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

Prepared for:
Department of Commerce, Energy
Environmental Review Analysis Staff

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and
RPS

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ABBREVIATIONS

AAR	Assessment of Accidental Releases
AOI	Area of Interest
C	Celsius
CLB	Cold Lake Blend
CLSB	Cold Lake Summer Blend
CLWB	Cold Lake Winter Blend
cm	centimeters
CN	Certificate of Need
DOC	Minnesota Department of Commerce
DOC-EERA	Minnesota Department of Commerce, Energy Environmental Review Analysis
EIS	Environmental Impact Statement
Enbridge	Enbridge Energy, Limited Partnership
ENC	Electronic Navigation Charts
ER	Emergency Response
EROM	Extended Unit Runoff Method
ESI	Environmental Sensitivity Index
F	Fahrenheit
FEIS	Final Environmental Impact Statement
ft	feet
FSDD	Final Scoping Decision Document
HCA	High Consequence Area
IBA	Important Bird Area
ICC	Incident Command Center
ICP	Integrated Contingency Plan
km	kilometer
L3RP	Line 3 Replacement Project
m	meter
MCBS	Minnesota County Biological Survey
mg/L	milligram per liter
MN DA	Minnesota Department of Agriculture
MN DNR	Minnesota Department of Natural Resources

MN PCA	Minnesota Pollution Control Agency
m/s	meters per second
NED	National Elevation Dataset
NHD	National Hydrography Dataset
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NRDA	Natural Resources Damage Assessment
OPA	oil-particle aggregate
OSRO	Oil Spill Removal Organizations
PAH	Polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PHMSA	Pipeline and Hazardous Materials Safety Administration
PLM	Superior Pipeline Maintenance
PUC	Minnesota Public Utilities Commission
ROW	right of way
RP	Routing Permit
RPS	RPS Group PLC
SLR SBPA	St. Louis River Stream Bank Protection Area
SOMP	Submerged Oil Management Program
Stantec	Stantec Consulting Services Inc.
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UV	ultraviolet
VOC	Volatile Organic Compound
WBD	Watershed Boundary Dataset

PREFACE

In 2017, Stantec Consulting Ltd. (Stantec), RPS Group PLC (RPS), and Dynamic Risk Assessment Systems, Inc. (Dynamic Risk) were retained to prepare a risk assessment for potential large releases of crude oil from the Line 3 Replacement Project (L3RP). Potential consequences associated with large volume releases of crude oil at seven representative sites in Minnesota were assessed.

On June 3, 2019, the State of Minnesota Court of Appeals ruled that the Minnesota Public Utilities Commission (PUC)'s order finding the Final Environmental Impact Statement (FEIS) adequate be reversed and remanded on the grounds that the FEIS did not adequately address the potential impact of an oil spill into the Lake Superior Watershed. This addendum is intended to provide the Minnesota Department of Commerce, Energy Environmental Review Analysis (DOC-EERA) with information to assist them in assessing the potential effects of an oil spill into the Lake Superior watershed.

The purpose of this document is to describe the potential consequences associated with large volume releases of crude oil into the Lake Superior watershed in Minnesota, if it were to occur. Little Otter Creek was selected as the eighth representative site for assessment of potential releases.

Direction on Technical Work

RPS and Stantec (referred to collectively as the Consulting Team) were retained by Enbridge Energy, Limited Partnership (Enbridge). The Consulting Team was responsible for identifying and characterizing potential candidate sites for a hypothetical oil release within the Lake Superior watershed. DOC-EERA selected the crossing of the Little Otter Creek as the representative site for oil spill modeling into the Lake Superior Watershed. The Consulting Team then undertook the assessment of effects under its own direction.

The Consulting Team was responsible for preparing this technical report for the Little Otter Creek representative site. Chapter 2: Emergency Response was the exception; it was prepared by Enbridge. Comments on the draft report were received from Enbridge and the DOC-EERA. Revisions to the draft report were undertaken by the Consulting Team, but only where changes were deemed appropriate. The work's technical conclusions were unchanged by the revisions accepted. A final report was prepared by the Consulting Team for submission to the DOC-EERA.

Funding for the work undertaken by the Consulting Team was provided by Enbridge.

Authorship

The risk assessment of large releases of crude oil was prepared by the Consulting Team. The Technical Lead for each section of the report was as follows:

Chapter	*Technical Lead(s) Responsible for the Chapter*
1.0 INTRODUCTION	Jeff Green, Stantec and Matt Horn, RPS
2.0 EMERGENCY RESPONSE	Enbridge
3.0 MODELING OF OIL RELEASES	Matt Horn, RPS
4.0 TRAJECTORY AND FATE RESULTS FOR MODELING LOCATIONS	Matt Horn, RPS
5.0 ASSESSMENT OF ENVIRONMENTAL EFFECTS OF OIL RELEASES	Malcolm Stephenson, Stantec and Chris Pekar, Stantec
6.0 REVIEW OF ENVIRONMENTAL RECOVERY FOLLOWING RELEASES OF OIL	Malcolm Stephenson, Stantec
7.0 SUMMARY AND CONCLUSIONS	Consulting Team
8.0 REFERENCES	Consulting Team

Declaration

We verify that we are responsible for leading and managing the preparation of the chapters of the report, as described in the above table. All technical analyses and all conclusions reflect our work and opinions. Modifications in response to verbal or written comments from the DOC-EERA, state and federal agencies or Enbridge have not modified the technical aspects and results of our work or our conclusions.

Jeff Green, Stantec

Matt Horn, RPS

Chris Pekar, Stantec

Malcolm Stephenson, Stantec

1 INTRODUCTION

1.1 Rationale for the Addendum

The RPS Group PLC (RPS) and Stantec Consulting Services Inc. (Stantec) (referred to collectively as the Consulting Team) were retained by Enbridge Energy, Limited Partnership (Enbridge) to prepare a risk assessment for potential large releases of oil from the Line 3 Replacement Project (L3RP). The Assessment of Accidental Releases (AAR) technical report (Stantec et al. 2017), prepared by Stantec, RPS, and Dynamic Risk Assessment Systems Inc., was submitted to the Minnesota Department of Commerce (DOC) by Enbridge as part of the record supporting the Applications for a Certificate of Need (CN) and a Routing Permit (RP) for the Proposed Line 3 Replacement Project.

Information from this and other technical reports was used by the Minnesota Department of Commerce, Energy Environmental Review Analysis (DOC-EERA) staff to prepare the initial draft Environmental Impact Statement (EIS). Following public review and revisions, the Final EIS (FEIS) was released by the Department of Commerce in mid-August 2017. The Minnesota Public Utilities Commission (PUC) held public hearings on the CN and RP during September to October 2017. In December 2017, the PUC found that the FEIS was not adequate until it contained specific additional information. The DOC revised the FEIS and submitted it to the PUC in mid- February 2018. The PUC issued an order finding the revised Final EIS adequate on May 1, 2018. On September 5, 2018, the PUC granted a CN for the L3RP, contingent on specific modification, and on October 26, 2018, the PUC issued a RP for the Applicant's Preferred Route with modifications (https://mn.gov/puc/line3/process).

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

1.2 Background on L3RP

Enbridge is proposing the L3RP to replace Enbridge's existing Line 3 pipeline, from the Joliette Valve in Pembina County, North Dakota to Clearbrook, Minnesota, and then on to an existing terminal in Superior, Wisconsin. The L3RP route is approximately 363 miles long, 337 of which are in Minnesota. The remainder of the pipeline is located in North Dakota and a small portion in Wisconsin.

Within Minnesota, L3RP would involve the construction and operation of a 36-inch diameter, underground crude oil pipeline. The Project would also include a new pump station and improvements at the existing Clearbrook Terminal, the expansion of three other existing pump stations west of Clearbrook, and the addition of four new pump stations in Minnesota east of Clearbrook.

L3RP would transport a variety of crude oils that range from light to heavier crude oils, including diluted bitumen.

1.3 Scope of the Assessment

The Final Scoping Decision Document (FSDD) for L3RP (Minnesota DOC-EERA 2016) describes the topics that need to be addressed in the EIS to be prepared by the DOC-EERA.

In regard to the analysis of large oil releases, the EIS is to include "*spill modeling and a summary and application of analysis methods from other projects*." The FSDD states that the Applicant (Enbridge) will provide "*data on maximum spill volumes, spill frequency, and the types of crude oil to be transported based on the proposed engineering and operations for the pipeline. This information will be applied to all large-volume spill impact analysis methods. An estimated large-volume spill footprint will be established using these data and based on methods used by other current or recent investigations. The methods will consider general geomorphic conditions in Minnesota to develop a general spill footprint. The analysis will also include a review of crude oil release data from the Pipeline and Hazardous Materials Safety Administration (PHMSA) database*."

In addition, the FSDD states that "*to assess potential impacts associated with an accidental release, the Applicant will provide maximum spill volume estimates based on response times, valve locations, and pipeline volumes at seven representative sites assuming a complete pipeline rupture. Data generated from modeling at representative sites will be used to make broad environmental comparisons among and across routes in areas with similar features*."

Modeling will include "*a set of scenarios that include the following crude oil types: light sweet Bakken crude oil, Cold Lake Blend (CLB), and Cold Lake Winter Blend (CLWB). These crude oils represent the range of oil densities and chemical compositions expected. Additional modeling parameters include seasonal variation to capture water flow volumes (high flow, low flow, and snow/ice covered), and a 24-hour model run with outputs at 6, 12, and 24 hours. The combinations of model inputs will result in more than 40 modeling scenarios from which to analyze potential impacts to resources along route alternatives*."

Further direction on the scope of the FEIS was provided by the Minnesota Court of Appeal Decision (pages 20-21; Potential impacts of an oil spill on Lake Superior). The decision acknowledged the assessment of the seven representative sites but identified that a representative site within the Lake Superior watershed was not addressed. Specifically, the decision states

> *"As the FEIS acknowledges, a potential environmental impact of this pipeline project is an accidental release of crude oil—an oil spill. Chapter 10 of the FEIS is devoted to analyzing the potential impacts of an oil spill for the APR and each of the project, route, and route-segment alternatives. In addition to providing a baseline spill-risk analysis based on past spills, analyzing the behavior of crude oil in a spill, assessing the potential resource impacts of an oil spill on resources along the APR and alternatives, and addressing spill prevention and mitigation, the FEIS incorporates a study modeling the potential spread of oil from spills at seven sites along the APR and alternative routes. The seven spill-modeling sites were chosen to represent a diversity of environmental conditions. Three of the sites are at separate locations on the Mississippi River; none of the sites are in the Lake Superior watershed."*

The Decision (page 21) goes on to note that in the section of the FSDD entitled "Issues Entirely or Partially Outside the Scope of the EIS", that the EIS should have considered "*potential impacts to the Lake Superior watershed including potential impacts of oil spills along the proposed Project*." The Minnesota Court of Appeal concluded (page 22) that FEIS "*did not address the potential impacts of an oil spill in the Lake Superior watershed*." Based on this, the Minnesota Court of Appeal reversed "*the commission's adequacy decision*" (page 39).

