08	1,364.2	25,050.1	24,248.5	52,100.7	3,156.4	105,919.9

Source: Minnesota DH 2017, pers. comm.

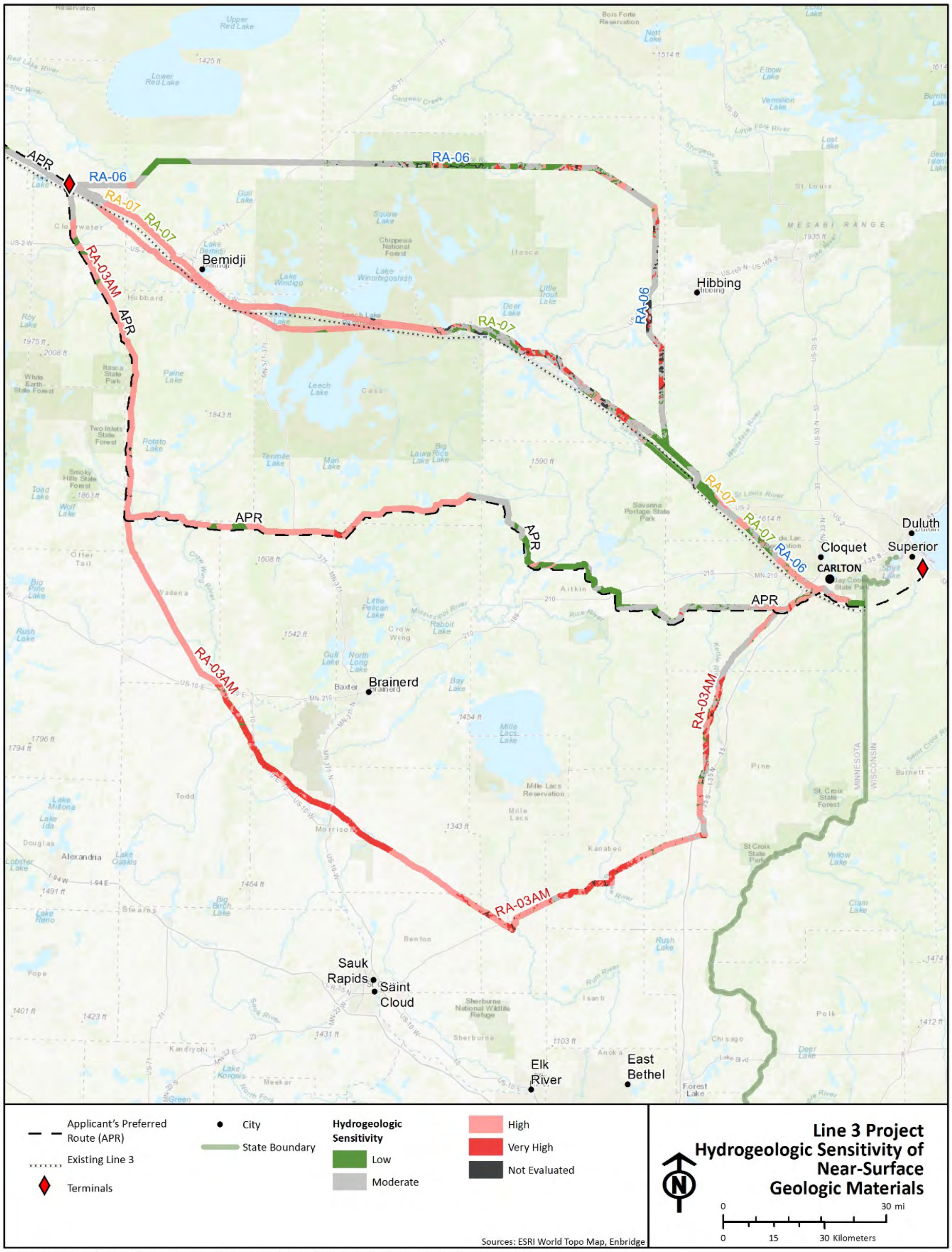

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Figure 10.4-9. Areas of Groundwater Hydrogeologic Sensitivity within 0.5 Mile of the Applicant's Preferred Route and Route Alternatives between Clearbrook and Carlton

Domestic Wells and Associated Geological Sensitivity Ratings

Domestic (private) drinking water wells and their sensitivity were identified within an established 1,000-foot-wide ROI of each route's centerline. The method of determining Low, Moderate, High, or Very High geologic sensitivity for a well considers the thickness of fine-grained geologic material (clay or shale) overlying an aquifer that is penetrated by a well. From Clearbrook to Carlton, RA-03AM has the greatest number of Very High and High sensitivity domestic wells, and RA-06 has the fewest number (Table 10.4-26).

Table 10.4-26. Geological Sensitivity Ratings of Domestic Wells within 1,000 Feet of the Applicant's Preferred Route and Route Alternatives in Minnesota (number of domestic wells)

Route	Low	Moderate	High	Very High	TOTAL
Applicant's Preferred Route	87	35	25	17	164
Route Alternative RA-03AM	242	99	24	31	396
Route Alternative RA-06	33	3	1	3	40
Route Alternative RA-07	118	46	10	9	183
Route Alternative RA-08	105	46	5	6	162

Source: Minnesota DH 2017, pers. comm.

Public Drinking Water Supplies

Sources of drinking water for the Minnesota public include groundwater (public water wells) and surface water (surface water intakes). The locations of public water wells were provided by Minnesota DH. According to Minnesota DH, no surface water intakes or sources of public drinking water are within the 2,500-foot-wide ROI of any route (Table 10.4-27 and Figure 10.4-10).

Table 10.4-27. Number of Public Wells and Geologic Sensitivity within 2,500 Feet of the Centerlines of the Applicant's Preferred Route and Route Alternatives

Route	Low	Moderate	High	Very High	TOTAL
Applicant's Preferred Route	3	1	0	5	**9**
Route Alternative RA-03AM	17	6	1	10	**34**
Route Alternative RA-06	0	0	0	3	**3**
Route Alternative RA-07	22	6	2	29	**59**
Route Alternative RA-08	13	0	0	13	**26**

Source: Minnesota DH 2017, pers. comm.

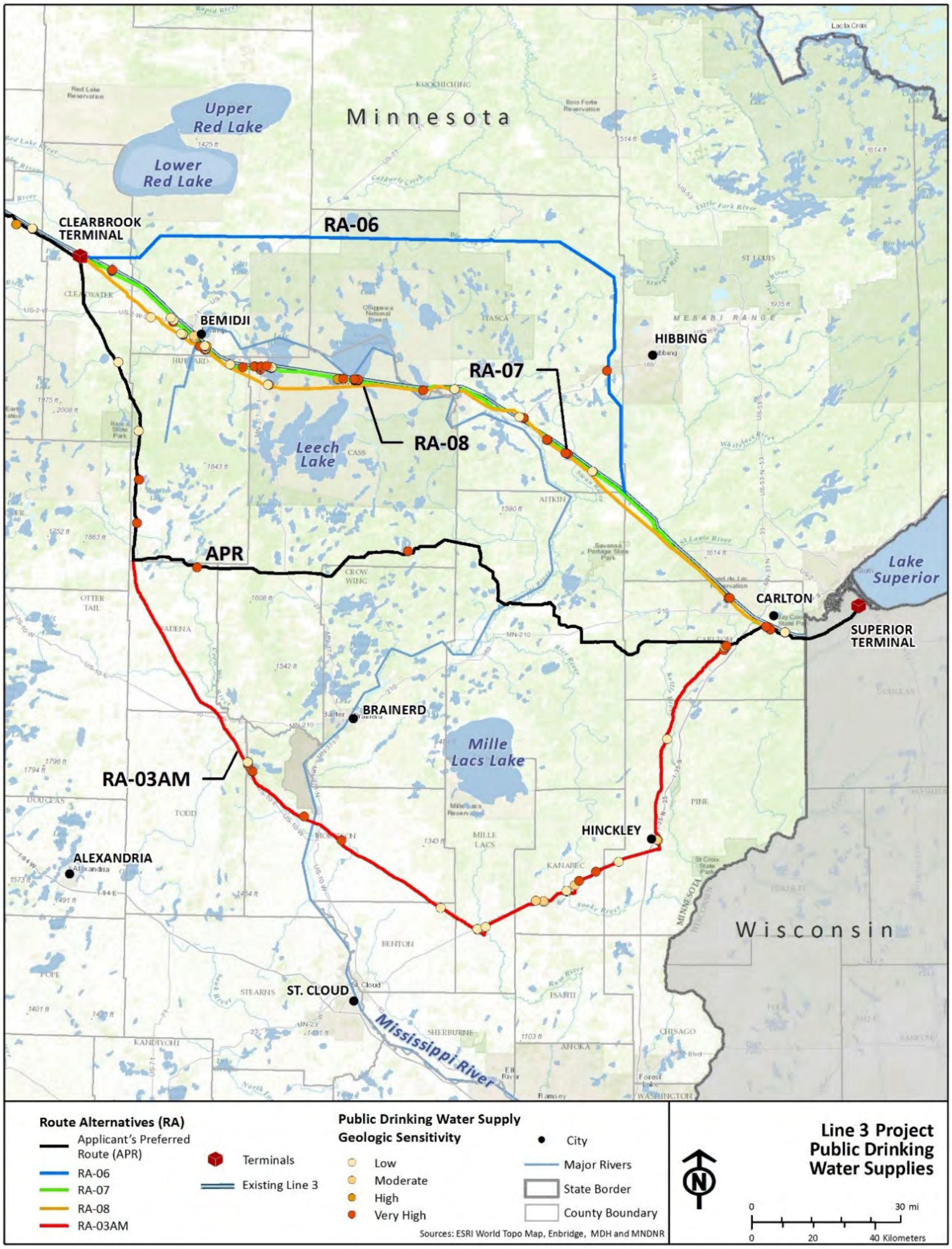

Figure 10.4-10. Public Drinking Water Wells (Groundwater) and Associated Geologic Sensitivity within 2,500 Feet of the Centerlines of the Applicant's Preferred Route and Route Alternatives between Clearbrook and Carlton

From Clearbrook to Carlton, RA-07 has the most wells within the ROI, followed by RA-03AM, RA-08, the Applicant's preferred route, and RA-06. RA-07 also has the most wells with a Very High sensitivity rating, followed by RA-08, RA-03AM, the Applicant's preferred route, and RA-06.

Figure 10.4-11 shows sensitive drinking water resources within 2,500 feet of either side of the centerlines for all routes.

Cultural Resources Areas of Interest

A crude oil release along any of the routes has the potential to result in exposure of reservation lands, archaeological resources, and historical resources (Table 10.4-28). Between Clearbrook and Carlton, RA-07 and RA-08 ROIs overlap with the greatest amounts of reservation land, followed by RA-06 and RA-03AM ROIs. The ROI for Applicant's preferred route does not overlap with any reservation land AOIs.

Within the 2,500-foot-wide ROI, RA-07 and RA-08 contain the greatest number of archaeological resources, while RA-06 contains the least. RA-07 also has the greatest number of historic sites, and RA-06 has the least.

Biological Areas of Interest

Biological AOIs were identified within the 2,500-foot-wide ROI of the routes from Clearbrook to Carlton (Table 10.4-29 and Figure 10.4-12). The ROI of the Applicant's preferred route has the most MBS Sites acres and the fewest acres of Aquatic Management Area, Minnesota BWSR conservation easement, and Muskie lakes. It is the only route that overlaps with trout lakes (16 acres).

RA-03AM has the most Scientific and Natural Area acres, Minnesota BWSR conservation easement acres, and Marginal Cropland acres, and has the fewest native plant community and sensitive lakeshore acres. RA-06 has the fewest number of Lakes of Biological Significance, Marginal Croplands, and MBS Sites acres.

RA-07 has the most acreage of Aquatic Management Area, Lakes of Biological Significance, Muskie lakes, sensitive lakeshore, and wild rice lakes. It has the fewest Scientific and Natural Area acres. RA-07 and RA-08 both overlap with wetland bank easement acres (71 and 113 acres, respectively), while the other three routes do not. RA-08 has the most native plant community acres and is the only route that overlaps with native prairies (less than 2 acres).

As identified above, the Applicant's preferred route is the only route that overlaps with trout lakes within its 2,500-foot-wide ROI. All routes would overlap with trout streams. RA-06 has the greatest overlap with trout streams (20.3 miles), followed by RA-03AM (14.9 miles), RA-07 (14.7 miles), RA-08 (12.9 miles), and the Applicant's preferred route (9.4 miles). There are five calcareous fens within 2,500 feet of each side of the common alignment of the routes in the North Dakota-to-Clearbrook segment.

Limited marginal cropland is a temporary conservation easement, while perpetual marginal cropland is a permanent easement as identified by the Minnesota Board of Water and Soil Resources. RA-03AM overlaps with the most acreage of marginal cropland within the 2,500-foot-wide ROI, followed by RA-08, RA-07, the Applicant's preferred route, and RA-06.

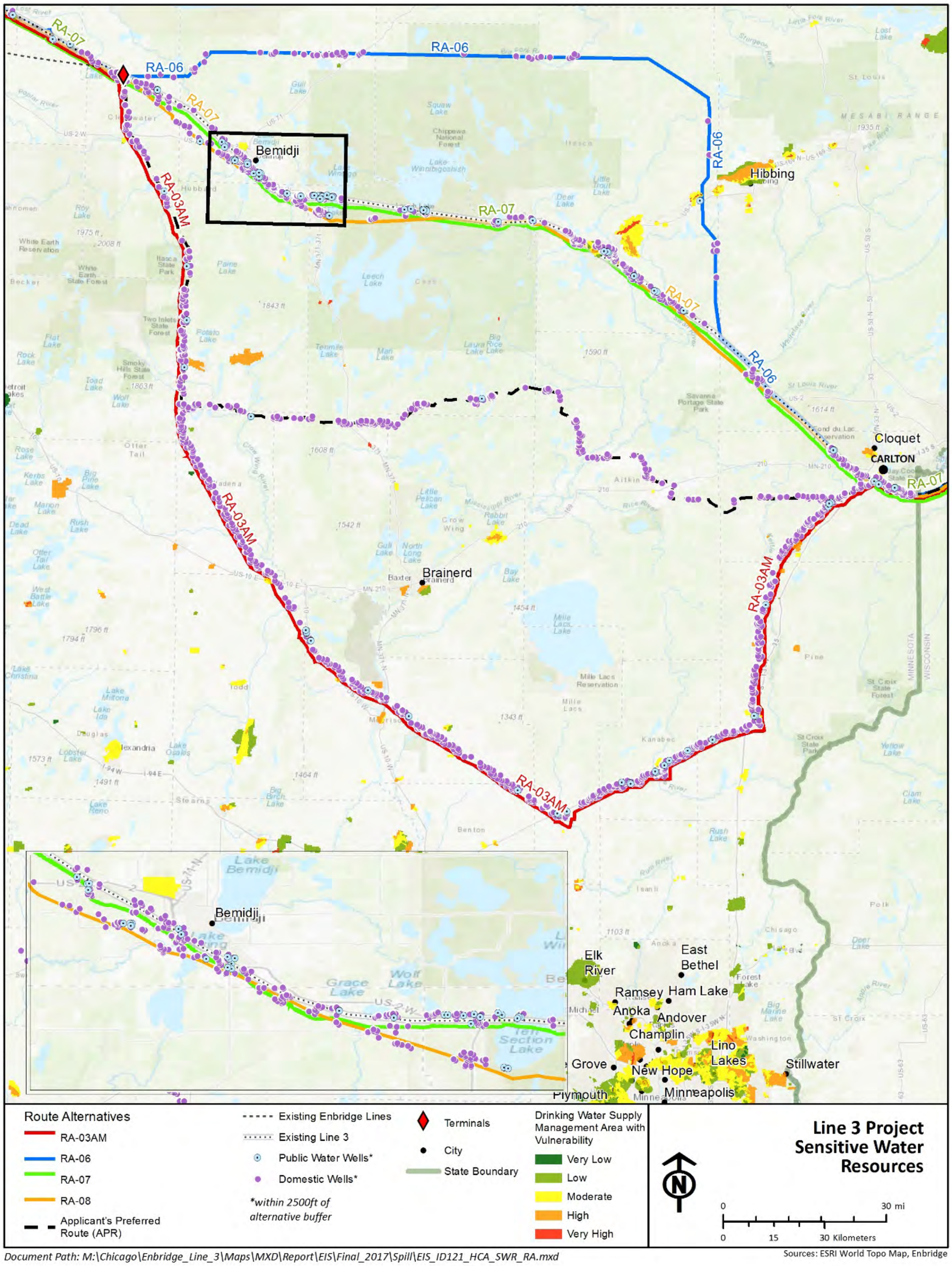

Figure 10.4-11. Drinking Water Sources within 2,500 Feet of the Centerlines of Applicant's Preferred Route and Route Alternatives between Clearbrook and Carlton

Table 10.4-28. Cultural Resource Areas of Interest within 2,500 Feet of the Centerlines of the Applicant's Preferred Route and Route Alternatives in Minnesota

Segment	Acres of Reservation Land					Number of Archaeological Resources[a]					Number of Historic Resources[1]				
	APR	RA-03AM	RA-06	RA-07	RA-08	APR	RA-03AM	RA-06	RA-07	RA-08	APR	RA-03AM	RA-06	RA-07	RA-08
Clearbrook to Carlton	0	13.5	7,858.1	33,689.6	33,894.5	50	51	8	97	103	21	73	11	83	35

Source: ESRI 2017; Minnesota Department of Transportation 2003.

[a] The archaeological and historic resources noted here are those that are found within the databases from the Minnesota Historical Society. The numbers do not account for the confluence of cultural and natural resources unless the resource was recorded in the database (see Chapter 9).

APR = Applicant's preferred route, RA = route alternative

Table 10.4-29. Biological Areas of Interest within 2,500 Feet of the Centerlines of the Applicant's Preferred Route and Route Alternatives from Clearbrook to Carlton (acres)

Area of Interest	Applicant's Preferred Route	Route Alternative RA-03AM	Route Alternative RA-06	Route Alternative RA-07	Route Alternative RA-08
Aquatic Management Area	125.0	112.5	204.6	227.5	190.5
Scientific and Natural Area	0	234.5	63.7	7.5	85.2
Minnesota BWSR conservation easement	14.0	1,288.5	25.9	165.2	183.7
Lakes of Biological Significance	300.2	220.3	99.2	2,103.4	1,280.8
Marginal Cropland	13.7	88.3	6.7	14.2	23.5
MBS Sites	25,016.2	16,339.8	8,952.1	9,962.2	12,257.6
Muskie lakes	41.4	0	0	976.6	55.8
Native plant communities	35,273.1	18,742.8	26,368.1	37,247.1	39,868.2
Native prairies	0	0	0	0	1.6
Sensitive lakeshore areas	300.5	178.6	0	1,329.8	1,151.6
Trout lakes[a]	16.3	0	0	0	0
Wetland bank easement	0	0	0	70.6	112.5
Wild rice lakes	675.4	708.6	92.4	1,240.4	1,119.5
TOTAL	**61,775.8**	**37,913.9**	**35,812.7**	**53,344.5**	**56,330.5**

Sources: Enbridge 2016c; Minnesota DNR 2016.

[a] Data are for acres of trout lakes; miles of trout streams potentially affected are described in the text.

MBS = Minnesota Biological Survey Sites of Biodiversity Significance, Minnesota BWSR = Minnesota Board of Water and Soil Resources

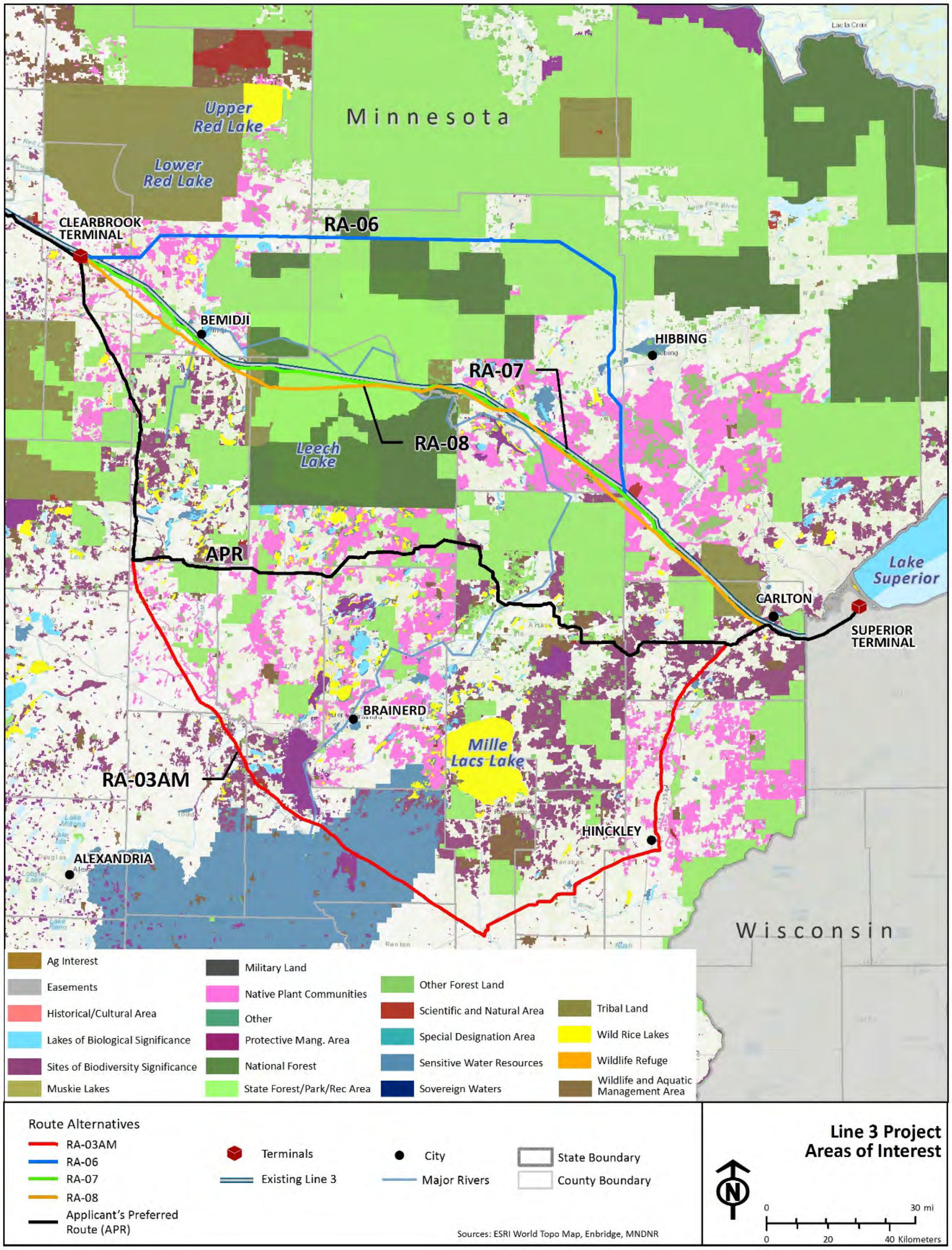

Figure 10.4-12. Areas of Interest along the Applicant's Preferred Route and Route Alternatives in Minnesota

Commodity Production Areas of Interest

The 2,500-foot-wide ROIs of all of the routes overlap with various forested lands (Figure 10.4-12). From Clearbrook to Carlton, RA-06 has the greatest number of national/state forest acres within its ROI, followed by RA-08, RA-07, the Applicant's preferred route, and RA-03AM (Table 10.4-30). All of the routes contain "other forested land" acres within their ROIs—RA-06 contains the most, followed by the Applicant's preferred route, RA-07, RA-08, and RA-03AM.

Table 10.4-30. Commodity Production Areas of Interest within 2,500 Feet of the Centerlines of the Applicant's Preferred Route and Route Alternatives from Clearbrook to Carlton (acres)

Area of Interest	Applicant's Preferred Route	Route Alternative RA-03AM	Route Alternative RA-06	Route Alternative RA-07	Route Alternative RA-08
National/state forest	31,764.3	2,334.7	55,377.7	48,861.8	52,121.1
Other forested land	3,312.4	1,640.2	5,884.7	2,790.1	2,593.9
Harvested Wild Rice[a]	181.6	180.7	72.1	241.9	761.8
TOTAL	**35,258.3**	**4,155.6**	**61,334.5**	**51,893.8**	**55,476.8**

Sources: Minnesota DNR 2016; Enbridge 2016c.

[a] Based on 2006 Minnesota Natural Wild Rice Harvester Survey data (Minnesota DNR 2007)

The route ROIs also overlap with areas of harvested wild rice identified in the 2006 Minnesota Natural Wild Rice Harvester Survey data (Minnesota DNR 2007). The 2,500-foot-wide ROIs cross greater areas of wild rice, as shown Table 10.4-29, the wild rice areas identified as harvested in the 2006 survey (Minnesota DNR 2007) indicated roughly 70 to 80 percent of the wild rice areas within 2,500 feet of RA-06 and RA-08 were harvested in 2006 and less than 30 percent of the areas of wild rice within 2,500 feet of the Applicant's preferred route, RA-03AM, and RA-07. The largest total acreage of wild rice harvest is in the ROI for RA-08, followed by RA-07, Applicant's preferred route, RA-03AM, and RA-06.

Recreation and Tourism Areas of Interest

The 2,500-foot-wide ROIs for RA-03AM and the Applicant's preferred route both overlap with approximately 318 acres of state recreation area and approximately 630 acres of state park from Clearbrook to Carlton. RA-06, RA-07, and RA-08 do not encompass any state recreation areas or state parks (Table 10.4-31).

WMAs and waterfowl protection areas are present within the ROIs of all of the route alternatives. The ROI for the Applicant's preferred route has the greatest acreage of WMAs, followed by RA-03AM, RA-08, RA-06, and RA-07. RA-06 has the greatest acreage of waterfowl production areas in its ROI, followed by RA-08, RA-03AM, RA-07, and the Applicant's preferred route. The ROI for the Applicant's preferred route crosses the most total recreation and tourism AOI acres, followed by RA-03AM, RA-08, RA-06, and RA-07.

Table 10.4-31. Recreation and Tourism Areas of Interest within 2,500 Feet of the Centerlines of the Applicant's Preferred Route and Route Alternatives from Clearbrook to Carlton (acres)

Area of Interest	Applicant's Preferred Route	Route Alternative RA-03AM	Route Alternative RA-06	Route Alternative RA-07	Route Alternative RA-08
State plan/recreational areas	317.7	317.7	0	0	0
State parks	629.9	630.3	0	0	0
Wildlife Management Areas	1,299.3	477.7	294.1	16.4	439.5
Waterfowl production areas	92.0	260.8	418.0	185.8	277.2
TOTAL	**2,339.0**	**1,686.5**	**712.1**	**202.2**	**716.7**

Sources: Minnesota DNR 2016; Enbridge 2016c.

10.4.3.2 Potential Downstream Spill Exposure

10.4.3.2.1 High Consequence Area Downstream Comparisons

Populated Areas

From Clearbrook to Carlton, RA-03AM has the most HCA populated area acres within the 10-mile-long ROI downstream of its waterbody crossings, followed by RA-08, RA-07, the Applicant's preferred route, and RA-06 (Table 10.4-32).