On October 8, 2019, the Minnesota Public Utilities Commission issued an Order Finding Environmental Impact Statement Inadequate on Remand and directed the DOC-EERA to "*revise the final EIS to include an analysis of the potential impact of an oil spill into the Lake Superior watershed consistent with the Court of Appeals' decision*.

1.4 Purpose of the Addendum

The purpose of this document is to describe the potential consequences associated with large volume releases of crude oil into the Lake Superior watershed in Minnesota, if it were to occur. As described later in this report (Section 3), Little Otter Creek was selected as the eighth representative site for assessment of potential releases.

As described in Stantec et al. (2017), a number of factors and aspects are considered in this assessment of consequences, and include:

- Modeling hypothetical large releases of several types of crude oil in terrestrial and freshwater environments at a single location in the Lake Superior watershed within Minnesota. The intent is to understand the trajectory and fate of potential large volume releases of oil with respect to the range of geographic and environmental conditions at a single hypothetical release site, taking into account the seasonal variability and conditions at the site.
- Assessment of the resources that may be affected at this representative site, and the range of potential effects on the natural (physical and biological) and human environment[1] that may result.
- Potential for the natural and human environment at this representative site to recover from the effects of a large oil release following the event, including a discussion of factors that can promote or impair recovery and the approximate timing of recovery.

Each of these topics is discussed in the corresponding sections of this report (see Section 1.6).

1.5 Use of the Oil Release Modeling Information

The intent of the modeling and assessment by RPS and Stantec (Stantec et al. 2017) was to investigate the range of potential outcomes (effects) to the natural and human environment if an accidental release of a large volume of crude oil was to occur at any point along the pipeline (including preferred and alternative routes). To accomplish this, seven representative sites across northern and central Minnesota were carefully and deliberately selected to address a broad spectrum of terrain, land-cover types,

[1] The natural environment includes the atmospheric environment, ground water and surface water, terrain, soils, freshwater fish, vegetation, wetlands, and wildlife, including rare and endangered species. The human environment includes human uses, social, cultural and economic values, and heritage resources.

watercourses, waterbodies, wetlands, associated freshwater and riparian habitat types, vegetation, environmentally-sensitive areas, and human land uses (Figure 1-1).

Through modeling and assessment of effects at representative sites with different terrain, land-cover types, types of watercourses and water features, associated freshwater and riparian habitat types, vegetation, environmentally-sensitive areas, and human land uses, the combined assessment was intended to be used to consider the range of consequences that may be possible should there be an accidental release of crude oil along the proposed route or the proposed alternative routes for L3RP.

The results of the initial modeling and assessment were then used by the DOC in the preparation of the FEIS.

1.6 Selection of a Hypothetical Spill Location Within the Lake Superior Watershed

The consequence assessment for a site within the Lake Superior watershed in Minnesota is intended to expand the range of biophysical, socio-cultural and economic conditions and potential consequences that may be possible in the event of an accidental release. As with the other seven representative sites, this assessment considers:

- the range of product types that may be shipped on the proposed pipeline (two product types -- a light oil and heavy crude oil – are considered)
- environmental variability (i.e., 3 time periods including seasonal differences in river flow rate, snow/ice coverage, temperature, wind speed, etc.)

1.6.1 Previous Identification of a Representative Hypothetical Release Scenarios

Even in the event of a full bore rupture incident, crude oil releases on land only often result in only small areas of land (e.g., a few hectares) becoming contaminated by released oil. This is not to suggest that such effects would not be consequential. Rather, it justifies the selection of crude oil releases that enter watercourses (rivers or lakes) as being a conservative choice with respect to the fate, transport, and potential effects of released oil. Unmitigated releases of oil into water would have a larger spatial distribution and a greater potential to cause adverse effects to larger numbers of ecological and human receptors. Therefore, this analysis focused on scenarios that result in the release of crude oil to watercourses as a conservative assumption. Specifically, this assessment addresses the potential environmental effects of a crude oil spill within the Lake Superior watershed.

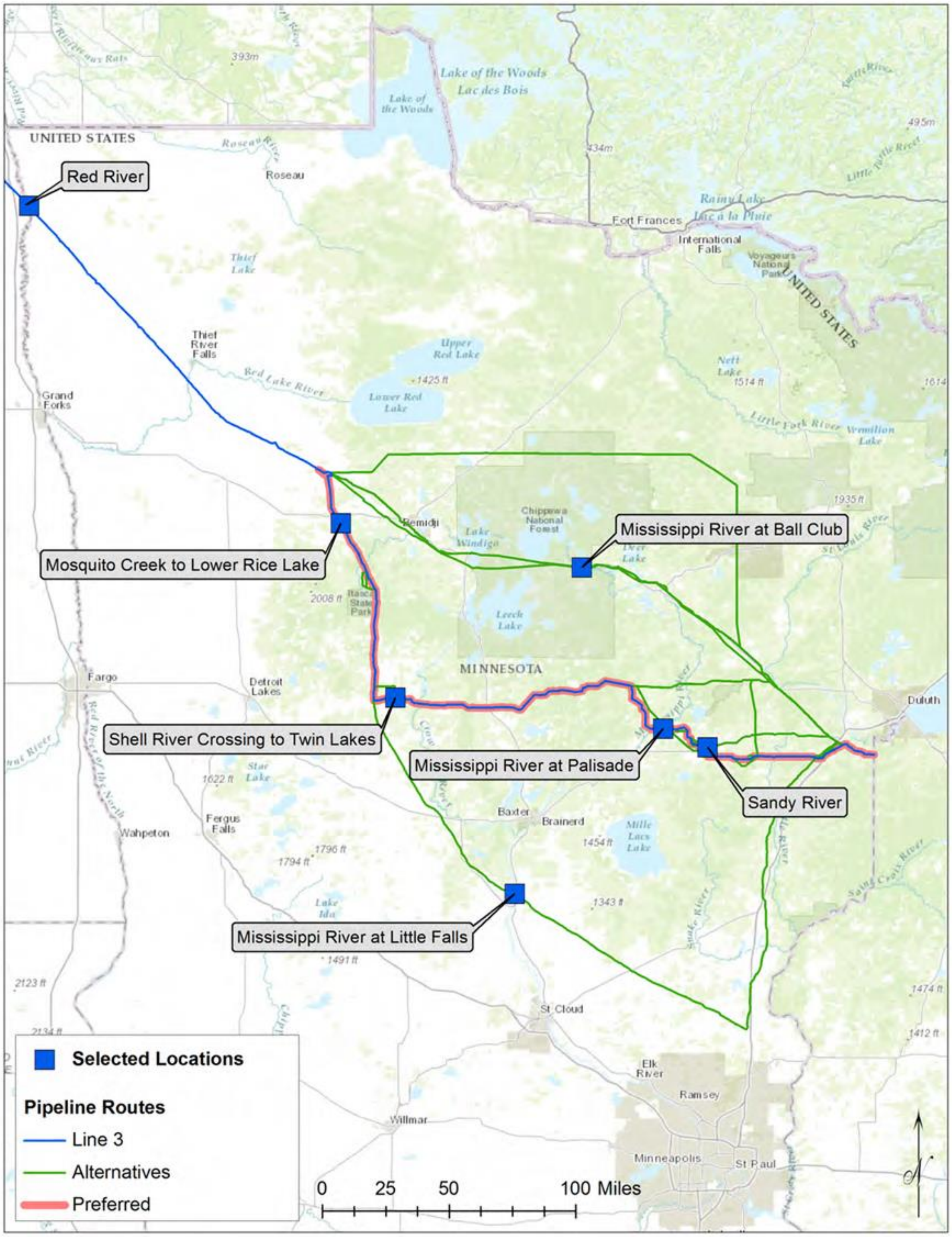

Figure 1-1 Final Representative Sites Selected for Modeling of Hypothetical Large Releases of Crude Oil.

As will be discussed in Section 2.0, Enbridge will have emergency response plans in place and would be ready to respond rapidly to an oil spill, if it were to occur, to contain released oil, remove remaining oil from the environment and initiate remediation and restoration measures. Such responses would help to reduce the amount of oil that would travel overland and potentially be transported into the St. Louis River and downstream.

Seven locations, each adjacent or close to a watercourse, were selected for modeling of hypothetical large releases of crude oil (Stantec et al. 2017) The selection of these seven modeling sites was guided by consideration of the following engineering and environmental/socio-economic risk factors (Stantec et al. 2017, Section 3.3.3):

- Located so that crude oil release volumes could potentially enter a watercourse; this included selection of locations where the hypothetical release of oil would either occur directly into a watercourse or would travel a short distance overland into a watercourse
- Located where shut-off valves would not overly restrict the volume of oil that could potentially be released (i.e., the hydraulic drain down of pipeline would be a substantial contributor to the oil release volume)
- Included sites along both the preferred and alternate routes
- Representative of the geographic and environmental conditions and land uses along the proposed right-of-way (ROW) for the pipeline to allow for an evaluation of the range of potential effects to the natural and human environment along the pipeline
- Included a range of watercourse types (e.g., size, flow, energy level) and water bodies, including wetlands
- Supported evaluation of potential effects to environmentally sensitive resources (e.g., spawning grounds for fish, wild rice lakes, or other sensitive habitats)
- Represented areas of expressed concern by Native American tribes, the general public, and/or state and federal agencies
- Supported evaluation of potential effects to traditional use, other human use or infrastructure (e.g., potable water intakes or treatment facilities)

Based on a review of potentially sensitive hypothetical release sites and collaboration with the MN DNR and MN PCA (Stantec et al. 2017, Sections 3.3.4 and 3.3.5), the scenarios were narrowed to seven sites in Minnesota (Figure 1-2):

- Site 1—Mosquito Creek to Lower Rice Lake
- Site 2—Mississippi River at Ball Club
- Site 3—Sandy River
- Site 4—Shell River to Twin Lakes
- Site 5—Red River
- Site 6—Mississippi River at Palisade

- Site 7—Mississippi River at Little Falls

To illustrate how the seven representative modeling sites represent different combinations of hydrological conditions, watercourse widths, water features and uses, the detailed summary of features and characteristics (i.e., site attributes) were condensed into a simpler summary format referred to as an "equivalency table" (Table 1-1). As shown in this table, for each attribute and the specific categories within each attribute (other than overland flow), at least two of the representative modeling locations and typically several were representative of that specific attribute and category. This summary demonstrates that the seven representative modeling locations did include a robust diversity of site characteristics that were identified in the scoping sessions. This included the features that are representative of most of the predominant ecological units along the pipeline, as well as the major hydrological features, watercourse widths, and watercourse features along any of the proposed routes.