Table 10.4-32. Populated HCAs within the 10-Mile-Long Downstream ROI for the Applicant's Preferred Route and Route Alternatives in Minnesota (acres)

Segment	Applicant's Preferred Route	Route Alternative RA-03AM	Route Alternative RA-06	Route Alternative RA-07	Route Alternative RA-08
Clearbrook to Carlton	3,054.6	4,564.3	958.2	3,379.2	4,102.5

Source: Enbridge 2016c.

HCA = high consequence area, ROI = region of interest

Unusually Sensitive Ecological Areas

From Clearbrook to Carlton, RA-08 has the most HCA unusually sensitive ecological area acres within the 10-mile-long ROI downstream of its waterbody crossings, followed by RA-07, RA-03AM, the Applicant's preferred route, and RA-06 (Table 10.4-33).

Table 10.4-33. Unusually Sensitive Ecological HCAs within the 10-Mile-Long Downstream ROI for the Applicant's Preferred Route and Route Alternatives In Minnesota (acres)

Segment	Applicant's Preferred Route	Route Alternative RA-03AM	Route Alternative RA-06	Route Alternative RA-07	Route Alternative RA-08
Clearbrook to Carlton	3,788.8	4,681.9	3,418.5	5,932.6	7,040.8

Source: Enbridge 2016c.
HCA = high consequence area, ROI = region of interest

Drinking Water Sources

From Clearbrook to Carlton, RA-03AM has the greatest number of HCA drinking water source acres within the 10-mile-long downstream ROI of its waterbody crossings, followed by RA-08, RA-06, RA-07, and the Applicant's preferred route (Table 10.4-34).

Table 10.4-34. Drinking Water Source HCAs within the 10-Mile-Long Downstream ROI for the Applicant's Preferred Route and Route Alternatives in Minnesota (acres)

Segment	Applicant's Preferred Route	Route Alternative RA-03AM	Route Alternative RA-06	Route Alternative RA-07	Route Alternative RA-08
Clearbrook to Carlton	417.7	1,076.6	549.8	546.7	892.7

Source: Enbridge 2016c.
HCA = high consequence area, ROI = region of interest

10.4.3.2.2 Areas of Interest Downstream Comparisons

Drinking Water Areas of Interest

Drinking Water Supply Management Areas and Vulnerability

From Clearbrook to Carlton, RA-03AM has the most DWSMA acres within the 10-mile-long downstream ROI as well as the most acres of Moderate, High, and Very High vulnerability DWSMAs (Table 10.4-35). It has approximately three times as many DWSMA acres as RA-06, RA-07, and RA-08. The Applicant's preferred route has the fewest DWSMA acres. The 10-mile-long downstream ROI for RA-03AM overlaps with 11 DWSMAs; RA-06, RA-07, and RA-08 overlap with four DWSMAs each; and the Applicant's preferred route overlaps with two.

Wellhead Protection Areas

From Clearbrook to Carlton, RA-03AM has the greatest number of WPA acres within the 10-mile-long downstream ROI (almost 502 acres), while the Applicant's preferred route has the least (approximately 30 acres). RA-03AM also overlaps with the most WPAs (eight), and all of the other routes overlap with two.

Domestic Wells and Associated Geological Sensitivity Ratings

Domestic water wells within 1 mile downstream of each water crossing and 500 feet from either side of the flowing waterbody were identified and are presented in Table 10.4-36. RA-03AM has the highest number of wells within the 1-mile-long downstream ROI, followed by the Applicant's preferred route, RA-08, RA-07, and RA-06. RA-03AM also has the greatest number of High and Very High sensitivity wells (40) and RA-06 and RA-07 have the least (each have two).

Public Water Drinking Supplies

Public water well data also were available only within 1 mile of the centerline of each route. Thus, the 10-mile-long downstream ROI was limited to capturing public water wells within approximately 1 mile of the route (or 1 mile downstream in most cases).

Public water wells that fall within 1 mile of the route and 500 feet from either side of the flowing waterbody were identified. From Clearbrook to Carlton, the approximately 1-mile-long downstream ROI for the Applicant's preferred route overlaps with three public water wells, while RA-03AM and RA-08 overlap with two, RA-07 overlaps with one, and RA-06 does not overlap with any.

Cultural Resources Areas of Interest

From Clearbrook to Carlton, the 10-mile-long downstream ROI for RA-08 overlaps with the most acreage of tribal reservation boundary, followed by RA-07 and RA-06. The Applicant's preferred route and RA-03AM do not overlap with any reservation boundaries within the downstream ROI. Table 10.4-37 identifies the extent of cultural resource AOIs for the Applicant's preferred route and the route alternatives. As described above, data on archaeological sites and historic resources were not available for all CN Alternatives.

Table 10.4-35. Drinking Water Special Management Areas with Vulnerability within the 10-Mile-Long Downstream ROI for the Applicant's Preferred Route and Route Alternatives in Minnesota

Route/Segment	Number of DWSMAs	Drinking Water Special Management Area Vulnerability (acres)					
		Very Low	Low	Moderate	High	Very High	Total
Applicant's Preferred Route	2	0	0	45.2	0	0	45.2
Route Alternative RA-03AM	11	0	197.5	334.0	423.6	41.0	996.0
Route Alternative RA-06	3	0	190.7	64.8	11.1	0.9	267.4
Route Alternative RA-07	3	0	312.6	13.1	11.1	0	336.7
Route Alternative RA-08	3	0	286.3	13.1	11.1	0	310.4

Source: Minnesota DH 2016.

DWSMA = drinking water special management area, ROI = region of interest

Table 10.4-36. Domestic Wells within the Approximately 1-Mile-Long Downstream ROI for the Applicant's Preferred Route and Route Alternatives in Minnesota (number of domestic wells)

Route/Segment	Low	Moderate	High	Very High	Total
Applicant's Preferred Route	73	16	14	19	122
Route Alternative RA-03AM	101	36	20	20	177
Route Alternative RA-06	21	5	0	2	28
Route Alternative RA-07	29	8	1	1	39
Route Alternative RA-08	30	11	2	1	44

Source: Enbridge 2016c; Minnesota DH 2017, personal communication.

ROI = region of interest

Table 10.4-37. Cultural Resources Areas of Interest within the 10-Mile-Long Downstream ROI for the Applicant's Preferred Route and Route Alternatives from Clearbrook to Carlton (acres)

Segment	Applicant's Preferred Route	Route Alternative RA-03AM	Route Alternative RA-06	Route Alternative RA-07	Route Alternative RA-08
Clearbrook to Carlton	0	0	3,567.5	10,357.2	11,871.5

Source: Minnesota Department of Transportation 2003.

ROI = region of interest

Biological Areas of Interest

Biological AOIs were identified within the 10-mile-long downstream ROIs for the routes from Clearbrook to Carlton (Table 10.4-38). The ROI for the Applicant's preferred route overlaps with the most MBS Sites acres and wetland bank easement acres. It overlaps with the fewest Aquatic Management Area and native plant community acres. The Applicant's preferred route and RA-03AM are the only two routes whose ROIs overlap with Scientific and Natural Areas (approximately 150 and 238 acres, respectively).

Table 10.4-38. Biological Areas of Interest within the 10-Mile-Long Downstream ROI for the Applicant's Preferred Route and Route Alternatives from Clearbrook to Carlton (acres)

Area of Interest	Applicant's Preferred Route	Route Alternative RA-03AM	Route Alternative RA-06	Route Alternative RA-07	Route Alternative RA-08
Aquatic Management Area	209.8	267.0	241.0	320.0	336.9
Scientific and Natural Areas	149.6	238.1	0	0	0
Minnesota BWSR conservation easement	37.4	385.1	0	36.1	35.9

Table 10.4-38. Biological Areas of Interest within the 10-Mile-Long Downstream ROI for the Applicant's Preferred Route and Route Alternatives from Clearbrook to Carlton (acres)

Area of Interest	Applicant's Preferred Route	Route Alternative RA-03AM	Route Alternative RA-06	Route Alternative RA-07	Route Alternative RA-08
Lakes of Biological Significance	3,608.9	1,952.6	1,222.5	3,400.1	4,286.4
Marginal Cropland	11.3	69.3	0	10	10
MBS Sites	9,692.7	5,138.5	4,774.4	5,834.6	6,531.2
Muskie lakes	676.0	0	0	2,107.0	2,676.3
Native plant communities	14,015.3	16,937.9	15,591.9	20,211.6	21,661.8
Sensitive lakeshore areas	441.9	188. 4	158.3	513.4	713.7
Wetland bank easement	38.5	0	0	30.3	30.3
Wild rice lakes	3,396.3	2,385.1	1,021.5	2,956.4	3.902.3
TOTAL	**32,277.7**	**27,373.6**	**23,009.6**	**35,419.5**	**36,282.5**

Sources: Enbridge 2016c; Minnesota DNR 2016.

MBS Sites = Minnesota Biological Survey Sites of Biodiversity Significance, Minnesota BWSR = Minnesota Board of Water and Soil Resources, ROI = region of interest

The RA-03AM ROI overlaps with the most Minnesota BWSR conservation easement acres. It does not overlap with any Muskie lakes or wetland bank easement acres.

The RA-06 ROI overlaps with the fewest acres of Lakes of Biological Significance, MBS Sites, sensitive lakeshore area, and wild rice lakes. It also does not overlap with any Scientific and Natural Area, Minnesota BWSR conservation easement, Muskie lakes, or wetland bank easement acres. The RA-07 ROI also does not overlap with any Scientific and Natural Area acres.

The RA-08 ROI overlaps with the most Aquatic Management Area, Lakes of Biological Significance, Muskie lakes, native plant community, sensitive lakeshore, and wild rice lake acres.

All route ROIs overlap trout streams with the mileage of trout stream crossed ranging from 29.6 miles for RA-08 to 37.0 miles for RA-03AM.

Only the Applicant's preferred route ROI overlaps calcareous fens: none of the other route ROIs overlap calcareous fens.

None of the 10-mile-long downstream ROIs of any of the routes overlap with native prairies.

The RA-03AM ROI overlaps with the most acreage of marginal cropland, followed by the Applicant's preferred route, and RA-08 and RA-07 (approximately 10 acres each). The RA-06 ROI does not overlap with any marginal cropland.

Commodity Production Areas of Interest

The 10-mile-long downstream ROIs of all of the routes overlap with various forested lands. From Clearbrook to Carlton, the RA-06 ROI overlaps with the greatest number of national/state forest acres, followed by RA-08, RA-07, the Applicant's preferred route, and RA-03AM. All of the route ROIs contain "other forested land" acres: RA-08 contains the most, followed by RA-07, RA-06, the Applicant's preferred route, and RA-03AM (Table 10.4-39).

Table 10.4-39. Commodity Production Areas of Interest within the 10-Mile-Long Downstream ROI of the Applicant's Preferred Route and Route Alternatives from Clearbrook to Carlton (acres)

Area of Interest	Applicant's Preferred Route	Route Alternative RA-03AM	Route Alternative RA-06	Route Alternative RA-07	Route Alternative RA-08
National/state forest	12,054.9	653.9	24,550.0	17,132.8	20,897.7
Other forested land	1,904.1	838.7	2,154.5	2,207.8	2,495.8
Harvested Wild Rice[a]	982.3	0	324.0	773.7	1,983.2
TOTAL	**14,941.3**	**1,492.6**	**27,028.5**	**20,114.3**	**25,376.7**

Source: Enbridge 2016c; Minnesota DH 2017, personal communication.

[a] Based on 2006 Minnesota Natural Wild Rice Harvester Survey data (Minnesota DNR 2007)

ROI = region of interest

While all 10-mile-long downstream ROIs cross areas of wild rice, as shown Table 10.4-38, the RA-03AM ROI did not intersect any wild rice areas identified as harvested in the 2006 survey (Minnesota DNR 2007). Of the harvested wild rice areas, RA-08 crossed more than double the acreage of the Applicant's preferred route and RA-07 and six times the amount crossed by the RA-06 10-mile-long downstream ROI. It should again be noted that these ROIs (10-mile-long, 1,000-foot-wide downstream corridors of potential exposure from spills) are calculating areas that intersect these corridors and do account for additional acreage resulting from spreading of a spill that may occur when entering a larger body of water, such as ponds and lakes.

Recreation and Tourism Areas of Interest

The 10-mile-long downstream ROI of RA-03AM overlaps with the most state recreational area acres, and the Applicant's preferred route ROI overlaps with the least. RA-06, RA-07, and RA-08 ROIs all overlap with the same amount of state recreational area acres. The RA-03AM ROI also overlaps with the most state park acres, followed by RA-06, RA-07, and RA-08 (which overlap with the same amount), and the Applicant's preferred route (Table 10.4-40).

Table 10.4-40. Recreation and Tourism Areas of Interest within the 10-Mile-Long Downstream ROI of the Applicant's Preferred Route and Route Alternatives from Clearbrook to Carlton

Area of Interest	Applicant's Preferred Route	Route Alternative RA-03AM	Route Alternative RA-06	Route Alternative RA-07	Route Alternative RA-08
State plan/recreational areas	180.7	1,178.0	543.7	543.7	543.7
State parks	0.2	1,740.3	941.3	941.3	941.3
Wildlife Management Areas	1,172.7	385.6	3.0	299.5	293.1
Waterfowl production areas	11.5	11.5	182.2	0	0
TOTAL	**1,365.2**	**3,315.3**	**1,670.2**	**1,784.5**	**1,778.1**

Source: Enbridge 2016c; Minnesota DH 2017, personal communication.
ROI = region of interest

The 10-mile-long downstream ROI of the Applicant's preferred route overlaps with the most WMA acres, followed by RA-03AM, RA-07, RA-08, and RA-06. The RA-06 ROI overlaps with the most waterfowl production acres, followed by the Applicant's preferred route and RA-03AM, and then RA-08. The RA-07 ROI does not overlap with any waterfowl production areas. The RA-03AM ROI crosses the most total recreation and tourism AOI acres, followed by RA-07, RA-08, RA-06, and the Applicant's preferred route.

10.5 SPILL PREVENTION, PREPAREDNESS, AND RESPONSE

Spill prevention is the most critical component to avoiding impacts from a crude oil release. If a release occurs, the most important actions to reduce environmental impacts are to minimize the size and spread of the release by implementing a rapid, coordinated, and effective spill response based on an established action plan. This section provides information on those activities in the following sections:

- Crude Oil Release Prevention Programs and Measures (Section 10.5.1),
- Emergency Response Planning and Preparedness (Section 10.5.2), and
- Initial Oil Spill Containment and Response Methods (Section 10.5.3).

10.5.1 Crude Oil Release Prevention Programs and Measures

The following sections address plans and programs to prevent, prepare, and respond to a crude oil release. Many of these plans are pursuant to safety standards and regulations described in Section 10.1.1.

10.5.1.1 Spill Prevention Measures

10.5.1.1.1 Pipeline Plans and Measures

The Applicant has proposed various oil spill prevention measures for the Applicant's preferred route that could also apply to operation and maintenance of system alternative SA-04 and any of the pipeline route alternatives. Enbridge's integrity management program (IMP) is a key component to preventing crude oil releases. It includes highly sensitive tools that travel through and scan the internal and external conditions of the pipeline. Data collected are analyzed to identify integrity risks to the pipeline, such as corrosion or cracking, which could lead to a release of crude oil.

The proposed pipeline would have cathodic protection systems[48] to prevent corrosion of pipes. Enbridge patrols all permanent pipeline rights-of-way by air at least 26 times per year (at maximum 3-week intervals). These inspections review conditions on or adjacent to the permanent right-of-way. Line walking inspections are also used, as warranted, to supplement aerial inspections in some areas. Enbridge regularly checks operation of isolating valves (at least twice per year) and equipment used to limit, regulate, control, or relieve pipeline pressure.

In 2010 and 2014, Enbridge added the following measures and procedures into its routine operation and maintenance activities (DOS 2017):

- Augmented Control Center staff, including additional engineering and operator positions;
- Provided additional training and technical support;
- Re-organized the functional areas responsible for pipeline and facility integrity;
- Increased the number of in-line inspection programs and integrity digs (excavation, examination, maintenance, and repair);
- Revised and improved many procedures within the IMP;
- Implemented additional leak detection analysis procedures, including improvements to the leak detection escalation process, shift change transitions, alternate leak detection procedures, and analysis and communication procedures;
- Formalized a quality management system to execute more effectively the critical work activities that meet pre-defined quality objectives;
- Established a Pipeline Control Systems and Leak Detection Department, doubling the number of employees and contractors dedicated to leak detection and pipeline control;
- Implemented a Leak Detection Instrumentation Improvement Program to add and upgrade instrumentation across its system based on the assessments;
- Enhanced the Leak Detection Analyst Training Program; and
- Made changes to its pipeline remote monitoring and control systems.

A component of Enbridge’s IMP is the Geohazard Management Program, which monitors for extreme weather events and for potential pipeline exposures at flowing water crossings. When an inspection is triggered by an event (such as flooding), the regional engineering group is notified and they deploy a local pipeline maintenance crew to make a visual site inspection. If the inspection finds damage within the permanent right-of-way, it is examined and repair work is completed as needed on a site-by-site basis.

Public Awareness Program

Since third-party damage is a leading cause of pipeline releases, Enbridge has a comprehensive Public Awareness Program in place. Enbridge maintains this Public Awareness Program to improve public

[48] Cathodic protection systems inhibit corrosion by applying a low-voltage electrical current to pipelines (see Section 2.3.2.3).

awareness of the presence of its underground pipelines and related facilities. As a part of the program, Enbridge installs aboveground markers to identify the presence of pipelines and identifies ways to prevent damage to the pipelines from excavating equipment. The program includes communication with local, state, and national officials and agencies; emergency responders; local fire and law enforcement departments; state pipeline safety and emergency management agencies; landowners along their pipeline rights-of-way; excavators; and others. Enbridge also facilitates face-to-face communication, advertising, e-campaigns, sponsorships, events, mailings, publications in local newspapers, and grants.

10.5.1.1.2 Rail Plans and Measures

Four companies operate on major railroads in Minnesota and could transport crude oil—Burlington Northern Santa Fe, Canadian National, Canadian Pacific, and Union Pacific (Minnesota Department of Transportation 2017a). Each of these railroad companies are required to follow the national safety regulations described in Section 10.1.1.2, which are designed to prevent accidents from occurring. Railroad companies have voluntarily agreed to slow down trains carrying crude oil in 45 “high-threat urban areas,” including the Twin Cities. Rail inspections to examine the tracks for flaws that could result in track failure are a key component to preventing rail accidents. The FRA specifies how many inspections should be done. Because of the risks, however, railroads have increased their own inspections well above required levels (Minnesota Department of Transportation 2017b).

10.5.1.1.3 Truck Plans and Measures

Accident prevention for transporting crude oil by truck would depend on the company hauling the crude oil. Plans would typically involve specialized employee training and safety awareness programs. Trucking companies are required to follow the national and state safety standards discussed in Section 10.1.1.3, which are designed to prevent accidents from occurring on the roads and highways. For instance the Federal Motor Carrier Safety Administration initiated the Federal Hazardous Materials Safety Permit Program for intrastate, interstate, and foreign trucks transporting certain types and amounts of hazardous materials, including crude oil. These carriers must maintain a certain level of safety in their operations and certify they have programs in place as required by regulations (Federal Motor Carrier Safety Administration 2017).

10.5.2 Emergency Response Planning and Preparedness

Spill response timing and effectiveness have a large effect on the extent, severity, and persistence of impacts from an accidental release of crude oil. A well-executed spill response that quickly stops the flow of oil and recovers the oil quickly can substantially reduce potential environmental impacts. This section addresses national oil spill response planning (Section 10.5.2.1) and regional oil spill response planning (Section 10.5.2.2) that would apply to all CN Alternatives and route alternatives. Applicant spill response planning that would apply to the Applicant’s preferred route and could also apply to system alternative SA-04 and any of the route alternatives are summarized in Section 10.5.2.3.

10.5.2.1 National Spill Response Planning

Provisions of the Clean Water Act of 1972 and the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) mandated development of a National Oil and Hazardous Substances Pollution Contingency Plan (NCP) to establish standard protocol for responding to oil spills and other hazardous substance releases in the United States. The NCP, developed by the U.S. EPA, ensures that the federal government’s resources and expertise are available immediately for emergencies that are beyond the capabilities of local and state responders. The NCP established the federal National Response System (NRS), provides the framework for the NRS and establishes how it works. The NRS routinely and effectively responds to a wide range of oil and hazardous substance releases. It is a multi-layered system of individuals and teams from local, state, and federal agencies, industry, and other organizations. These groups share expertise and resources to ensure that cleanup activities are timely, efficient, and minimize threats to human health and the environment. The NRS is made up of a network of cooperating response teams consisting of personnel from federal, state, and local agencies as well as organizations with specialized skills and knowledge that can be called on to respond to spill emergencies. To facilitate a rapid and effective response, NRS teams ensure that technical, financial, and operational information on responding to oil spills is available; the roles of different agencies on the NRS teams are clearly outlined; regional plans to respond to spills are maintained; oversight and consistency reviews for response plans are undertaken; and appropriate technical advice, equipment, or manpower are available to assist with a response.

10.5.2.2 Regional Spill Response Planning

The NCP also established Regional Response Teams (RRTs) with defined roles and responsibilities within the NRS. Each RRT consists of a core team (made up of federal and state government representatives) that can be supplemented with appropriate incident-specific teams during a response. Minnesota is included in Region 5 of the NCP (Region 5 RRT), which also includes Illinois, Indiana, Michigan, Ohio, and Wisconsin (Region 5 RRT 2017). Since Region 5 includes areas along the U.S.-Canada border, Canadian agencies often work with members of the RRT during response plan development and may provide or request assistance in the event of a spill along the border.

The RRT acts as a regional planning and coordination body for preparedness and response actions. Preparedness activities are carried out in conjunction with appropriate state emergency response committees, area committees, local emergency planning committees, and tribal councils.

The governor of each state in Region 5 designates a lead agency that can direct state-led response operations (Region 5 RRT 2017). The primary agency representative to the Region 5 RRT for Minnesota is the Minnesota PCA. The state of Minnesota has an Emergency Operations Plan as does each state agency. In case of a spill, Minnesota PCA's emergency response plan would be implemented in coordination with the regional and area plans. Minnesota PCA has environmental emergency management staff in five offices throughout the state: Duluth Office, Brainerd Office, Marshall Office, St. Paul Office, and Rochester Office. These staff lead and coordinate Minnesota PCA's oversight and response to environmental emergencies which include oil spills.

10.5.2.3 Pipeline Spill Response Planning

Control of the Applicant's preferred route (or any of the pipeline alternative routes) would be incorporated into the existing Enbridge Supervisory Control and Data Acquisition system, which can automatically initiate pump station shutdowns to maintain safe operating pressures. Pipeline control operators also can manually initiate pipeline shutdown if abnormal conditions are suspected or observed. Enbridge enforces a "10-minute rule" that requires operators to shut down a pipeline within 10 minutes of observation of an abnormal condition that cannot be attributed to normal fluctuations in pressures and operating conditions.

In addition to the operations and maintenance measures described in Chapter 2 of this EIS, contingency oil spill response plans for the Project would require approval by appropriate federal agencies prior to construction and operation if a pipeline were approved. For example, PHMSA regulations require the submission of emergency response plans to PHMSA for review and approval (49 CFR 194). Minnesota Statute 115E requires submission of emergency response plans to Minnesota PCA for review and approval.

Following the July 2010 rupture of Enbridge's Line 6B pipeline and subsequent major oil release into wetlands and the Kalamazoo River in Marshall, Michigan, Enbridge developed an Integrated Contingency Plan (ICP) that serves as the emergency response plan for Enbridge's pipelines for the Superior Region (from the Canadian border near Neche, North Dakota, across Minnesota, and into Wisconsin and Michigan). Input on the ICP was provided by the EPA, U.S. Coast Guard (USCG), Occupational Safety and Health Administration, and other agencies. Enbridge's ICP was approved by PHMSA on July 11, 2013, for other Enbridge pipelines, and Enbridge would require approval of the ICP from PHMSA in order for the plan to cover a Line 3 pipeline. The Applicant's preferred route and route alternatives are within the Superior Region. System alternative SA-04 is partially within the North Dakota and Mid-Continent regions.[49]

Each of the four U.S. regional annexes to the ICP contains an Emergency Response Action Plan (ERAP),[50] which is an Enbridge region-specific, concentrated version of the ICP focused on the unique features of the region. Each region-specific ERAP is designed to be used by first responders and Enbridge personnel in the field. The ERAPs provide first responders and others with important information needed to work with Enbridge spill response equipment and personnel in the event of an emergency. They contain notification lists and protocols, detailed lists of response equipment maintained by Enbridge along the pipeline routes, organization charts, decision-making flowcharts, evacuation information, mitigation and recovery efforts information, specific response and recovery techniques, Safety Data Sheets for the products transported by Enbridge, and other important forms.

Enbridge's ICP and ERAPs are prepared to fulfill the requirements of local, state, and federal regulatory agencies mandating written procedures to address planning and response to emergencies, including PHMSA's pipeline safety regulations specified in 49 CFR Parts 194 and 195, Minnesota Statute 115E, and applicable Occupational Safety and Health Administration, USCG, and API national technical standards.

At EPA's direction, Enbridge has also developed a Submerged Oil Recovery Plan to describe tactical methods that could be employed to recover spills submerged in water.[51] The plan includes methods to identify areas containing submerged oil after a spill including geomorphologic assessment, pooling surveys, and sediment sampling and core logging. The plan also provides methods that would be used to recover submerged oil including raking, tilling, air injection, chain dragging, and other procedures.

Enbridge owns and maintains spill response equipment stored in several locations across the United States. Enbridge has established pipeline maintenance shops along the Enbridge Mainline system, including at Bemidji and Thief River Falls, Minnesota, and in Superior, Wisconsin. Equipment stored in these shops includes apparatus to contain and absorb oil released to water including various booms (e.g., river booms, sorbent booms, and containment booms), pumps and portable dam systems,

49 The Enbridge Central Region ICP is available at http://www.cnpl.enbridge.com/Projects-and-Infrastructure/Public-Awareness/Emergency-Response-Action-Plans.aspx.

50 ERAPs are sometimes referred to as Field Emergency Response Plans in other planning documents.

51 The Enbridge Submerged Oil Recovery Plan is available at http://dnr.wi.gov/files/PDF/pubs/ea/EA0230.pdf.

skimmers, sorbent pads and rolls; boats and response vessels to handle water-based activities; and specialized equipment for land-based activities including portable tanks, generators, and trailers.

Enbridge also has portable emergency response trailers, which contain hard boom, sorbent boom, skimmers, and portable water tanks as well as various tools for initial emergency response to both land and water releases. Response equipment and supplies also include personal protective equipment for responders including respiratory equipment, hard hats, gloves, safety glasses, safety boots, and chemically protective clothing. The ICP contains guidance on personal protective equipment requirements, use, maintenance, storage, and disposal. Periodic inspection and maintenance is performed on each piece of equipment in accordance with recommendations from the manufacturer. After an equipment deployment exercise or actual response, each piece of deployed equipment is inspected to assess its condition and determine if any repairs or replacements need to be made. Equipment is also periodically inspected and if found to be defective, is repaired or replaced.

Enbridge employees in the United States and Canada participate in regular emergency response drills and simulations to practice and improve preparedness procedures. Employees are trained through workshops, tabletop and full-scale exercises, and procedural drills, often in partnership with local response agencies, regulators, and external observers.