1.6.2 Evaluation of Options for A Release Location

In selecting a single hypothetical release site within the Lake Superior watershed, watercourse crossings within the watershed that had direct hydrologic connection to Lake Superior needed to be identified. In the original assessment, nearly 1,000 watercourses were considered with 274 watercourses transacted by the preferred route for L3RP and another 641 along the alternative routes (Stantec et al. 2017). In a series of meetings over several months, a number of candidate locations where modeling of crude oil releases might be conducted was compiled. The meetings involved representatives of the state and federal agencies, and the technical support consultant for the DOC-EERA, as well as Enbridge and their corresponding technical support consultants (Stantec, RPS, and Dynamic Risk). Through several meetings with DOC-EERA, state and federal agencies, and the Consulting Team, a total of 27 candidate sites were identified for detailed evaluation as modeling locations. The selection of the candidate sites considered the geospatial distribution of the sites along the preferred and alternate routes in central and northern Minnesota, as well as the need to capture credible worst cases. The original candidate locations did include several potential watercourse crossings within the Lake Superior watershed, including Otter Creek. However, based upon the other representative sites that were identified and ultimately selected for analysis, it was deemed unnecessary to model Otter Creek, as other locations captured the site characteristics that would have been present. Therefore, to reduce the potential for any unnecessary redundancy, Otter Creek was not selected in the original AAR (Stantec et al. 2017).

Similar to this approach, approximately 150 watercourses were considered within the Lake Superior watershed for this assessment. However, because many of the watercourses were quite small and had limited potential for oil to reach Lake Superior within 24 hours, the list was refined to an identified smaller number of potential sites (nine) where, as a result of topography and water features, an oil release might result in either downstream and/or overland flow that had the potential to reach the St. Louis River. Table 1-3 and Figure 1-2 summarize the options that were considered, starting with the westernmost site (top of table) and working east, as well as the rationale for considering or not considering these optional release sites for modeling and assessment. Similar to the equivalency table provided for the previously modeled seven representative sites (Table 1-1), an equivalency table was generated to compare the characteristics of each of these optional representative sites within the Great Lakes watershed for this additional oil spill modeling (Table 1-2).

Table 1-1 Equivalency Table of the Previously Modeled Representative Release Locations.

Representative Release Location		Mississippi River at Ball Club	Mississippi River at Little Falls	Mississippi River 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**
Hydrology Features	Ditch/Creek							
	Watercourse (stream/River)							
	Lake/Pond							
	Flat Water							
	Rapids/Falls							
	Dams							
	Wetland/Marsh/Fen							
Watercourse Width	Small (<10 m)							
	Medium (10-50 m)							
	Large (>50 m)							
Watercourse Features	Agricultural Land							
	Forested Region							
	Mississippi River							
	Urban Area							
	Wild Rice							
Identified Uses	Recreational							
	Drinking Water							
	Populated Area							
	Sensitive Ecosystem							
Includes Overland Transport								

Table 1-2 Summary of Optional Locations Considered for Modeling of Hypothetical Oil Releases within the Lake Superior Watershed within Minnesota.

Potential Hypothetical Release Site	Notes on Rationale for Selection/Rejection
East Savanah River #1	• Within the Lake Superior watershed • Pathway of oil had a near zero probability of oil reaching the Lake Superior region within the modeled timeframe. • No L3RP construction has occurred at this site. • Not Selected
East Savannah River #2	• Within the Lake Superior watershed • Pathway of oil had a near zero probability of oil reaching the Lake Superior region within the modeled timeframe. • No L3RP construction has occurred at this site. • Not Selected
Ahmik River	• Within the Lake Superior watershed • Pathway of oil had a near zero probability of oil reaching the Lake Superior region within the modeled timeframe. • No L3RP construction has occurred at this site. • Not Selected
Stoneybrook River	• Within the Lake Superior watershed • Pathway of oil had a near zero probability of oil reaching the Lake Superior region within the modeled timeframe. • No L3RP construction has occurred at this site. • Not Selected
Little Otter Creek	• Has direct connection (small watercourse) to St. Louis River (large river) with a hydrologic connection to Lake Superior • Furthest east crossing of a waterway within Minnesota that is in the Lake Superior watershed that is hydrologically connected to Lake Superior and is along the pipeline route with a crossing • Included rapids and waterfalls with the potential for sinking oil • Includes large regions of environmentally susceptible receptors (e.g. Jay Cooke State Park, sturgeon habitat, etc.) • No L3RP construction has occurred at this site. • Site Selected
Blackhoof River	• Within the Lake Superior watershed • Pathway of oil had a near zero probability of oil reaching the Lake Superior region within the modeled timeframe. • No L3RP construction has occurred at this site. • Not Selected
Pokegama River Crossing 2 (Wisconsin)	• Close to Lake Superior with hydrologic connection to Lake Superior • Already approved and pipeline has been constructed • Slow moving watercourse with low potential for entrainment and sinking oil • Much of downstream receptors is industrialized (e.g. docks and man-made banks) • Not Selected

Potential Hypothetical Release Site	Notes on Rationale for Selection/Rejection
Little Pokegama River (Wisconsin)	• Close to Lake Superior with a hydrologic connection to Lake Superior • Already approved and constructed • Slow moving watercourse with low potential for entrainment and sinking oil • Much of downstream receptor area is industrialized (e.g., docks and man-made banks) • Not Selected
Pokegama River Crossing 1 (Wisconsin)	• Closest river crossing with a hydrologic connection to Lake Superior • Already approved and pipeline has been constructed • Slow moving watercourse with low potential for entrainment and sinking oil • Much of downstream receptor area is industrialized (e.g., docks and man-made banks) • Not Selected

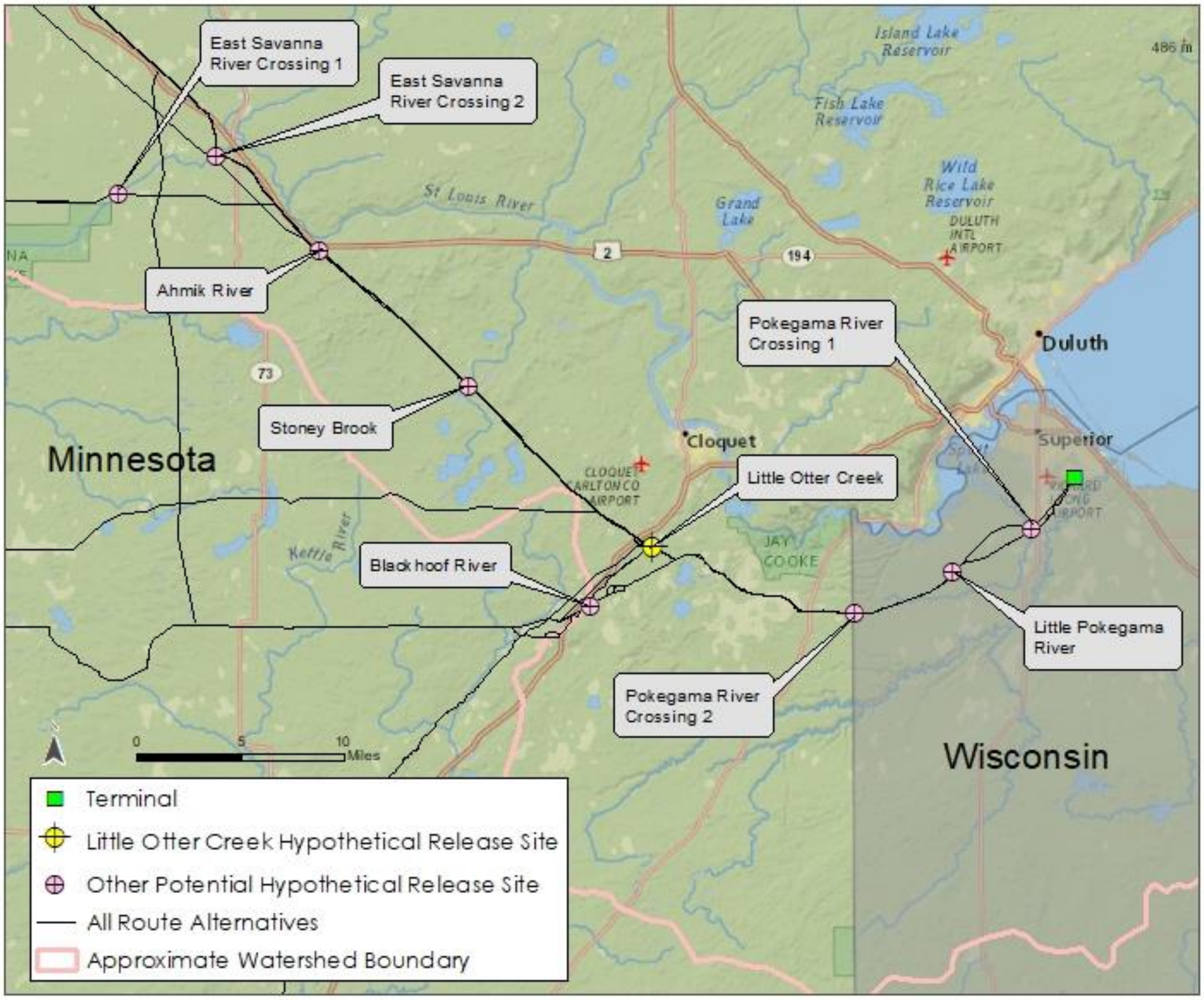

Figure 1-2. **Locations of optional representative sites for modeling of an oil spill in the Lake Superior Watershed.**

Table 1-3 Equivalency Table for the Optional Representative Sites for Oil Spill Modeling in the Lake Superior Watershed.