The National Transportation Safety Board (NTSB) identified deficiencies in training of first responders and emergency response resources as one of the inadequacies of the response following the 2010 Line 6B rupture in Marshall, Michigan (NTSB 2012). To improve safety training, the Enbridge Enterprise Emergency Response Team was created in 2011 as a cross-company team with specialized training. The team regularly conducts major training exercises involving emergency response contractors and consultants, as well as emergency response agencies at the local, state/provincial, and federal levels. The Enbridge Enterprise Emergency Response Team is trained to respond to large-scale events in Enbridge operational locations in North America. Enbridge states that its training programs meet the National Preparedness for Response Exercise Program standards, which were developed by PHMSA, the USCG, the EPA, and the U.S. Department of the Interior to establish a minimum preparedness exercise program for federally regulated companies. Enbridge also operates Pipeline Public Awareness and Emergency Response Programs, as described in Section 2.8.1, to address the problems noted by NTSB.

10.5.3 Initial Oil Spill Containment and Response Methods

The following sections describe the response framework designed to contain a release of crude oil and minimize the potential effects on the natural and human environment due to a release:

- Notification, Mobilization, and Response (Section 10.5.3.1); and
- Potential Spill Response Challenges (Section 10.5.3.2).

10.5.3.1 Notification, Mobilization, and Response

In the event of a pipeline crude oil release, leak detection systems would be in place to alert the Control Center (see Section 2.8.1 for details on leak detection systems). The amount of time required to identify a leak depends on the nature of the release. Large ruptures result in multiple leak triggers and alarms that notify the controller almost instantaneously. Small leaks are typically detected by the computational pipeline monitoring systems and the line balance calculation process, both of which are tuned to detect large and small leaks. The smaller the leak, the more time it takes for an alarm to be triggered by these systems.

Although leak detection systems would be in place, some leaks might not be detected by the system for an extended period of time. A pinhole leak, for example, could remain undetected for a period of time if the release volume rate is below detectable levels. Detection of such leaks would likely occur through visual or olfactory identification, either by regular pipeline aerial inspections, ground patrols, or landowner or citizen observation. Pinhole leaks can also be detected by an acoustical pipeline inspection gauge (see Section 2.8.2.1).

In the event of a release of crude oil from an Enbridge pipeline during operations, the Control Center would shut down the pumps and close the MLVs in the area of the release. Following pump shutdown and valve closure, on-call operations personnel and managers would be notified internally by the Control Center. Notifications would occur for both internal and external parties, including the National Response Center, the state, and local police. Enbridge first responders would work to confirm the nature and location of the incident as notifications occur. The ERAP provides specific response steps and tactics to be used within each region, considering the unique topography and features along a pipeline route within the region. First responders would generally arrive on the scene within minutes of being alerted of an incident and work to secure the scene, undertake evacuations when necessary, and implement the ERAP procedures (Enbridge 2015a).

Enbridge's ERAP includes predetermined steps to take in the event of an incident. Maps and tables based on information in established regional response plans are included to identify HCAs along pipeline routes for each region. The maps and tables allow responders to know where to direct response resources, so that emergency responders can begin work immediately upon deployment. For example, ERAPs contain information on the location of resources of concern, such as wetland vegetation, sensitive shoreline areas, and other features. Emergency responders use the maps and tables to place booms and take other necessary response measures to protect resources and limit the scope of an oil spill incident.

In the event of an oil spill, Enbridge emergency response staff would inform the appropriate public agencies, which would determine if evacuation is necessary to safeguard human health. Evacuation parameters include consideration of the potential for fire, explosion, and presence of hazardous gases. Containment and absorbent materials would be applied to spills with the potential to reach surface waters or wetlands. If a spill did reach a waterbody, sorbent booms and pads would be applied to initiate containment and recovery of released materials in standing water. For large spills in waterbodies, Enbridge would secure emergency response contractors to further contain and clean up the spill. Spills to waters require immediate notification of the NRC (for any oil sheen, sludge or emulsification in waters as required under 40 CFR 110) and Minnesota PCA (for spills greater than five gallons as required under Minnesota Statute 115.061).

Except on federal lands, response actions are generally monitored and/or implemented by the most immediate level of government with authority and capability to conduct such activities (Region 5 RRT 2017). The first level of response to a spill during Project operations would generally be onsite Enbridge personnel and contractors followed by local government agencies, or state agencies if local capabilities are exceeded (Region 5 RRT 2017). The Minnesota PCA has regulatory authority to oversee pipeline spill cleanups and would work closely with Enbridge to ensure appropriate response actions are taken. When incident response is beyond the capability of the state, the EPA is authorized to take response measures deemed necessary to protect the public health or welfare or the environment from discharges of oil or releases of hazardous substances, pollutants, or contaminants. The EPA also has authority to respond to spills on reservations.

If an oil spill required additional response measures, the national and regional plans described in Section 10.5.2 could be implemented to contain and control the release. In a large response effort, a Unified Command and an Incident Management Team made up of NRS personnel would be created to address site/spill-specific concerns. In the event of a pipeline spill on land or in inland waters, the EPA would be the lead federal agency in charge of the response. In the event of a pipeline spill in coastal or international border waters, the USCG is the lead federal agency in charge of the response.

The actions that could be taken with the resources outlined in the Region 5 RRT Regional Contingency Plan/Area Contingency Plan include, but are not limited to, the following:

- Placing containment and recovery booms and pads,
- Sampling runoff and surface waters,
- Excavating soil,
- Performing hydrogeological investigations,
- Conducting wildlife rescue and rehabilitation,
- Closing drinking water intakes, and
- Providing an alternate water supply (Region 5 RRT 2017).

The Regional Contingency Plan/Area Contingency Plan identifies environmentally and economically sensitive areas in an atlas series and a set of GIS products intended to provide oil spill contingency planners and spill responders in Region 5 with the most accurate and relevant information possible for spill preparedness and response (Region 5 RRT 2017). Information mapped in GIS includes:

- Species data including federal and state-listed threatened and endangered species;
- Federal, state, regional, and privately owned and managed natural resource areas;
- Reservations;
- Federal, state, regional, and private designations of natural resource areas (no ownership);
- Drinking water intakes;
- Industrial water intakes;
- Locks and dams;
- Marinas and boat accesses;
- Oil storage (above 1,000 bbl [42,000 gallons]) and oil pipelines; and
- Federal, state, and tribal trustees (Region 5 RRT 2017).

The Region 5 RRT has developed an Inland Response Tactics Manual to direct responders on appropriate response methods depending on the spill location, prevailing environmental factors, and response technique considerations and limitations (Region 5 RRT 2013). For example, the manual describes and diagrams containment methods on ice with trenches and sumps, various land barriers that can be constructed with available materials (e.g., earth, gravel, snow), and the purposes of different booming configurations in streams, rivers, and open water (Region 5 RRT 2013).

10.5.3.2 Potential Spill Response Challenges

The immediate response to a crude oil release from the Project would be by local first response agencies to secure the area, along with public and environmental health officials, local response contractors, and other parties qualified to assist with the response effort. Response times for first responders would depend on the location of the incident; crude oil releases in or near populated areas would likely result in faster response times than incidents occurring in more remote areas since there are typically more response facilities and personnel in more developed areas. Weather conditions, topography, visibility and proximity of access roads to the spill area may also retard response times.

In Minnesota, the Applicant's preferred route and route alternatives generally pass through rural, sparsely populated areas. Rural communities can face challenges regarding emergency preparedness and response, such as proximity to adequate response personnel and equipment, and may lack needed space, supplies, and staff to respond quickly and effectively to emergencies (see Section 10.5.3.2.1 below). If an oil spill incident becomes too large or complex for the responsible party's local and onsite capabilities, the regional or national response capabilities described above would be mobilized to support the response effort.

Oil released into aquatic environments can be difficult to contain and recover in large quantities, since water surface and weather conditions must be sufficiently calm to permit the selected equipment to function well and for response personnel to safely operate equipment. In addition, spilled oil must be recoverable with available skimmers and other equipment that would be used in waterbodies. Oil spills that enter large, flowing waterbodies can spread rapidly and be difficult to completely contain and recover. Riverine currents can make spills particularly difficult to contain because oil can be rapidly carried to shorelines, wetlands, and flats. Containment in these environments can be increased with the use of underflow dams, overflow dams, containment boom, sorbent barriers, or a combination of these techniques (Crosby et al. 2013).

Some crude oil spills into waterbodies can sink, making it more difficult to detect, track, and map. In addition, submerged oil is often highly viscous, making it difficult to pump. Every submerged oil spill is a unique combination of conditions based on oil type, environmental setting, and physical processes (U.S. Department of Homeland Security 2013). Dilbit that reaches or is directly released to waterbodies may pose unique challenges because of its propensity to form dense residues during weathering and sink to the bottom, or combine with particles present in the water column (forming tarballs) to submerge and then remain in suspension or sink (National Academies of Sciences, Engineering, and Medicine 2016).

Winter oil spills may be harder to detect and more difficult to contain and recover due to the presence of snow and ice cover. An oil spill that results in oil reaching waterbodies during freeze-up[52] or breakup[53] may also be difficult to manage because ice may not be strong enough to support people or equipment. In rivers, spilled oil may be transported several miles under ice or in broken ice before it can be contained. If ice cover is not strong enough to support people and equipment, oil spilled underneath may be more difficult to detect and it may be more difficult to implement rapid containment and cleanup at and near the spill site. Major flooding or adverse weather conditions (e.g., high winds,

52 The freezing over of a waterbody.

53 The breaking, melting, and loosening of ice in the spring.

blizzards, and extreme cold) may also hinder spill response contractors from implementing timely and effective oil spill containment and clean-up operations. Enbridge and its response contractors have access to specialized response equipment in case of a spill during harsh winter conditions. Such response equipment includes:

- Remotely operated vehicles that can move below the surface of ice to detect oil with sensors and can transport equipment below the surface to remove oil;
- Ice drills or augers that cut holes in the ice to allow hoses and pumps to suction oil from beneath ice;
- Arctic-specific water skimming equipment that can be used in both open water and icy conditions;
- Specialized ice and fire booms that can be deployed to contain oil; and
- Vessels with water cannons that move spilled oil to containment and collection areas (Enbridge n.d.).

Training in winter conditions is undertaken by response personnel to improve readiness for such situations (Enbridge n.d.).

Five organizations are recognized in the NCP with specialized expertise that can be used to respond to difficult situations. These organizations are:

- USCG National Strike Force,
- USCG Public Information Assist Team,
- EPA Environmental Response Team,
- NOAA's Scientific Support Coordinators, and
- Natural Resource Trustees.

The lead agencies designated within the NRS are responsible for coordinating spill response efforts.

10.5.3.2.1 Remote Area Analysis

The magnitude of potential impacts on a resource may be directly related to response time and response time may be related to the accessibility of the spill. Rapid detection and response can reduce crude oil exposures and impacts on resources. Remote areas may be less accessible to spill response teams and therefore potentially more vulnerable to effects from crude oil spills. When a final route is selected, spill response strategies will be developed for areas with difficult access.

10.6 CLEANUP, RESTORATION, AND RECOVERY

After the initial spill response (focused on containment and recovery as discussed in Section 10.5.3), further cleanup would be undertaken, followed by more long-term restoration and recovery efforts. The following sections address those activities:

- Clean-Up Techniques and Equipment (Section 10.6.1),

- Restoration and Recovery Framework and Methods (Section 10.6.2), and
- Liability and Compensation (Section 10.6.3).

10.6.1 Clean-Up Techniques and Equipment

Typically implemented techniques for containment, recovery and cleanup of spilled crude oil are described in Table 10.6-1.

Table 10.6-1. Oil Spill Containment, Recovery and Clean-Up Techniques and Equipment

Technique	Actions and Equipment	Additional Supporting Equipment	Locations Typically Used
Containment of oil	Booms contain, deflect, or divert oil	Trucks or vessels to install, reposition, and maintain the booms	Open water
	Barriers and booms prevent the entry of oil into an area of concern	Vehicles or small vessels to transport equipment/personnel	Land, shoreline, and open water
	Sorbent booms, pillows and socks	Trucks or vessels to install, reposition, and maintain the sorbent materials	Land, shoreline, and open water
Recovery of oil	Sorbent pads or rolls are placed in water to contain and remove floating oil	Trucks or vessels to install, reposition, and maintain the sorbent materials	Land, shoreline, and open water
	Mechanized skimmers, pumps, and vacuums collect oil from puddles and the water surface into containers or storage tanks	Vessels to position the skimmers Pumps and hoses Truck-mounted vacuums Truck tankers to offload vacuum trucks Trucks to place or remove containers and tanks Oil/water separator to remove water and treat or return the water to the environment, if necessary	Land, shoreline, open water, and near shore
	Hand tools and earth moving equipment are used to manually collect solid waste with oil residue and contaminated soil into containers for transport	All-terrain vehicles, vessels, and trucks to transport personnel and equipment	Land, shorelines, and areas with lots of organic debris
Cleanup	Hand tools and earth moving equipment are used to manually collect solid waste with oil residue and contaminated soil into containers for transport	All-terrain vehicles, vessels, and trucks to transport personnel and equipment	Land, shorelines, and areas with lots of organic debris

Table 10.6-1. Oil Spill Containment, Recovery and Clean-Up Techniques and Equipment

Technique	Actions and Equipment	Additional Supporting Equipment	Locations Typically Used
	Oil is passively collected through sorbent materials	All-terrain vehicles to transport personnel and equipment Vessel to transport sorbent Bags, containers and trucks for used sorbent	Land/shoreline/open water/nearshore, and storm sewers, trenches, and low areas
Chemical dispersion	Cleaning agents are sprayed onto the oil slick.	Boats or Airplane to spray dispersants	Open water
In situ burning	Oil is contained in wetlands/bogs or corralled into a fire-resistant boom on water and burned	Backhoes and dozers to create a fire barrier on land Vessel to transport boom Diesel fuel to start the burn Fire department resources on standby	Open water and nearshore wetlands and bogs
Natural attenuation	Oil is allowed to degrade naturally or with tilling and possible fertilizer application to enhance bio-degradation	Tractor, cultivator, applicator	Areas where removal of oiled soil could damage resources of concern and land areas with suitable conditions for degradation

The use of these and other clean-up techniques would be determined on a case-by-case basis, with approval from regulatory agencies and according to regional or site-specific plans. For example, EPA Region 5 does not recommend the use of dispersants or other oil emulsifiers in fresh water because of limited effectiveness, so this clean-up method would not be used within Minnesota freshwater systems (Region 5 RRT 2017). The Minnesota PCA also does not recommend the use of dispersants. In addition, the use of burning on surface waters in Region 5, particularly near wetlands or water supplies, must be approved by state and/or federal agencies (Region 5 RRT 2017).