											MN EcoRegion			River Width			River Length to Nearest Waterbody		Watercourse Characteristics			Identified Uses			
Site Name	Proposed Route	N	W	Nearest Municipality	Description	Rice Lake	Agricultural Land	Forested Region	Urban Area	Mississippi River	Province	Section	Subsection	Small (<10 m)	Medium (10-50 m)	Large (>50 m)	Short (<5 km)	Long (>5 km)	Flat Water	Rapids / Falls	Lake	Recreational	Drinking Water	Populated Area	Sensitive Ecosystem
East Savanah River #1	RSA-21-L3, RSA-22-L3	46.8886	-93.0308	Floodwood	Water crossing of the East Savanah River (~10 m wide) in a sinuous and slow moving waterway winding through approximately 3.5 km of forest before entering the St. Louis River at Floodwood, 62 km above Cloquet, 92 km upstream of Spirit lake and over 110 km from Lake Superior			X			Laurentian Mixed Forest Province	Northern Minnesota Drift and Lake Plains	Tamarack Lowlands	X		X	X		X			X			X
East Savanah River #2	RA-06-L3, RA-07-L3, RA-08-L3	46.9147	-92.9308	Floodwood	Water crossing of the East Savanah River (~10 m wide) in a sinuous and slow moving waterway winding through approximately 2.5 km of forest before entering the St. Louis River at Floodwood, 62 km above Cloquet, 92 km upstream of Spirit lake and over 110 km from Lake Superior			X			Laurentian Mixed Forest Province	Northern Minnesota Drift and Lake Plains	Tamarack Lowlands	X		X	X		X			X			X
Ahmik River	RSA-22-L3, RA-06-L3, RA-07-L3, RA-08-L3	46.85	-92.8278	Gowan	Water crossing of the Ahmik River (~5 m wide) in a sinuous and slow moving waterway winding through approximately 3 km of scrub, wetland, and forest before entering the St. Louis River 50 km above Cloquet, 80 km upstream of Spirit lake and nearly 100 km from Lake Superior	X		X	X		Laurentian Mixed Forest Province	Northern Minnesota Drift and Lake Plains	Tamarack Lowlands	X		X	X		X			X			X
Stoney Brook	RSA-22-L3, RA-06-L3, RA-07-L3, RA-08-L3	46.7547	-92.6765	Cloquet	Water crossing of Stoney Brook (~10 m wide) in a straight channel to the north and east passing through forested and marshy wetland areas over 15 km before entering the St. Louis			X			Laurentian Mixed Forest Province	Western Superior Uplands	Northshore Highlands	X	X			X	X		X	X			X

											MN EcoRegion			River Width			River Length to Nearest Waterbody		Watercourse Characteristics			Identified Uses			
Site Name	Proposed Route	N	W	Nearest Municipality	Description	Rice Lake	Agricultural Land	Forested Region	Urban Area	Mississippi River	Province	Section	Subsection	Small (<10 m)	Medium (10-50 m)	Large (>50 m)	Short (<5 km)	Long (>5 km)	Flat Water	Rapids / Falls	Lake	Recreational	Drinking Water	Populated Area	Sensitive Ecosystem
					River approximately 25 km above Cloquet, 55 km upstream of Spirit Lake, and 75 km from Lake Superior																				
Little Otter Creek	RSA-22-L3, RA-06-L3, RA-07-L3, RA-08-L3, RSA-37-L3, RSA-44-L3, RSA-45-L3, RSA-49-L3	46.642992	-92.4933	Carlton	Water crossing of the Otter Creek (~5 m) in a marshy wetland area ultimately draining into Lake Superior.	X		X	X		Laurentian Mixed Forest Province	Western Superior Uplands	Mille Lacs Uplands	X	X	X		X	X	X	X	X		X	X
Blackhoof River	RA-03AM-L3	46.6027	-92.5553	Atkinson	Water crossing of the Blackhoof River (~5 m wide), with a sinuous marshy and scrub channel winding through forest and agricultural land before draining into the Nemadji River	X	X	X			Laurentian Mixed Forest Province	Western Superior Uplands	Mille Lacs Uplands	X	X			X	X		X	X			X
Pokegama River Crossing 2	RA-03AM-L3, RA-06-L3, RA-07-L3, RA-08-L3	46.5968	-92.2893	Dewey, WI	Water crossing of the Pokegama River (~2-5 m wide) in a sinuous and slow moving waterway with high sediment load winding through nearly 20 km of heavily forested area before entering Pokegama Bay			X			N/A	N/A	N/A	X				X	X			X			X
Little Pokegama River	RA-03AM-L3, RA-06-L3, RA-07-L3, RA-08-L3	46.6243	-92.1904	Oliver, WI	Water crossing of the Pokegama River (~5 m wide) in a sinuous and slow moving waterway with high sediment load winding through approximately 10-15 km of heavily forested area before entering Pokegama Bay			X			N/A	N/A	N/A	X				X	X			X			X

											MN EcoRegion			River Width			River Length to Nearest Waterbody		Watercourse Characteristics			Identified Uses			
Site Name	Proposed Route	N	W	Nearest Municipality	Description	Rice Lake	Agricultural Land	Forested Region	Urban Area	Mississippi River	Province	Section	Subsection	Small (<10 m)	Medium (10-50 m)	Large (>50 m)	Short (<5 km)	Long (>5 km)	Flat Water	Rapids / Falls	Lake	Recreational	Drinking Water	Populated Area	Sensitive Ecosystem
Pokegama River Crossing 1	RA-03AM-L3, RA-06-L3, RA-07-L3, RA-08-L3	46.6538	-92.1101	Superior, WI	Water crossing of the Pokegama River (~10 m wide) in a sinuous and slow moving waterway with high sediment load winding through heavily forested area before entering Pokegama Bay	X		X	X		N/A	N/A	N/A	X	X	X	X		X		X	X		X	X

To address the potential impact of an oil spill into the Lake Superior watershed, DOC-EERA selected the crossing of the Little Otter Creek as the eighth representative site for oil spill modeling.

- Site 8—Little Otter Creek to St. Louis River and Estuary

Modeling of hypothetical release scenarios at Little Otter Creek was completed to predict the potential trajectory of released oil, the fate of released oil, and the potential effects of accidental oil releases on the natural and human environment. The intent of these analyses was to infer a range of potential effects that may occur at other locations in Minnesota with similar biophysical and human use characteristics. This information is intended to provide the DOC with information to assist them in assessing the potential effects of an oil spill into the Lake Superior watershed in Minnesota.

1.6.3 The Little Otter Creek Release Location

Little Otter Creek was chosen as the representative release site as it is the site in Minnesota where a hypothetical oil release is more likely to enter the St. Louis River, and ultimately have the potential to reach Lake Superior, than the other options considered.

Little Otter Creek includes a small watercourse that flows to the east into Otter Creek, before entering the St. Louis River below Thompson Reservoir, which includes rapids, waterfalls, and dams, before widening into the St. Louis Harbor and ultimately draining into Lake Superior.

The equivalency table contained in the original AAR (Stantec et al. 2017; Table 3-3) (Table 1-1 in this report) can be used to compare this new eighth representative site to previously modeled sites. The Little Otter Creek hypothetical release site has aspects in common with the modeled release cases for Mosquito Creek with modeled oil transport to Lower Rice Lake (Case 1) and the Sandy River, with modeled oil transport into Steamboat, Davis, and Flowage lakes (Case 3). These different modeling cases investigated releases into small waterways that had the potential to transport oil multiple kilometers downstream before entering larger waterbodies, albeit much smaller than Lake Superior. The previous results from the Mississippi River at Little Falls (Case 7) representative site are comparable to potential transport of crude oil within the St. Louis River (a mid- to large-size river with waterfalls, dams, and rapids).

When considered together with the seven previously modeled sites, Little Otter Creek as the eighth representative release site can be used to further bound the range of trajectory, fate, and potential consequences.

Table 1-4 Summary Table of the Eight Representative Modeled Release Sites, including Little Otter Creek.

Representative Release Location		Mississippi River at Ball Club	Mississippi River at Little Falls	Mississippi River at Palisade	Mosquito Creek to Lower Rice Lake	Red River	Sandy River	Shell River Crossing to Twin Lakes	Little Otter Creek
EcoProvince		**Laurentian Mixed Forest**	**East Broadleaf Forest**	**Laurentian Mixed Forest**	**Laurentian Mixed Forest**	**Prairie Parkland**	**Laurentian Mixed Forest**	**Laurentian Mixed Forest**	**Laurentian Mixed Forest**
Site Features									
Hydrology Features	Ditch/Creek								
	Watercourse (stream/River)								
	Lake/Pond								
	Flat Water								
	Rapids/Falls								
	Dams								
	Wetland/Marsh/Fen								
Watercourse Width	Small (<10 m)								
	Medium (10-50 m)								
	Large (>50 m)								
Watercourse Features	Agricultural Land								
	Forested Region								

Representative Release Location		Mississippi River at Ball Club	Mississippi River at Little Falls	Mississippi River at Palisade	Mosquito Creek to Lower Rice Lake	Red River	Sandy River	Shell River Crossing to Twin Lakes	Little Otter Creek
EcoProvince		**Laurentian Mixed Forest**	**East Broadleaf Forest**	**Laurentian Mixed Forest**	**Laurentian Mixed Forest**	**Prairie Parkland**	**Laurentian Mixed Forest**	**Laurentian Mixed Forest**	**Laurentian Mixed Forest**
Site Features									
	Mississippi River								
	Urban Area								
	Wild Rice								
Identified Uses	Recreational								
	Drinking Water								
	Populated Area								
	Sensitive Ecosystem								
Includes Overland Transport									

1.7 Organization of the Report

This report follows a similar structure and approach to that of Stantec et al. (2017) with a specific focus on the eighth hypothetical release site, at the Little Otter Creek crossing within the Lake Superior watershed; it includes:

- Section 2: Emergency Response—provides a description of the Enbridge pipelines within the area, emergency response goals, tactics, equipment/resources, capabilities, plans, and timing.
- Section 3: Modeling of Crude Oil Releases—provides a description of the modeling tools used to predict the trajectory and fate of several types of crude oil under different seasonal conditions, including a description of key assumptions and the input data used for modeling.
- Section 4: Trajectory and Fate Results—this section describes the predicted oil release modeling outputs for hypothetical, unmitigated, full bore releases of several types of crude oil and varying environmental conditions at the Little Otter Creek release site.
- Section 5: Assessment of Environmental Effects of Crude Oil Releases—the assessment begins with a summary of the observed and expected effects of crude oil on key ecological and human receptors in the Lake Superior watershed, including how crude oil behaves (i.e., its fate) in atmospheric, freshwater and terrestrial environments; details are provided in Stantec et al. 2017. This is followed by an assessment of effects for the Little Otter Creek release site. The assessment for this site includes a description of the environmental setting, the potential overlap of the modeled oil releases on High Consequence Areas (HCAs) and Areas of Interest (AOIs), and a description of the effects of a large release of crude oil on the natural and human environment.
- Section 6: Review of Environmental Recovery Following Releases of Crude Oil—this section summarizes the current state of knowledge of how various components of the natural and human environment are known to recover following a release of crude oil, with a focus on those resources of greatest relevance to the Little Otter Creek site within the Lake Superior Watershed in Minnesota. It also addresses how emergency response, clean-up, and remediation measures can promote or impair recovery.
- Section 7: Summary and Conclusions—this section provides general conclusions on the predicted range of potential effects at the Little Otter Creek hypothetical release site, including the benefits of emergency response, site clean-up and remediation, and environmental recovery of the receiving environment.