Recovery and cleanup for sunken/submerged crude oil may require additional techniques and equipment such as diver-directed pump and vacuum systems, remotely operated vehicles in the water column, sub-bottom profiling, manned submersibles, manual removal by divers, the use of nets and trawls, and dredging. Each of these recovery and clean-up methods for sunken/submerged oil has advantages and disadvantages, and the use of these clean-up strategies would be determined on a case-by-case basis.

10.6.2 Restoration and Recovery Framework and Methods

Effective oil spill remediation, habitat restoration, and environmental recovery can influence the magnitude and duration of impacts on receptors and resources. Recovery and restoration plans are prepared by the Responsible Party[54] and submitted to the federal or state agency in charge of spill response for a particular event. After review and approval of these plans, the Responsible Party and its contractors implement these plans, with ongoing oversight by agencies.

54 The term "Responsible Party" has a specific meaning for different sources of oil spills. For oil pipelines, the Responsible Party is the owner or operator of the pipeline (OPA 90, Section 1001[32][E]).

If it appears that there are impacts on natural resources due to a spill, a NRDA may be initiated. NRDA is a legal process under the Oil Pollution Act of 1990 (OPA 90) that is used by federal, state, and tribal governments (referred to as "trustees") to seek compensation for natural resource damages and restore vegetation; fish, wildlife, and their habitat; recreation resources; and other affected resources to pre-spill baseline conditions. Natural resource trustees conduct NRDAs on behalf of the public. Trustees assess and collect data on spill impacts on natural resources and use these data to identify and select projects to restore affected resources. For example, NRDA trustees for the July 2010 oil spill in Marshall, Michigan, were the U.S. Fish and Wildlife Service (USFWS), NOAA, affected tribes, and Michigan state agencies. Restoration planning by these trustees consisted of two steps: (1) assessment of impacts on instream habitats including riverine and lake habitats; floodplain habitats, including wetlands; upland habitats; specific species; public recreational uses; and tribal uses; and (2) restoration project selection. The NRDA trustees for the Marshall, Michigan, spill coordinated with the larger spill response efforts via the Incident Command System and began assessment of impacts within days of the spill occurring (USFWS 2015; USFWS et al. 2015).

Studies and programs conducted in support of natural resource recovery may include:

- Submerged oil assessment and recovery;
- Overbank assessment and recovery;
- Shoreline Cleanup Assessment Technique and Shoreline and Habitat Reassessment Technique;
- Water and sediment sampling;
- Contaminant monitoring and recovery;
- Emerging oil management program;
- Geomorphic assessments;
- Rapid vegetation assessments;
- Wildlife and avian surveys and rehabilitation; and
- Fish and benthic invertebrate surveys.

The primary responsibility for conducting these surveys lies with the Responsible Party, but the surveys may be conducted by the lead federal or state agency, assisting agencies, and/or NRDA trustees, either independently or jointly with the Responsible Party. In addition, volunteers may be allowed to participate in certain aspects of these programs, such as providing support for wildlife programs.

Restoration efforts in natural environments may include the following:

- Wetlands: sediment dredging, compensatory wetland restoration and creation actions, and monitoring for wetland functions and values.
- Fresh water: improvement of fish passage, stream and floodplain connectivity, and water quality, and reduction of erosion and sedimentation. Specific actions may include replacement of inadequate or undersized culverts, monitoring fish health, removal of invasive species, restoration of wild rice beds, dam removal, and channel restoration.

- Agricultural land: restoring upland habitats, controlling invasive species, pasture enhancement, and planting cover crops.
- Forest/woodland: planting, wildlife rehabilitation and tracking/monitoring, and enhancement of wildlife habitat.

Selection of specific projects and methods for restoration of affected resources varies based on the types and extents of habitats affected and the time needed for resource recovery (which is highly variable but can require decades). The costs of recovery and restoration efforts are addressed in the following section.

10.6.3 Liability and Compensation

OPA 90 establishes a framework that addresses the liability of Responsible Parties in connection with discharge of oil into navigable waters of the United States, adjoining shorelines, or the exclusive economic zone. OPA 90 replaced the liability limitations previously established in the Clean Water Act with much higher liability limits and expanded the class of persons authorized to recover removal costs from the Responsible Party to include any person rather than only the federal government. Liability limits are set by OPA 90 and differ depending on the type of facility. The Responsible Party of an incident is the person, business, or entity that has been identified as owning the pipeline that caused the spill. The Responsible Party is liable for the removal costs and damages up to their limit of liability unless the spill was caused by an act of God, an act of war, negligence on the part of the U.S. government, and/or an act or omission of a third party.

Under the provisions of CERCLA, OPA 90, and several state statutes, cost recovery can be obtained from industry for natural resource damage caused by the release of oil or hazardous substances to the environment. Natural resources are defined as land, air, biota, groundwater, and surface water. A federal or state government entity, an Indian tribe, or other entity acting as a public trustee of a natural resource may file claims for damages to natural resources. Costs for damages that are recoverable under OPA 90 include the following:

- Natural Resources: Damages for injury to, destruction of, loss of, or loss of use of natural resources, including the reasonable costs of assessing the damage, which are recoverable by a U.S. trustee, a state trustee, an Indian tribe trustee, or a foreign trustee.
- Real or Personal Property: Damages for injury to, or economic losses resulting from destruction of, real or personal property, which are recoverable by a claimant who owns or leases that property.
- Subsistence Use: Damages for loss of subsistence use of natural resources, which are recoverable by any claimant who uses natural resources for subsistence that have been injured, destroyed, or lost, without regard to the ownership or management of the resources.
- Revenues: Damages equal to the net loss of taxes, royalties, rents, fees, or net profit shares due to the injury, destruction, or loss of real property, personal property, or natural resources, which are recoverable by the federal government, a state, or a political subdivision thereof.

- Profits and Earning Capacity: Damages equal to the loss of profits or impairment of earning capacity due to the injury, destruction, or loss of real property, personal property, or natural resources, which are recoverable by any claimant.
- Public Services: Damages for net costs of providing increased or additional public services during or after removal activities, including protection from fire, safety, or health hazards, due to a discharge of oil, which are recoverable by a state, or political subdivision of a state.

Table 10.6-2 provides descriptions of federal and state laws and regulations that establish liability for crude oil spills that may be applicable to the Project.

OPA 90 also authorized use of the Oil Spill Liability Trust Fund (OSLTF), which currently contains $1 billion. To ensure rapid, effective response to oil spills, the U.S. president has the authority to make available—without Congressional appropriation—up to $50 million each year from the OSLTF to fund removal activities and initiate NRDAs (USCG 2016). Fund uses delineated by OPA 90 include:

- Removal costs incurred by the USCG and EPA;
- State access to the OSLTF for removal activities;[55]
- Payments to federal, state, and Indian tribe trustees to conduct NRDAs and restorations;
- Payment of claims for uncompensated removal costs and damages;
- Research and development; and
- Other specific appropriations (USCG 2016).

Enbridge maintains comprehensive insurance for its subsidiaries and affiliates. Coverage includes commercial general liability insurance that applies to Enbridge's legal liability for third-party property damage and injuries arising from operational activities, including an oil spill. Since the July 2010 rupture of Enbridge's Line 6B pipeline and subsequent oil release into wetlands and the Kalamazoo River in Marshall, Michigan, Enbridge has paid over $1.2 billion in response, clean-up, and restoration costs as well as fines from state and federal agencies (U.S. Securities and Exchange Commission 2014). Enbridge currently maintains a general liability insurance program with a total limit of $860 million for the policy period. The retention (deductible) for sudden and accidental pollution events is $30 million per event, and the program is renewed annually (Enbridge 2015b).

55 To encourage greater state participation in response to actual or threatened discharges of oil.

Table 10.6-2. Potentially Applicable Federal and State Laws and Regulations That Establish Liability for Crude Oil Spills

Statute/Regulation	Description
Oil Pollution Act of 1990 (OPA 90), 33 U.S. Code 2701 et seq.	OPA 90 established a program of prevention, response, liability, and compensation to address vessel and facility-caused oil pollution to navigable waters of the United States. Section 1002(a) provides that the Responsible Party for a pipeline from which oil is discharged, or which poses a substantial threat of a discharge, is liable for (1) certain specified damages resulting from the discharged oil; and (2) removal costs incurred in a manner consistent with the National Contingency Plan. Per Section 1018(a), OPA 90, does not preempt state law. States may impose additional liability (including unlimited liability), funding mechanisms, requirements for removal actions, and fines and penalties for Responsible Parties.
Resource Conservation and Recovery Act (RCRA), 42 U.S. Code 6973	The U.S. Environmental Agency (EPA) may issue an order or bring a suit in district court against any person who has contributed or who is contributing to the handling, treatment, storage, transportation, or disposal of solid or hazardous waste that may present an imminent and substantial endangerment to health or the environment. Persons who violate an order are subject to civil penalties of up to $7,500 per day. RCRA Section 7003(a), 42 U.S. Code 6973(a), authorizes the EPA "upon receipt of evidence that the past or present handling, storage, treatment, transportation or disposal of any solid waste or hazardous waste may present an imminent and substantial endangerment to health or the environment" to "bring suit in district court or to issue an administrative order to any person who contributed or is contributing to that handling, storage, treatment, transportation," to restrain or take any other action in response. Oil released from a pipeline would constitute solid or hazardous waste, and the authority allows the EPA to require action if the spill "may present an imminent and substantial endangerment."
Safe Drinking Water Act (SDWA), 42 U.S. Code 300f et seq.	The EPA may issue orders to any person in circumstances where a "contaminant" is present in or is likely to enter a public water system or an underground source of drinking water (defined broadly to include almost all groundwater), which may present an imminent and substantial endangerment to the health of persons and states (to whom primary responsibility is granted under the SDWA) that are not acting. The orders may require that person to take such actions as the EPA deems necessary to protect health (42 U.S. Code 300i [a]). Civil penalties are available for failure to comply with such an order. SDWA Section 1431(a), 42 U.S. Code 300i(a), authorizes the EPA "upon receipt of information that a contaminant which is present in or is likely to enter a public water system or an underground source of drinking water, which may present an imminent and substantial endangerment to the health of persons," to take "such actions as [it] deems necessary," including issuance of orders and civil judicial actions. This authority is quite broad. An underground source of drinking water is virtually any underground water that has the potential to be used for drinking water, and a "contaminant" is any biological, chemical, or physical substance in water.
Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 42 U.S. Code 9601 et. seq.	This act is similar to OPA 90 but addresses releases of hazardous substances and specifically *excludes* oil and petroleum. CERCLA created a tax on the chemical and petroleum industries and provided broad federal authority to respond directly to releases or threatened releases of hazardous substances that may endanger public health or the environment. It provides for liability for response costs and natural resource damages against owners or operators of a pipeline who arranged for disposal of hazardous substances. The act contains similar defenses as OPA 90, as well as contribution rights. It also provides the EPA authority to issue administrative orders requiring response actions. Local CERCLA access provides funds (limited to $25,000) in the form of reimbursements for expenses, to local, county, and tribal governments that respond to a hazardous substance release in their jurisdiction (Region 5 RRT 2017).

Table 10.6-2. Potentially Applicable Federal and State Laws and Regulations That Establish Liability for Crude Oil Spills

Statute/Regulation	Description
Environmental Response and Liability Act (MERLA) Minnesota Statutes § 115B	MERLA is the Minnesota State Superfund law. Among other things, it allows the Minnesota Pollution Control Agency and the Minnesota Department of Agriculture to clean up contaminated sites and seek recovery of their expenses from those persons who are responsible for the contamination. The law creates a Superfund account to provide funding for the cleanup and provides that any money recovered shall be deposited in the account. The law provides a statute of limitations for the state to bring a cost recovery lawsuit.
Oil and Hazardous Substance Discharge Preparedness Minnesota Statutes § 115E	Statute 115E requires persons handling oil and hazardous substances to prevent discharges that endanger the environment or public health. It also requires certain kinds of facilities to prepare spill response plans.

10.7 COMPARISONS OF ALTERNATIVES BASED ON FAILURE PROBABILITY AND POTENTIAL EXPOSURES OF RESOURCES

The following sections summarize and compare the key results of the failure probability analysis among the transport mode alternatives and an evaluation of resources of concern that could be exposed following a crude oil release:

- Comparison of Failure Probability Estimates for the Applicant's Preferred Route and Certificate of Need Alternatives (Section 10.7.1),
- Comparisons of Potential Exposure Assessment Results for the Applicant's Preferred Route and Certificate of Need Alternatives (Section 10.7.3), and
- Comparisons of Potential Exposure Assessment Results for the Applicant's Preferred Route and Route Alternatives (Section 10.7.4).

10.7.1 Comparison of Failure Probability Estimates for the Applicant's Preferred Route and Certificate of Need Alternatives

The potential causes for spills for truck, rail, and pipeline are presented in section 10.1.2 and the baseline crude oil pipeline spill risk analysis is presented in section 10.1.3.

Compared to pipelines, both truck and rail transportation alternatives have a higher likelihood of accidents and spills due to the number of transits required to transport the crude oil and the associated increase in risk due to human error. Tanker trucks use major roadways and present a greater risk of injury and fatalities to personnel and the public; this transport mode has a substantially greater annual probability of a spill incident and an estimated recurrence interval of 1.46 days (0.004 years multiplied by 365 days per year). Even though the risk of an event occurring is higher for trains and trucks, the size of the release, if an incident occurs, is typically much smaller because the volume of a tanker truck or train car is smaller. The average size of crude oil from a truck incident is 16 barrels (687 gallons); from a train incident, 40 barrels (1,688 gallons); and from a pipeline incident, 462 barrels (19,412) gallons

The very large number of trucks required for this alternative would greatly increase the risk of releases and impacts on other roadway users along the major routes between loading and offloading facilities. Similarly, the large number of unit trains required to transport 760,000 bpd of crude oil results in a relatively high estimated annual probability of a spill incident, with such an incident estimated to occur approximately once per year. When total volume of releases is compared to the volume of crude oil transported, rail and truck transport release a significantly higher percentage of the volume transported, 0.309 percent and 0.154 percent respectively. Comparatively, pipeline transport releases an average of 0.006 percent of the volume of crude oil transported.

Table 10.7-1 provides additional context in the form of historical incident data for truck and rail transport of hazardous materials, a category that includes crude oil, normalized to reportable incidents per year. Figure 10.7-1 shows the average annual volume of crude oil transported and percent of transported crude oil spilled for different transportation modes.[56]

Table 10.7-1. Annual Number of Incidents for Rail and Truck Transportation of Hazardous Materials

Mode	Number of Incidents per Year[a]
Rail (2007–2017)	623
Truck (2007–2017)	1,199
Pipeline (2010–2017)	391

Sources: PHMSA 2017a, 2017b.

[a] Hazardous material transport includes the transport of crude oil; hazardous materials transportation incidents required to be reported are defined in 49 CFR 171.15, 171.16 (Form F 5800.1).

[56] Average number of crude oil (49 CFR 171.15, 171.16 [Form F 5800.1]) transport incidents based on Pipeline and Hazardous Materials Safety Administration data. Average number of rail incidents per year based on data spanning the period 2007–2017. Average number of truck incidents per year based on data spanning the period 2007–2017. Average number of pipeline incidents per year based on data spanning the period 2010–2017. Average volume of yearly transport based on Energy Information Administration U.S. Refinery Receipts of Crude Oil by Method of Transportation data spanning the period 2010–2016.

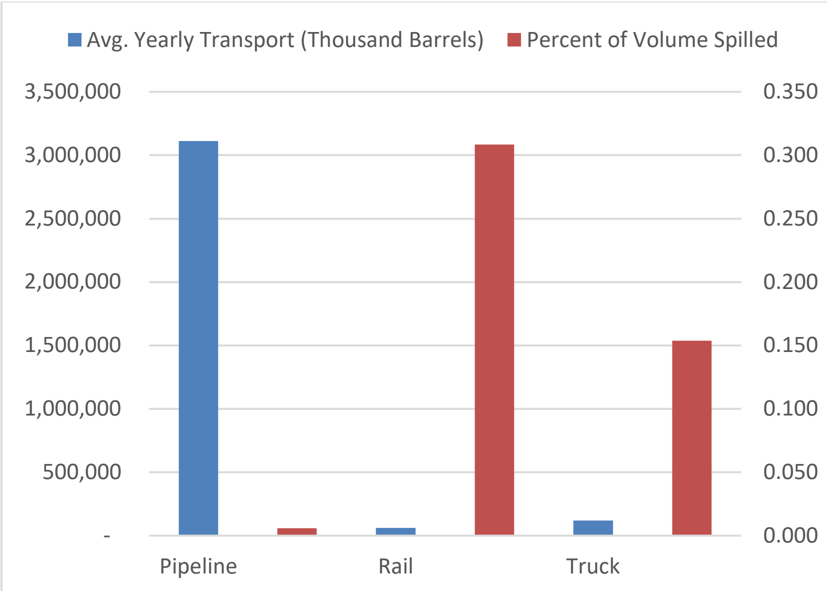

Figure 10.7-1. Annual Average Volume of Oil Transported and Percent Spilled

10.7.2 Comparisons of Potential Exposure Assessment Results for the Applicant's Preferred Route and Certificate of Need Alternatives

The presence of HCAs and AOIs within the ROIs, as described in Section 10.4.1, was compared among the Applicant's preferred route and the CN Alternatives. These are considered the resources of concern. The two ROIs consist of a 5,000-foot-wide (2,500 feet on each side of the centerline of the pipeline or train or truck route) ROI corridor for releases on land and a 10-mile-long, 1,000-foot-wide (500 feet on each side of the centerline of the waterbody crossed) downstream ROI corridor for releases to water; these were established as areas within which oil could be present after a release. Table 10.7-2 summarizes the exposure of resources of concern in the ROIs and is presented along a color gradient (green to red). CN Alternatives are coded in a gradient from green to red based on the extent of the potential exposure of resources in their ROIs in comparison to the other alternatives.

A more detailed listing of each HCA and AOI category is provided in Table 10.7-3, and this table also codes CN Alternatives using the same gradient from red to green. The same approach to comparing the Applicant's preferred route and route alternatives is provided associated with resources of concern and HCA and AOI categories in Tables 10.7-4- and 10.7-5-.

As shown in Tables 10.7-2 and 10.7-3 for the Applicant's preferred route compared to the CN Alternatives, system alternative SA-04 has the lowest total acreage of AOIs, followed by the Applicant's preferred route, existing use of Line 3, transportation by rail, and transportation by truck. Existing Line 3 supplemented by truck and existing line 3 supplemented by rail have the greatest total AOI acreages, being over three times greater than that of the Applicant's preferred route and system alternative SA-04.

With respect to total acreages of AOIs for the Applicant's preferred route compared to the other route alternatives (Tables 10.7-4 and 10.7-5), which range from about 193,000 to 334,000 acres, RA-06 has the lowest total acreage of AOIs, followed by RA-03AM, and the Applicant's preferred route. RA-07 and RA-08 have the highest total acreages of AOIs.

Table 10.7-2. Summary of Potentially Exposed Resources of Concern from an Unanticipated Release of Crude Oil along the Applicant's Proposed Project and Certificate of Need Alternatives (acres)

Resources of Concern	Applicant's Proposed route	Continued Use of Existing Line 3	System Alternative SA-04	Transportation by Rail	Transportation by Truck	Existing Line 3 Supplemented by Rail	Existing Line 3 Supplemented by Truck
HCA populated area	10,959.8	25,697.9	25,128.7	41,579.2	44,431.8	67,277.1	70,129.6
HCA unusually sensitive ecological area	12,318.0	27,527.8	20,378.4	27,578.6	37,272.0	55,106.4	64,799.8
HCA drinking water source	2,443.9	4,521.9	24,468.7	14,787.2	27,941.9	19,309.1	32,463.8
Drinking water AOIs	319.7	1,599.9	15,486.1	3,838.0	9,796.9	5,428.9	11,396.8
Cultural resources AOIs	48.0	44,137.6	11,606.4	55,356.8	40,236.6	99,493.9	84,374.0
Biological AOIs	102,426.2	99,970.0	369.4	96,325.3	87,205.8	195,007.8	187,166.2
Commodity production AOIs	38,188.6	63,408.8	191.6	56,363.8	69,083.4	118,726.3	137,522.1
Recreation/tourism AOIs	3,704.1	1,872.3	1,791.9	11,325.5	2,394.5	13,197.9	4,266.8
TOTAL	**170,408.3**	**268,736.2**	**99,421.2**	**307,154.4**	**318,362.9**	**573,547.4**	**592,119.1**

Notes:

Acreages are the sum of acres within the 2,500-foot-wide and 10-mile-long downstream ROIs for each metric, with the exception of Drinking Water AOIs, which reflects Wellhead Protection Areas within a 1-mile ROI.

Drinking Water Areas of Interest include only Wellhead Protection Areas, as other resources were specific to Minnesota.

See Section 10.4.1 for a discussion of the use and limitations of HCA and AOI data analysis.

AOI = area of interest (see Section 10.4.1 for descriptions of AOIs); HCA = high consequence area (see Section 10.4.1 for descriptions of HCAs)

Table 10.7-3. High Consequence Areas and Areas of Interest within 2,500 Feet of Either Side of the Centerline and 10 Miles Downstream of the Applicant's Proposed Project and Certificate of Need Alternative Routes

Resources of Concern	Within 2,500 Feet of Either Side of the Centerline							Within 10 Miles Downstream						
	Applicant's Preferred Route	Continued Use of Existing Line 3	System Alternative SA-04	Transportation by Rail	Transportation by Truck	Existing Line 3 Supplemented by Rail	Existing Line 3 Supplemented by Truck	Applicant's Preferred Route	Continued Use of Existing Line 3	System Alternative SA-04	Transportation by Rail	Transportation by Truck	Existing Line 3 Supplemented by Rail	Existing Line 3 Supplemented by Truck
High Consequence Areas														
HCA populated area (acres)	6,545.2	22,318.7	13,075.3	34,724.2	35,639.4	57,042.9	57,958.1	4,414.6	3,379.2	12,053.4	6,855.0	8,792.4	10,234.2	12,171.6
HCA unusually sensitive ecological area (acres)	6,903.4	19,045.5	10,530.3	17,960.0	26,016.8	37,005.4	45,062.3	5,414.6	8,482.3	9,848.1	9,618.7	11,255.2	18,101.0	19,737.5
HCA drinking water source (acres)	1,614.6	3,975.2	11,058.9	11,862.6	18,726.6	15,837.8	22,701.8	829.3	546.7	13,409.8	2,924.6	9,215.3	3,471.3	9,762.0
Drinking Water Areas of Interest														
Wellhead protection area (acres)	189.7	1,391.3	3,579.7	3,350.2	3,747.0	4,741.5	5,138.3	130.0	208.6	11,906.4	487.8	6,049.9	687.4	6,258.5
Number of domestic and public wells	638.0	690.0	946.0	648.0	568.0	1,338.0	1,258.0	146.0	39.0	228.0	367.0	184.0	406.0	223.0
Cultural Resources Areas of Interest														
Reservation land (acres)	48.0	33,737.6	6,738.1	31,854.3	30,280.4	65,591.9	64,018.0	0.0	10,400.0	4,868.3	23,502.5	9,956.2	33,902.0	20,356.0

Table 10.7-3. High Consequence Areas and Areas of Interest within 2,500 Feet of Either Side of the Centerline and 10 Miles Downstream of the Applicant's Proposed Project and Certificate of Need Alternative Routes

Resources of Concern	Within 2,500 Feet of Either Side of the Centerline							Within 10 Miles Downstream						
	Applicant's Preferred Route	Continued Use of Existing Line 3	System Alternative SA-04	Transportation by Rail	Transportation by Truck	Existing Line 3 Supplemented by Rail	Existing Line 3 Supplemented by Truck	Applicant's Preferred Route	Continued Use of Existing Line 3	System Alternative SA-04	Transportation by Rail	Transportation by Truck	Existing Line 3 Supplemented by Rail	Existing Line 3 Supplemented by Truck
Biological Areas of Interest														
Aquatic Management Area (acres)	125.0	227.5	0.0	228.6	93.9	456.0	321.4	209.8	320.0	0.0	196.4	183.5	516.4	503.5.52
Scientific and Natural Area (acres)	0.0	7.5	0.0	186.7	0.0	380.8	7.5	342.3	192.7	0.0	63.4	0.0	256.1	192.7
Minnesota BWSR conservation easement (acres)	15.8	167.1	0.0	736.0	33.0	903.1	200.1	262.0	260.7	29.8	158.2	90.9	418.8	351.5
Lakes of Biological Significance (acres)	406.7	2,209.8	0.0	1,951.5	2,617.9	4,161.4	4,827.8	3,608.9	3,400.1	0.0	3,659.1	4,559.4	7,059.2	7,959.5
Marginal cropland (acres)	15.6	16.1	0.0	87.4	5.4	103.5	21.5	44.2	10.0	0.0	0.0	0.0	10.0	0.0
MBS Sites of Biodiversity Significance (acres)	28,046.8	12,992.7	0.0	18,309.7	6,285.4	31,302.3	19,278.1	11,589.4	8,001.2	120.6	11,117.4	5,740.2	19,118.6	13,741.5
Muskie lakes (acres)	41.4	976.6	0.0	1,060.9	1,882.1	2,037.5	2,858.8	676.0	2,107.0	0.0	1,990.8	3,526.5	4,097.8	5,633.5

Table 10.7-3. High Consequence Areas and Areas of Interest within 2,500 Feet of Either Side of the Centerline and 10 Miles Downstream of the Applicant's Proposed Project and Certificate of Need Alternative Routes