Each of the individual sections were prepared by one or more members of the Consultant Team other than Section 2, which was written by Enbridge. The lead authors for each section of the report are identified in the Preface.

2 EMERGENCY RESPONSE

2.1 Enbridge Operations

In the Midwest Region, Enbridge operates over 4,000 miles of pipeline through Minnesota, North Dakota, and Wisconsin. At the Little Otter Creek crossing, Enbridge has 6 pipelines ranging from 18 inches to 48 inches in diameter. The Superior Terminal and Enbridge's Superior Pipeline Maintenance (PLM) shop, located in Superior, Wisconsin, are approximately 28 miles from the modeled pipeline crossing of Little Otter Creek.

2.2 Little Otter Creek and Downstream Waterbodies

As described in Table 1-1, Little Otter Creek is classified as a small watercourse that is approximately 6-13 feet (ft) (2-4 meters [m]) in width and flows to the east into the St. Louis River (large river) with a hydrologic connection to Lake Superior. The St. Louis River below the Thomson Reservoir, where Little Otter Creek enters the watercourse, includes rapids, waterfalls, and dams, before widening into Spirit Lake, the St. Louis Harbor and ultimately draining into Lake Superior. Figure 2-1 depicts Little Otter Creek and downstream waterbodies including the St. Louis River, Spirit Lake, St. Louis Bay, and Lake Superior.

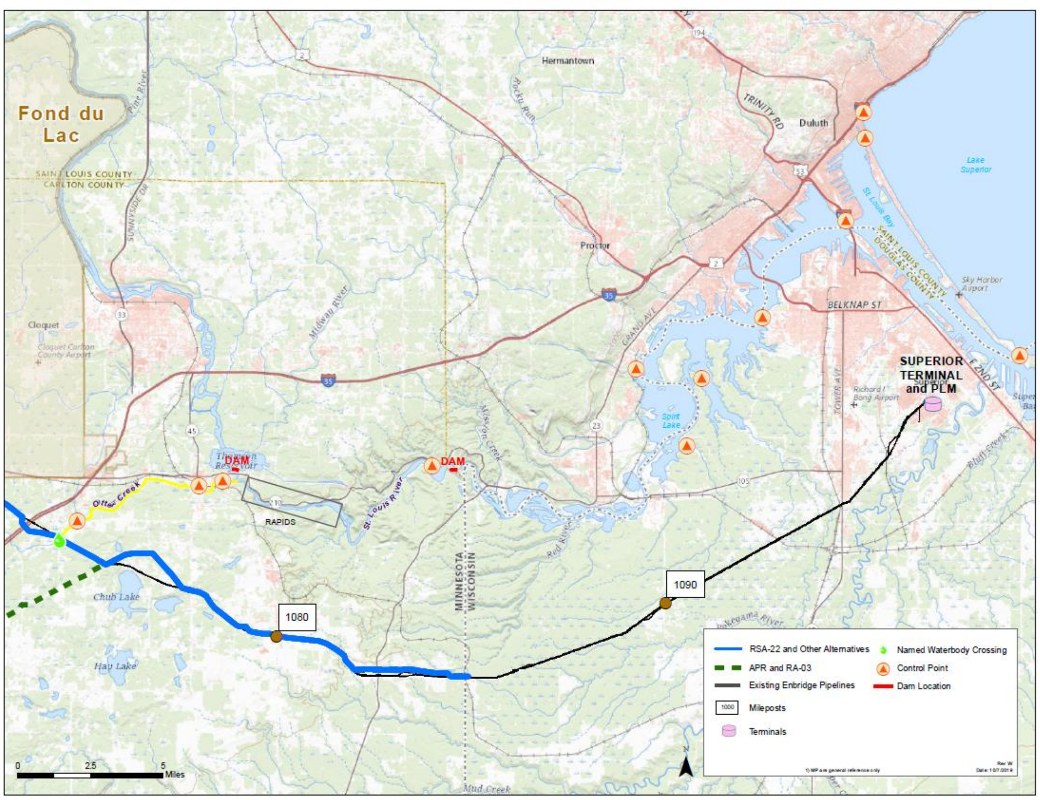

Figure 2-1 Little Otter Creek and Downstream Waterbodies (including Control Point Locations).

2.3 Emergency Response Plans

In accordance with federal and state regulations (49 CFR 194 & Minnesota Statute Chapter 115E), Enbridge has an Integrated Contingency Plan (ICP) approved by the PHMSA that fulfills the requirement for a responsible party to have an Emergency Response (ER) plan to ensure an effective, safe, and comprehensive response to all types of incidents to protect public health and safety, the environment, and infrastructure. PHMSA considers Enbridge's ICP to be an example of industry best practice for emergency response planning. Enbridge currently maintains a high state of readiness across all areas of operations, with trained personnel having the capability to deploy a cache of Enbridge-owned equipment.

As a supplemental guide to the ICP, Enbridge maintains core technical information references such as the Inland Spill Response Tactics Guide (Attachment 1) and the Incident Management Handbook that apply universally to field operations' tactical response and incident management of a response. The Inland Spill Response Tactics Guide is an internal Enbridge document that can be used as a quick reference by Enbridge first-on-scene responders to select and implement containment and recovery tactics with Enbridge-owned oil spill response equipment during the first 72 hours of the response. It illustrates a collection of inland spill tactics that can be applied using obtainable resources to a liquid products release until additional resources and personnel arrive on site. This document is also placed on the emergencyresponderinfo.com site for use by first responders. Enbridge conducts periodic reviews of this document, and adjusts its tactics based on internal lessons learned and lessons from external agencies.

Additionally, Enbridge has specific, pre-identified Control Point locations along hydrologically-connected watercourses. A Control Point is a predetermined location from where spill containment and recovery operations may be conducted with the expectation of a high degree of success. Control Point information sheets recommend the optimum equipment and deployment techniques for that location, considering the river flow. Figure 2-1 depicts 12 downstream Control Points Enbridge has established along Little Otter Creek, St. Louis River, Spirit Lake, St. Louis Harbor and the western edge of Lake Superior. Pre-established Control Points enhance the response time and effectiveness for containment and recovery of released product into a watercourse. It should be noted, however, that a response is not limited by these pre-established Control Points. In the event of an actual release, containment and recovery/collection locations would be tailored to the environmental conditions and the specific location of the release to most effectively target containment and collection activities. This could result in Enbridge and its Oil Spill Removal Organizations (OSROs) deploying at Control Points and other locations.

2.4 Emergency Response Capabilities

Enbridge maintains a large cache of spill response equipment that can be mobilized in the unlikely event of a release. All Enbridge response personnel are field safety and response trained to meet the requirements of 49 CFR 194.117. These trainings including HAZWOPER, Incident Command System (ICS), Table Top Exercises, Full Scale Equipment Deployment Exercises, Dryland Equipment Training, Boat Operation, Oil Spill Response, and Winter/Ice Tactics. Winter tactics include the prevention of oil moving downstream using physical barriers (e.g. ice slotting and the insertion of plywood barriers) to form collection areas/points. Contracted OSROs have similar qualifications.

Additionally, Enbridge maintains ER equipment at locations along its ROWs. Major equipment available in Enbridge's Midwest Region includes:

- Command Post Trailers
- Response Boats
- Air Boats
- Amphibious Vehicles
- All-Terrain Vehicles
- Fixed-Wing Aircraft (Enbridge Enterprise-owned)
- Helicopters (Enbridge Enterprise-owned)
- Portable ATV Vacuum Units
- Heavy Construction Equipment
- Spill Response Trailers (includes winter equipment such as chainsaws, augers, plywood, etc.)
- Wildlife Response Trailers
- Containment Boom (Multiple sizes)
- Oil Skimmers (Multiple types and sizes)
- Temporary Storage Tanks
- WaterGate™
- Vacuum Trucks

The following Table 2-1 lists the nearest Enbridge locations where ER equipment is stored, as well as the approximate response time to Little Otter Creek.

Table 2-1 Proximate Enbridge Locations Where ER Equipment is Stored.

Location	Approximate response time to Little Otter Creek (Hours)	Containment & Recovery Equipment Type	Oil Skimmer Quantity
Superior, WI	1 Hour	• Response Boats • Amphibious Vehicles • All-Terrain Vehicles • Response Trailers • Vacuum Truck • Boom • Watergate™ • Winter ER equipment • Command Post Trailer • Submerged Oil Response Trailer	6
Bemidji, MN	3 Hours	• Response Boats • Amphibious Vehicles • All-Terrain Vehicles • Response Trailers • Vacuum Truck • Snow Mobile • Boom	16

Location	Approximate response time to Little Otter Creek (Hours)	Containment & Recovery Equipment Type	Oil Skimmer Quantity
		• Watergate™ • Winter ER equipment	
Ironwood, MI	3 Hours	• Response Boats • All-Terrain Vehicles • Response Trailers • Vacuum Truck • Boom • Winter ER equipment	5
Clearbrook, MN	4 Hours	• Response Boats • All-Terrain Vehicles • Response Trailers • Vacuum Truck • Boom • Winter ER equipment	3
Vesper, WI	5 Hours	• Response Boats • All-Terrain Vehicles • Response Trailers • Vacuum Truck • All-Terrain Vacuum Unit • Boom • Watergate™ • Winter ER equipment	2
Thief River Falls, MN	5 Hours	• Response Boats • All-Terrain Vehicles • Response Trailers • Vacuum Truck • Snow Mobile • Boom • Winter equipment	3
Ft. Atkinson, WI	6 Hours	• Response Boats • All-Terrain Vehicles • Response Trailers • Vacuum Truck • All-Terrain Vacuum Unit • Boom • Watergate™ • Winter ER equipment • Submerged Oil Response Trailer	12

Recovery capacity volumes and effectiveness for various response equipment (e.g., oil skimmers and boom) employed by Enbridge have been rigorously tested at the Oil and Hazardous Materials Simulated Environmental Test Tank (Ohmsett) in Leonard, New Jersey. The National Oil Spill Response Research & Renewable Energy Test Facility provides independent and objective performance testing of full-scale oil spill response equipment and helps improve technologies through research and development. Ohmsett uses American Society for Testing and Materials standards F-2084—01 Standard Test for Determining Nameplate Recovery Rate of Stationary Oil Skimmer Systems. Data has been compiled into a "World Catalog of Oil Spill Response Products" published by SL Ross Environmental Research Limited (SLRoss, 2013; 2017). Along with the standardized recovery capacity listed by Ohmsett testing, the recovery capacity of oil skimmers in use by Enbridge have further been simulated for the L3RP by previous modeling conducted by RPS at the Mississippi River at Palisades in Dr. Horn's Rebuttal Testimony, Schedule 2.

In addition to the ER equipment owned by the company, Enbridge also has OSROs under contract to support an Enbridge response both in the field and managing the incident. OSROs have the ability to add equipment to the response and provide the required capacity to scale the response efforts for the conditions encountered. In addition to having an OSRO of record (a PHMSA requirement), OSROs typically employed by Enbridge include:

- Marine Spill Response Organization
- The Response Group (for ICS)
- SWAT
- Bay West
- Beltrami Industrial
- T&T Marine
- Marine Pollution Control
- Minnesota Limited

2.5 Emergency Response Tactics

In the unlikely event of a release into Little Otter Creek, there are a range of tactics that Enbridge and its contracted OSROs can deploy based on the conditions of the various sites. Tactical response measures for containment and recovery/collection of released product from within watercourses can vary depending on the specific conditions present at the time of release including: watercourse depth, flow speeds and type, substrate of the watercourse, access, product type and amount, weather conditions, etc.

Overall, Enbridge's response tactics for Little Otter Creek would focus on the containment and recovery of oil prior to the released product reaching the St. Louis River. However, response plans are not limited to just Little Otter Creek, and operations would be conducted at additional downstream containment and recovery locations.

2.5.1 Recovery Methods

Generally, there are three main types of oil spill response methods: mechanical recovery, non-mechanical recovery, and manual recovery.

1. Mechanical recovery: oil is contained using a conventional boom, physical barrier or within a hydraulic stall, and mechanical skimmers are used to remove the released product from the surface of the water.
2. Non-mechanical recovery: in situ-burning or biological remediation are used to degrade an oil slick.

3. Manual recovery: the use of shovels, rakes, buckets, nets and other means to remove the oil.

Mechanical recovery of released product has been determined to be the most effective and appropriate response method for the unlikely release of product from Line 3 Replacement that would affect a watercourse. While response conditions can vary as described in the paragraphs below, Enbridge has equipment to address each of the conditions, plus the addition of available OSRO equipment if required.

2.5.2 Small Watercourse Response (Little Otter Creek)

Small watercourses, as described in the Inland Spill Tactics Guide, are usually characterized by a combination of shallow depth (< 1.6 ft), narrow width (< 33 ft), and low current velocity (< 1 knot). Tactics that are typically implemented in small watercourses rely on man-made fixtures that either halt the flow of surface water while allowing underflow to continue, or in extreme cases can halt the entire flow of the watercourse by completely blocking the flow. Tactics that are successful in containment and recovery of small watercourses for which Enbridge has the equipment include the following:

- Stream Dams: Water Bags, Aqua Dams™, Tiger Dams™, WaterGate™ and earthen material.
- Weirs: Inverted Weir dams, Board Weirs, Turner Valley Gates, Culvert Weirs and filter fence.
- Boom: Creek Boom.

The simplest form of a stream dam involves placing earthen material (typically clay) within a small watercourse to block the entire flow of the watercourse. Water bags are made from a non-permeable fabric bladder, filled with water and held in place across a watercourse. Aqua Dams™ are made of multiple parallel chambers called fill tubes which give the dam more stability against shifting within a watercourse. Similar to an Aqua Dam™ a Tiger Dam™ utilizes multiple water tubes for increased freeboard and resistance to sliding, but unlike the Aqua Dam™ a Tiger Dam™ can use individual units which are strapped together after placement. A WaterGate™ is an open self-filling barrier that relies on the hydrostatic pressure differential to provide a bottom seal to the substrate.

Weirs installed within a watercourse allow for subsurface flow of water. Due to the specific gravity and chemical properties of released liquid hydrocarbons, the released product tends to float on the upper surface of the water column. A weir stalls the flow within the upper surface of the watercourse while allowing the subsurface flow to proceed past the weir. This tactic allows for control of the watercourse flow and height which can prevent back flooding within the watercourse. Inverted weir dams can be created with earthen material (or prefabricated weirs) to create the channel block and underflow pipes are installed during construction to allow for subsurface flow. Board Weir's, Turner Valley Gates and culvert weirs operate in a similar manner by placing an impermeable membrane within the upper surface of the water column while allowing subsurface flow to continue. In areas where the concentration of oil is limited a filter fence can be employed as a tactic to contain small quantities of released product within a small watercourse. A filter fence is constructed using a semi-permeable membrane or sorbent materials that allows for oil to adhere to the membrane while permitting water to flow through.

Conventional boom is specifically engineered in various sizes, including smaller boom designed specifically for use in smaller watercourses. Boom can be efficiently and effectively deployed rapidly within small watercourses due to the limited personnel and equipment requirements for deployment.

Enbridge would respond along Little Otter Creek at the planned Control Points and in any locations that would be found suitable to implement the tactics described above. The Inland Spill Tactics Guide included as Attachment 1 further describes and illustrates each of these tactics. The goal of these efforts would be to ensure the containment and recovery of oil prior to it reaching the turbulent, fast water downstream and onward to the St. Louis River and Lake Superior.

2.5.3 Large Watercourse Response (St. Louis River)

Larger watercourses are those where any combination of water depth, watercourse width, or current velocity would make the installation of bottom-founded or rigid structures impractical. The tactics for larger watercourses rely on the installation of flexible, floating barriers to redirect or divert surface contamination from sensitive areas or towards areas of hydraulic stalls where slower velocities allow for collection of the product. Shoreline protection will also be employed using shoreline booming tactics.

Skimmers are used in the mechanical recovery tactic whereby they remove the oil from the surface of the water. Skimmers are mechanical devices that physically remove oil from the surface of the water. Skimmers are grouped into two main categories (oleophilic and non-oleophilic). Oleophilic skimmers are manufactured using materials in which the oils have an affinity towards, non-oleophilic skimmers are typically weir type skimmers that are adjusted to function just below the interface between the oil and water. The Inland Spill Tactics Guide (Attachment 1) provides additional description and illustrations of these tactics.

2.5.4 High Velocity and Turbulent Water Response (sections of the St. Louis River)

Tactics would be employed in areas where watercourse characteristics would permit for safe and effective containment and recovery conditions. Exclusionary booming along sensitive areas would be employed to prevent released product from entering particularly sensitive areas, with the intent to contain and recover the released product further downstream where conditions are more favorable. The goal of deflection booming is to divert surface oil away from sensitive areas and recover the released product downstream at low-velocity and turbulent areas such as back eddies where it can be successfully contained and recovered.

2.5.5 Open Water Response (Spirit Lake, St. Louis Harbor, Lake Superior)

An assortment of open water containment and recovery tactics can be employed for large open water systems. Methods include containment utilizing lake boom and open water skimming tactics. Lake boom is specifically designed for oil containment in large open water systems. Open water skimming can utilize lake boom, skimmers and various boat configurations to perform sweeps throughout the slick to contain and recover the released product. In addition to conventional sweep tactics specialized equipment such as a NOFI Current Buster® can be used. A Current Buster® is currently the most effective oil spill response equipment for towing in open water sweeps at speeds up to 5 knots. Current Busters®, which are part of Enbridge's equipment inventory, are suitable for a wide variety of oil types, and are unique to the inland waterways. These tactics are further described and illustrated in the Inland Spill Tactics Guide (Attachment 1).

The stretch of water between Spirit Lake and Lake Superior is suitable for deployment of Open Water, Large Watercourse, and Small Watercourse Response tactics. In addition to the pre-established Control Points, numerous areas within this stretch could be utilized as containment and recovery locations, such as the small bays, inlets, and manmade structures, to corral, contain, and recover oil before it reaches Lake Superior.

2.5.6 Submerged Oil Response

In the unlikely event of a release that could lead to submerging and/or sinking oil, Enbridge would implement its own Submerged Oil Management Program (SOMP). A copy of the SOMP is provided as Attachment 2. The aim of this program is to limit and/or completely avoid oil from submerging into the water column and/or avoid submerged oil from falling out of the water column and into sediment. This Program would be used in conjunction with the Inland Spill Response Tactics Guide.

The early implementation of submerged oil tactics can greatly limit the amount of oil that sinks to the sediment layer. Submerged oil tactics capture submerged oil out of the water column before it sinks, which would eliminate or decrease the amount of potential dredging needed for remediation and thereby materially reduce the resources and time necessary to remediate a release. As shown in Attachment 2, some of the specific tactics include the use of Filter Fences or Gabion Baskets filled with sorbent materials, and/or the addition of filter curtains (X-Tex material) attached to the bottom of boom. This equipment along with others are part of Enbridge’s Submerged Oil Response trailers that are found in each region in the U.S. and Canada. The containment and recovery techniques established in the Enbridge SOMP aligns with the American Petroleum Institute (API) technical report for sunken oil recovery (API 2016).

Enbridge would manage the response to a submerged oil incident like any other response, using ICS with potentially a Submerged Oil Branch formed as part of the Operations Section. The Submerged Oil Branch is comprised of response personnel who would focus their efforts in the deployment of applicable tactics to locate and capture submerged oil.

2.5.7 Response Management, Coordination & Liaison

All Enbridge operational regions have multiple individuals identified for key leadership positions on the Incident Management Teams that are trained in the ICS positions for which they are assigned. The use of ICS allows Enbridge to work together with local, tribal, state, and federal agencies within a unified command structure to ensure any emergency is carefully coordinated and planned, and with input from all participating agencies. The employment of ICS also ensures Enbridge is able to inform the public on what is occurring via a Public Information Officer and a Liaison Officer, with the latter liaising with all potentially impacted third party agencies not part of unified command (e.g., dam operators).

2.6 Estimated Response Effectiveness

The hypothetical full-bore pipeline rupture that is considered and modeled in later sections is extremely unlikely. In addition, the completely unmitigated nature of the hypothetical scenario is beyond a credible worst-case scenario, in that it maximizes the potential release volume and does nothing to mitigate the downstream movement or limit the potential effects (i.e., contain and collect the release described above). Enbridge and its OSROs have numerous caches of response equipment and trained and capable responders nearby such that, in the unlikely event of a release, Enbridge has the ability to contain and recover the released product prior to the product entering the St. Louis River.