Resources of Concern	Applicant's Preferred Route	Continued Use of Existing Line 3	System Alternative SA-04	Transportation by Rail	Transportation by Truck	Existing Line 3 Supplemented by Rail	Existing Line 3 Supplemented by Truck	Applicant's Preferred Route	Continued Use of Existing Line 3	System Alternative SA-04	Transportation by Rail	Transportation by Truck	Existing Line 3 Supplemented by Rail	Existing Line 3 Supplemented by Truck
	Within 2,500 Feet of Either Side of the Centerline							Within 10 Miles Downstream						
Native plant communities (acres)	38,173.8	40,195.4	0.0	33,852.4	35,643.9	74,047.8	75,839.3	14,015.3	22,744.8	219.0	16,735.5	19,166.4	39,480.3	41,911.3
Sensitive lakeshore areas (acres)	300.5	1,329.8	0.0	743.4	1,387.9	2,073.2	2,717.7	441.9	513.4	0.0	305.3	373.6	818.7	887.0
Wetland bank easements (acres)	0.0	70.6	0.0	120.3	33.6	190.9	104.2	38.5	30.3	0.0	49.7	21.9	80.0	52.2
Wild rice lakes (acres)	675.4	1,240.4	0.0	1,474.05	1,661.0	1,240.4	2,901.4	3,396.3	2,956.4	0.0	3,298.6	3,899.3	6,255.0	6,855.7
Commodity Production Areas of Interest														
Federal and state forests (acres)	31,764.3	48,861.8	145.9	27,654.5	45,469.4	76,516.3	94,331.2	0.0	8,496.3	0.0	14,417.2	16,965.6	22,915.5	31,384.8
Other forested land (acres)	3,349.5	2,827.2	45.7	2,735.5	2,954.0	5,562.7	5,781.2	1,910.9	2,207.8	0.0	1,311.3	2,451.7	3,519.1	4,659.5
Harvested Wild Rice Lakes	181.6	241.9	0	384.7	328.5	345.1	430.1	982.3	773.7	0.0	1603.6	914.2	1612.6	935.3

Table 10.7-3. High Consequence Areas and Areas of Interest within 2,500 Feet of Either Side of the Centerline and 10 Miles Downstream of the Applicant's Proposed Project and Certificate of Need Alternative Routes

Resources of Concern	Applicant's Preferred Route	Continued Use of Existing Line 3	System Alternative SA-04	Transportation by Rail	Transportation by Truck	Existing Line 3 Supplemented by Rail	Existing Line 3 Supplemented by Truck	Applicant's Preferred Route	Continued Use of Existing Line 3	System Alternative SA-04	Transportation by Rail	Transportation by Truck	Existing Line 3 Supplemented by Rail	Existing Line 3 Supplemented by Truck
	Within 2,500 Feet of Either Side of the Centerline							Within 10 Miles Downstream						
Recreation/Tourism Areas of Interest														
State park and recreation areas (acres)	947.6	0.0	790.5	5,989.6	335.8	5,989.6	335.8	180.9	1,485.0	790.5	0.0	54.1	1,485.0	1,539.1
Waterfowl production areas (acres)	92.0	185.8	0.0	421.3	484.9	607.1	670.7	11.5	182.2	0.0	0.0	0.0	182.2	182.2
Wildlife Management Areas (acres)	1,299.3	16.4	105.5	3,352.1	820.6	3,368.5	836.9	1,172.7	3.0	105.5	1,562.5	699.1	1,565.5	702.1
TOTALS														
AOI Total (acres)	**121,374.2**	**192,724.6**	**47,015.8**	**198,213.8**	**215,015.7**	**390,843.6**	**407,600.0**	**49,817.3**	**76,740.3**	**53,579.3**	**100,224.4**	**104,099.2**	**176,192.5**	**185,496.2**
Combined AOI Total (acres)	**171,191.5**	**269,464.9**	**100,595.1**	**298,438.2**	**319,114.9**	**567,036.1**	**593,096.2**							

Notes:

The establishment of ROIs and GIS analysis methods are described in Section 10.4.1.

Acreages are the sum of acres within the 2,500-foot-wide and 10-mile-long downstream ROIs for each metric, with the exception of Drinking Water AOIs, which reflects Wellhead Protection Areas within a 1-mile ROI.

See Section 10.4.1 for a discussion of the use and limitations of HCA and AOI data analysis.

Minnesota BWSR = Minnesota Board of Water and Soil Resources; HCA = high sequence area (see Section 10.4.1 for descriptions of HCAs)

Table 10.7-3. High Consequence Areas and Areas of Interest within 2,500 Feet of Either Side of the Centerline and 10 Miles Downstream of the Applicant's Proposed Project and Certificate of Need Alternative Routes

Resources of Concern	Applicant's Preferred Route	Continued Use of Existing Line 3	System Alternative SA-04	Transportation by Rail	Transportation by Truck	Existing Line 3 Supplemented by Rail	Existing Line 3 Supplemented by Truck	Applicant's Preferred Route	Continued Use of Existing Line 3	System Alternative SA-04	Transportation by Rail	Transportation by Truck	Existing Line 3 Supplemented by Rail	Existing Line 3 Supplemented by Truck
	Within 2,500 Feet of Either Side of the Centerline							Within 10 Miles Downstream						

Table 10.7-4. Summary of Potentially Exposed Resources of Concern from an Unanticipated Release of Crude Oil from the Applicant's Preferred Route and Route Alternatives (acres)

Resources of Concern	Applicant's Preferred Route	Route Alternative RA-03AM	Route Alternative RA-06	Route Alternative RA-07	Route Alternative RA-08
HCA populated area (acres)	4,814.1	12,829.2	3,230.0	20,806.6	17,363.7
HCA unusually sensitive ecological area (acres)	10,978.1	7,752.3	12,674.4	26,854.4	27,566.9
HCA drinking water source (acres)	501.1	2,399.1	718.0	2,942.0	2,998.3
Drinking water AOIs	83,833.7	153,971.9	16,196.0	64,785.5	63,726.0
Cultural resources AOIs	0.0	13.5	11,425.6	44,046.8	45,766.0
Biological AOIs	94,053.5	65,287.5	58,822.3	88,764.0	92,613.0
Commodity production AOIs	50,199.6	5,648.2	88,363.0	72,008.1	80,853.5
Recreation/tourism AOIs	3,704.1	4,100.9	1,838.6	1,443.0	1,924.3
TOTAL	**248,084.2**	**252,002.6**	**193,267.9**	**321,650.4**	**332,811.7**

Notes:

Acreages are the sum of acres within the 2,500-foot-wide and 10-mile-long downstream ROIs for each metric, with the exception of Drinking Water AOIs, which reflect: DWSMAs and Wellhead Protection Areas within a 1-mile ROI, and Hydrogeologic Sensitivity within a 0.5-mile ROI.

See Section 10.4.1 for a discussion of the use and limitations of HCA and AOI data analysis.

See Section 10.4.3 for a discussion of corridor sharing considerations.

HCA = high consequence area (see Section 10.4.1 for descriptions of HCAs); AOI = area of interest (see Section 10.4.1 for descriptions of AOIs)

Table 10.7-5. High Consequence Areas and Areas of Interest within 2,500 Feet of Either Side of the Centerline and 10-Mile-Long Downstream ROI of the Applicant's Preferred Route and Route Alternatives Between Clearbrook and Carlton

Resources of Concern	Applicant's Preferred Route	Route Alternative RA-03AM	Route Alternative RA-06	Route Alternative RA-07	Route Alternative RA-08	Applicant's Preferred Route	Route Alternative RA-03AM	Route Alternative RA-06	Route Alternative RA-07	Route Alternative RA-08
	Within 2,500 of Either Side of the Centerline					Within 10-Mile-Long Downstream ROI				
High Consequence Areas										
HCA populated area (acres)	1,759.5	8,264.9	2,271.8	17,427.4	13,261.2	3,054.6	4,564.3	958.2	3,379.2	4,102.5
HCA unusually sensitive ecological area (acres)	6,230.0	2,906.9	8,468.7	18,372.1	18,498.1	4,748.1	4,845.4	4,205.7	8,482.3	9,068.8
HCA drinking water source (acres)	83.4	1,322.5	168.2	2,395.3	2,105.6	417.7	1,076.6	549.8	546.7	892.7
Drinking Water Areas of Interest										
DWSMA (acres)	790.6	5,676.7	1,111.0	3,190.5	2,975.4	197.1	996.0	267.4	336.7	310.4
High/very high DWSMA vulnerability (acres)	790.6	2,637.0	109.0	2,272.5	2,338.0	0.0	464.5	12.0	11.1	11.1
WPAs (acres)	219.5	3,159.1	653.6	2,646.5	2,626.8	30.4	501.9	114.6	208.6	207.2
High/very high hydrogeologic sensitivity (acres)	81,805.5	140,536.7	13,928.4	56,119.6	55,257.1	N/A	N/A	N/A	N/A	N/A
Number of domestic and public wells	173.0	430.0	43.0	242.0	188.0	125.0	179.0	28.0	40.0	46.0
Cultural Resources Areas of Interest										
Reservation land (acres)	0.0	13.5	7,858.1	33,689.6	33,894.5	0.0	0.0	3,567.5	10,357.2	11,871.5
Number of archaeological and historical sites	71.0	124.0	19.0	180.0	138.0	N/A	N/A	N/A	N/A	N/A

Table 10.7-5. High Consequence Areas and Areas of Interest within 2,500 Feet of Either Side of the Centerline and 10-Mile-Long Downstream ROI of the Applicant's Preferred Route and Route Alternatives Between Clearbrook and Carlton

Resources of Concern	Applicant's Preferred Route	Route Alternative RA-03AM	Route Alternative RA-06	Route Alternative RA-07	Route Alternative RA-08	Applicant's Preferred Route	Route Alternative RA-03AM	Route Alternative RA-06	Route Alternative RA-07	Route Alternative RA-08
	Within 2,500 of Either Side of the Centerline					Within 10-Mile-Long Downstream ROI				
Biological Areas of Interest										
Aquatic Management Areas (acres)	125.0	112.5	204.6	227.5	190.5	209.8	267.0	241.0	320.0	336.9
Scientific and Natural Areas (acres)	0.0	234.5	63.7	7.5	85.2	149.6	238.1	0.0	0.0	0.0
Minnesota BWSR conservation easement (acres)	14.0	1,288.5	25.9	165.2	183.7	37.4	385.1	0.0	36.1	35.9
Lakes of Biological Significance (acres)	300.2	220.3	99.2	2,103.4	1,280.8	3,608.9	1,952.6	1,222.5	3,400.1	4,286.4
Marginal cropland (acres)	13.7	88.3	6.7	14.2	23.5	11.3	69.3	0.0	10.0	10.0
MBS Sites of Biodiversity Significance (acres)	25,016.2	16,339.8	8,952.1	9,962.2	12,257.6	9,692.7	5,138.5	4,774.4	5,834.6	6,531.2
Muskie lakes (acres)	41.4	0.0	0.0	976.6	55.8	676.0	0.0	0.0	2,107.1	2,676.3
Native plant communities (acres)	35,273.1	18,742. 8	26,368.1	37,247.1	39,868.2	14,015.3	16,937.9	15,591.9	20,211.6	21,661.8
Sensitive lakeshore areas (acres)	300.5	178.6	0.0	1,329.8	1,151.6	441.9	188.4	158.3	513.4	713.7
Trout stream/lake (acres)	16.3	0.0	0.0	0.0	0.0	N/A	N/A	N/A	N/A	N/A
Wetland bank easements (acres)	0.0	0.0	0.0	70.6	112.5	38.5	0.0	0.0	30.3	30.3
Wild rice lakes (acres)	675.4	708.6	92.4	1,240.4	1,119.5	3,396.3	2,385.1	1,021.5	2,956.4	3,902.3

Table 10.7-5. High Consequence Areas and Areas of Interest within 2,500 Feet of Either Side of the Centerline and 10-Mile-Long Downstream ROI of the Applicant's Preferred Route and Route Alternatives Between Clearbrook and Carlton

Resources of Concern	Applicant's Preferred Route	Route Alternative RA-03AM	Route Alternative RA-06	Route Alternative RA-07	Route Alternative RA-08	Applicant's Preferred Route	Route Alternative RA-03AM	Route Alternative RA-06	Route Alternative RA-07	Route Alternative RA-08
	Within 2,500 of Either Side of the Centerline					Within 10-Mile-Long Downstream ROI				
Commodity Production Areas of Interest										
Federal and state forests (acres)	31,764.3	2,334.7	55,377.7	48,861.8	52,121.1	12,054.9	653.9	24,550.0	17,132.8	20,897.7
Other forested land (acres)	33,12.4	1,640.2	5,884.7	2,790.1	2,593.9	1,904.1	838.7	2,154.5	2,207.8	2,495.8
Harvested Wild Rice	181.6	180.7	72.1	241.9	761.8	982.3	0	324	773.7	1,983.20
Recreation/Tourism Areas of Interest										
State park and recreation areas (acres)	947.8	947.8	0.0	0.0	0.0	180.8	1,920.9	941.3	941.3	914.3
Waterfowl production areas (acres)	92.0	260.8	418.0	185.8	277.2	11.5	11.5	182.2	0.0	0.2
Wildlife Management Areas (acres)	1,299.3	477.7	294.1	16.4	439.5	1,172.7	482.2	3.0	299.5	293.1
TOTALS										
AOI Total (acres)	**187,983.9**	**190,084.3**	**132,490.1**	**241,976.0**	**243,805.1**	**57,156.9**	**44,096.9**	**60,867.8**	**80,136.5**	**93,279.3**
Combined AOI Total (acres)	**244,771.8**	**233,448.2**	**193,267.9**	**321,650.5**	**336,712.4**					

Notes:
The establishment of ROIs and GIS analysis methods are described in Section 10.4.1.
Acreages are the sum of acres within the 2,500-foot-wide and 10-mile-long downstream ROIs for each metric, with the exception of Drinking Water AOIs, which reflect: DWSMAs and Wellhead Protection Areas within a 1-mile ROI, and Hydrogeologic Sensitivity within a 0.5-mile ROI.
See Section 10.4.1 for a discussion of the use and limitations of HCA and AOI data analysis.
See Section 10.4.3 for a discussion of corridor sharing considerations.
AOI = area of interest, MBS Sites = Minnesota Biological Survey Sites of Biodiversity Significance; Minnesota BWSR = Minnesota Board of Water and Soil Resources; HCA = high consequence area (see Section 10.4.1 for descriptions of HCAs); DWSMA = Drinking Water Supply Management Area, ROI = region of interest; WPAs = Wellhead Protection Areas

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