3 MODELING OF OIL RELEASES

Hypothetical releases of crude oil were modeled downstream from the L3RP crossing of Little Otter Creek using the OILMAPLand and SIMAP computation models that have been developed by RPS (Figure 1-2). This section contains a high level description of the computational models used for different scenarios (Sections 3.1.1 and 3.1.2, respectively), the key assumptions made for these simulations (Section 3.2), and the input data sources, processing, and assumptions for environmental and chemical data (Section 3.3). Sections 3.1.1 and 3.1.2 are abbreviated, as these sections discuss the OILMAPLand and SIMAP models, which were described in detail within the AAR (Stantec et al. 2017). Section 3.3 includes a full set of geographic and environmental input parameters for the hypothetical release site at Little Otter Creek. Trajectory and fates results are presented in Section 4 for this site, organized by crude oil type released and then season.

3.1 Brief Description of Modeling Tools

Large releases of crude oil from the pipeline were simulated for the Little Otter Creek release site using a combination of the OILMAPLand and SIMAP computation models. Because Little Otter Creek and Otter Creek are small watercourses, the 2-dimensional OILMAPLand model was sufficient to capture the movement and behavior of oil within these watercourses. However, once Otter Creek enters the St. Louis River, the 3-dimensional SIMAP model was used to characterize the movement and behavior of oil in this larger and more dynamic watercourse.

Modeling of large releases of crude oil at Little Otter Creek provided quantitative predictions of the trajectory and fate of released oil under a range of environmental conditions (in-stream flows and seasons) and a range of crude oil types (i.e., light and heavy crude oils). Information on the trajectory and fate of crude oil for these hypothetical releases was used to assess a wide range of potential effects on key receptors under different seasonal flow conditions and with light and heavy crude oils. The assessment of potential environmental effects included site-specific assessments of potential effects on environmentally-sensitive areas (e.g., HCAs and AOIs; Sections 5.1.2 and 5.1.3), and on key receptors.

Seasonal variations in river flow rate, temperature, wind speed, and snow and ice cover are expected at Little Otter Creek and would affect the trajectory and fate of a crude oil release. Because river discharge controls the downstream velocity of water and, therefore, the potential transport of oil, a hydrologic analysis was conducted to characterize seasonal differences for the hypothetical release site. Historical stream discharge (flow) data was used to determine the monthly average flow rate. The seasonally appropriate environmental conditions that would be present during each month were then identified for use in modeling. The combination of multiple environmental conditions and oil types modeled at Little Otter Creek provide a realistic range of anticipated seasonal conditions upon which to base the hypothetical release scenarios. The three seasons modeled bound the range of likely conditions spanning high to low river flow rate, temperature, ice cover, and wind speed.

Months representing the average, maximum, and minimum river flow rates were identified, and the corresponding temperatures and wind speeds during those seasons were used in the modeling. The average annual river flow rate was considered representative of baseline conditions. As the mean annual flow can occur in two seasons (typically observed around summer and fall), the period with the warmest temperature (i.e., late July and August) was selected to represent the maximum amount of evaporation, potentially resulting in the largest exposure to hydrocarbon vapors in air as a potential trigger for human health effects. The month with the highest flow rate represented the spring freshet (i.e., a spring thaw and increased river flow rates during April), a result of rising temperatures and snow and ice melt. The month with the lowest flow rate represented the winter (i.e., January), and was typified by freezing conditions and probable snow cover on land and ice cover on water. The three modeled seasons bound the range of likely conditions, spanning high to low river flow rate, temperature, ice cover, and wind speed.

3.1.1 OILMAPLand

OILMAPLand is a two-dimensional modeling system that is used to simulate the movement of released oil in the environment. It simulates the flow of oil over land as it travels over the land surface and into a surface water body. The model itself has three components, including an overland release model, a surface water transport model, and an evaporative model that describes the weathering of oil in the environment under specified conditions. The outputs include an assessment of the expected overland and downstream trajectory of crude oil and resulting locations (e.g., shoreline reaches or segments) where oil may be found at specific times following a release. A simplified mass balance is provided to determine how much oil is retained on land, evaporates, is on the water surface, or adhered to shorelines. The trajectory results from OILMAPLand can be used in an HCA and AOI analysis, which consists of overlaying the presence of oil onto specific identified regions of interest to determine which resources potentially may be affected. In addition, OILMAPLand outputs can be used to initialize SIMAP, when oil may have overland or downstream trajectories within small watercourses before entering a larger watercourse. A detailed description of the OILMAPLand model was provided in the AAR (Stantec et al. 2017).

OILMAPLand was used to simulate the downstream trajectory of a release into Little Otter Creek. The trajectory and fate of the hypothetical releases of crude oil into the creek were modeled based upon the assumption of a full bore release and drain down of the pipeline near Little Otter Creek (13,007 bbl or 2,068 m^3). As with the other seven representative sites, the maximum volume of oil hypothetically released at this representative site included both the initial release volume prior to shutdown (i.e., actively pumping oil for 10 minutes), followed by a 3-minute period for valve closure (shutdown), and then hydraulic drain down of the pipeline (i.e., gravity drained oil within the pipeline between the valves), following isolation and shutdown at the site. The specific volume of oil released at Little Otter Creek is described in Section 3.2.3.

As with the other representative sites, three seasonal and environmental conditions and two oil types were modeled. The three seasons included high, average, and low river flows that represented spring, summer, and winter conditions, respectively. Two oil types were Bakken crude and CLB (Section 3.2.5). The chemical and physical parameters of CLB were varied between warmer conditions (Cold Lake Summer Blend [CLSB] was used for spring, summer/fall conditions) and winter months (CLWB was used) to represent changes in the composition of the oil over the course of a year.

For each of the three flow-defined seasons, scenarios for the hypothetical oil releases were run under the corresponding environmental conditions including temperature, wind speed, the concentration of total suspended solids within the water column, etc.

3.1.2 SIMAP

SIMAP is a three-dimensional modeling system that is used to simulate the physical fates of crude oil in the water. It estimates the distribution (as mass and concentrations) of whole oil and components of oil on the water surface, on shorelines, in the water column, in sediments, and evaporated to the atmosphere. This comprehensive modeling system allows for a more in-depth understanding of the behavior of oil in the environment, when compared to OILMAPLand. Oil fate processes included in SIMAP are oil spreading (gravitational and by shearing), evaporation, transport, randomized dispersion, emulsification, natural entrainment, dissolution, volatilization of dissolved hydrocarbons from the surface water, adherence of oil droplets to suspended sediments, adsorption of soluble and sparingly-soluble aromatics to suspended sediments, sedimentation, and degradation.

The outputs of the SIMAP physical fates model include the distribution of the released crude oil in three-dimensional space and time. This can include instantaneous snapshots and cumulative areas covered by a thickness of oil on the water surface, volumes of water at various concentrations of dissolved aromatics and total hydrocarbons, masses of total hydrocarbon and aromatics on sediments, and the length and location of shorelines affected by oil. A detailed description of the SIMAP model was provided in the AAR (Stantec et al. 2017).

3.1.3 Combined Modeling Approach

A combined modeling approach was used for the hypothetical release at Little Otter Creek using both OILMAPLand and SIMAP. OILMAPLand was used to provide the timing and volume of oil that was predicted to move down Little Otter Creek and Otter Creek to reach the St. Louis River, while SIMAP was used to provide detailed three-dimensional predictions of surface oil thickness, shoreline and sediment oil mass, and in water contamination at points downstream towards Lake Superior. The effects of potential releases into riverine environments were modeled based on the assumption of a full bore release. The same three seasonal and environmental conditions and two types of crude oil modeled in the OILMAPLand portion were continued and modeled within the SIMAP portion of the assessment. The output from OILMAPLand included the timing and amount of oil that was predicted to reach the St. Louis River. These values were then used as inputs to initialize the SIMAP model.

3.2 Key Assumptions

The OILMAPLand and SIMAP modeling was based on a number of assumptions relating to the type of release event (i.e., full bore rupture, release of oil into watercourses), the type and volume of oil released, the duration of the release and subsequent downstream movement prior to mitigation (i.e., 24 hours), and the types of crude oil released. Each of these are discussed below.

3.2.1 Full Bore Rupture is an Unlikely Event

A full bore rupture means that the pipeline is severed or burst, such that the opening is equivalent to the cross-sectional area of the pipe (regardless of the mechanism leading to the rupture) and crude oil is assumed to spill freely from this opening. By design, and as a result of Enbridge's pipeline operation and maintenance programs (Enbridge 2014), a full bore rupture pipeline incident is considered to be a highly unlikely event. The selection of full bore, and the calculation of release volumes based on a full bore rupture, is therefore a highly conservative assumption.

3.2.2 Crude Oil Release Volume

The environmental effects of a hypothetical full bore pipeline rupture were evaluated for a hypothetical release site at the Little Otter Creek crossing. It was conservatively assumed that released oil would enter directly into the watercourse with no retention of oil on land. These circumstances would produce a scenario where the entire estimated volume of released crude oil would enter the aquatic environment close to the point of release. Making the assumption that the damage to the pipeline occurred near a topographic low point maximizes the hypothetical release volume (due to drain-down of the pipeline following the initial volume that was released under pressure before the pipeline was shut down), but also implies that the hypothetical release occurred in proximity to a watercourse. This is a conservative assumption, due to the potential for watercourses to effectively and rapidly transport released crude oil away from the release location.

The hypothetical release scenario is modeled such that a change in pipeline flow characteristics due to the rupture would be detected at the Control Center and the pipeline would be shut down (see next paragraph). For the purposes of this analysis, it is assumed that the location of the full bore rupture would be at a low point (e.g., in proximity to a watercourse) between two control valves, and that oil would continue to drain by gravity from the pipeline, between the location of the rupture and the nearest valves.

The crude oil release volume was calculated as a full bore rupture, with a conservative response in the pipeline Control Centre of a maximum of 10 minutes, followed by a 3-minute period to allow for valve closure, and then drain-down of the elevated segments of pipeline; the same assumption was used for each of the other seven representative locations. The maximum 13-minute duration of Control Center response time to valve closure is a standard for safe operations and leak detection for Enbridge. This includes the combination of identification of the rupture, analysis of the pipeline condition, pipeline shutdown and full valve closure in the affected pipeline section. While 13 minutes is the maximum time, this is a conservative assumption, since a response through to valve closure would be expected to occur in less than 13 minutes in a full bore rupture leak scenario. The maximum volume of oil that could be hypothetically released from the L3RP at the Little Otter Creek modeling site, based upon the 13-minutes noted above, is 13,007 bbl (2,068 m^3).

The release duration is the amount of time required for the total released oil volume to be released from the ruptured pipeline (including drain-down, which can continue minutes to hours following shut-down of the pipeline). The OILMAPLand and SIMAP modeling systems used a constant release rate based upon the defined total release volume and duration of release. The release duration was calculated using the release volume, pipeline diameter, pipeline shutdown time, pipeline design flow rate, and elevation profile of the pipeline.

3.2.3 24-hour Unmitigated Oil Release

The analysis was carried out following a highly conservative assumption that the release would be unmitigated for 24 hours, and that the released crude oil would travel downstream unimpeded for that length of time. This is a conservative assumption because Enbridge would mobilize a response that would contain and collect oil in the event that a release was detected (Section 5.0). The 24-hour time frame is roughly consistent with guidance from the U.S. Environmental Protection Agency (USEPA), which stipulates a 27-hour period, representing 24-hours for arrival and 3-hours for deployment (USEPA 2003). As such, modeled results should not be interpreted as representative of expected effects, but rather as an unlikely, unmitigated worst-case potential outcome.

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 unmitigated for the modeled 24 hour period (i.e., no benefits of emergency response operations were incorporated into the model). In a real-life scenario, emergency response procedures would be expected to be initiated sooner than 24 hours (Section 2.0) and would help mitigate the effects of the modeled incidents (Section 5.0).

3.2.4 Crude Oil Types

The range of product types expected to be shipped in the L3RP may range from light crude oils such as those in the Alberta Light Sweet Crude category, to heavy oils such as conventional heavy crude oils and diluted bitumen products. The physical and chemical characteristics of light and heavy crude oils are quite different, although the characteristics of diluted bitumens are similar to those of heavy conventional crude oils (Zhou et al. 2015). Therefore, two crude oil types were selected for their representative characteristics and conservatively high potential for effects to serve as the basis for the analysis. The two oil types include Bakken Crude Oil (a light conventional crude oil with a high aromatic content) and CLB (a diluted bitumen). As the chemical and physical characteristics of the CLB will vary seasonally, CLSB and CLWB were considered in the modeling of hypothetical releases. CLSB was used for spring and summer scenarios, while the CLWB was used for winter scenarios. The oil types and the chemical and physical characteristics of each used in the modeling are identical to those used in the previous assessment and are detailed in Section 5.3.1 of Stantec et al. (2017).

3.3 Input Data Sets

The OILMAPLand modeling system was used to predict the trajectory and fate of hypothetical large releases of crude oil from the crossing of Little Otter Creek down to the St. Louis River. From there, the SIMAP modeling system was used throughout the St. Louis River towards Lake Superior. The two modeling systems require different sets of inputs to define the geographic and environmental conditions.

The list of inputs is extensive, including elevation, shore types, velocity, wind, temperature, and snow and ice for OILMAPLand and geographic and habitat data, river depth, hydrodynamics, watercourse features (rapids, dams, waterfalls, etc.), wind, temperature, and ice cover for SIMAP. The following sections include site- and season-specific data for the hypothetical release cases at Little Otter Creek. For full detail on the background behind each input characterization can be found in Sections 5.3.2 and 5.3.3 of Stantec et al. (2017).

3.3.1 OILMAPLand

3.3.1.1 Elevation Data

The OILMAPLand model uses land elevation data to determine the overland pathways of releases occurring in the terrestrial environment. The elevation data are stored in a grid (raster) format and the model calculates the down slope pathway by determining the direction of steepest slope, as the leading edge of the release moves from grid cell to grid cell.

The ability of the model to accurately determine the overland release pathways is in large part controlled by the vertical and horizontal resolution of the elevation grid.

The horizontal resolution refers to the size of the individual grid cells of the elevation data in north-south and east-west directions. As the horizontal resolution increases it is possible to include smaller terrain features in the elevation data in the OILMAPLand model. This may include roads, ditches, and other smaller-scale features. As each horizontal grid cell is assigned a single elevation value, small-scale features can be flattened or smoothed in the larger grid cell and have limited effects on the elevation, especially when the resolution of the horizontal elevation data is coarse.

The vertical resolution refers to the level of precision available for each cell’s elevation value. Sub-meter precision is critical for accurate modeling of flow over a land surface. Without the small sub-meter variations in the elevation surface, larger areas of no apparent elevation change may be present. In this case, the surface flow model will have greater difficulty in determining an overland flow direction, as multiple cells need to be crossed to find the downslope gradient.

Elevation data was obtained from the United States Geological Survey (USGS) National Elevation Dataset (NED) (USGS 2015). These data have 1 arc second (approximately 98.4 ft [30 m]) horizontal resolution and were primarily used as a reference for the topography surrounding the Little Otter Creek. The land elevation map for the portion of Little Otter Creek modeled in OILMAPLand are presented below (Figure 3-1).

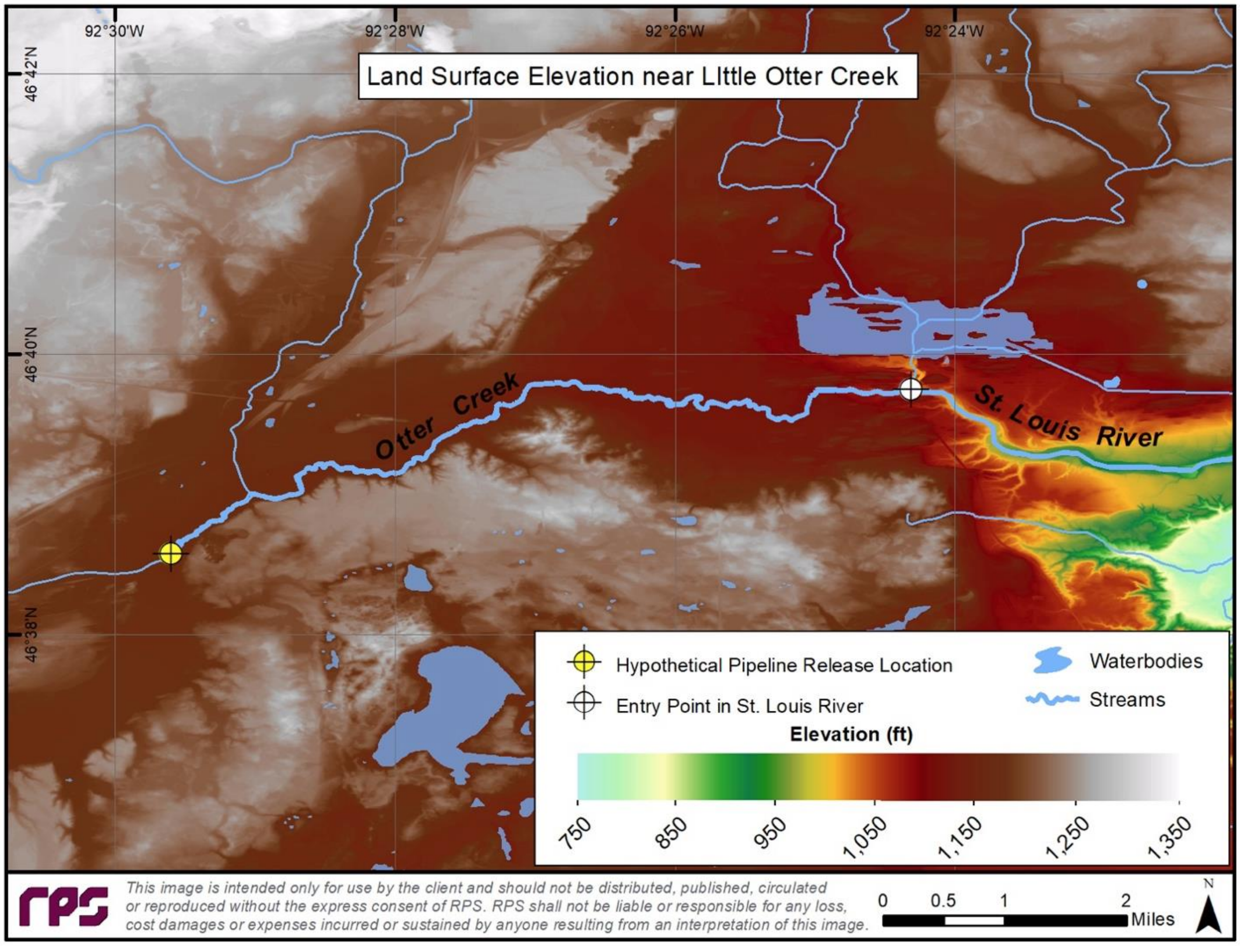

Figure 3-1 Land Surface Elevation (m) for the Little Otter Creek Release Location down to the St. Louis River.

3.3.1.2 Physical Data for Watercourses

The OILMAPLand model uses data for networked streams and lakes to model the pathways of oil once it reaches surface water. Streams and rivers are represented in the model as a polyline feature of the stream centerline, which has been digitized according to the flow direction. The streams must be networked in a way such that the model can determine where each single stream segment joins the next, as the downstream movement of oil is modeled. Lakes are represented as polygon features and connect to the streams that both feed and drain them, as appropriate.

Each individual stream segment has its own defined stream velocity and width. Therefore, the model calculates an appropriate downstream transport as a river or stream changes. As an example, a section of a river may widen and slow, and be followed by a narrower and faster reach. The OILMAPLand model uses the location specific river velocity to more accurately model the oil pathway and fate in the stream network.

Physical data for watercourses were derived from multiple sources. Stream centrelines, stream polygons and lake polygons were derived from the USGS high resolution National Hydrography Dataset (NHD) (USGS 2014). This data provides geospatial vector data, at a 1:24,000 scale, describing hydrographic features such as lakes, reservoirs, rivers, streams and canals in the form of a linear drainage network. Stream centerlines, networking, and flow information was used from the USEPA's NHDPlus version 2 data (NHDPlus v2; Horizon Systems 2012). NHDPlus integrates the USGS's medium resolution (1:100,00 scale) NHD, the 1/3 arc-second resolution National Elevation Database (NED), and National Watershed Boundary Dataset (WBD) to improve stream networking information and estimate stream flow and velocity for every stream segment.

NHDPlus includes an estimated monthly and annual average stream flow rate and velocity for each stream segment. Flow is estimated using the Extended Unit Runoff Method (EROM). This method determines flow based on estimate of accumulated runoff based on the elevation data, evaporative loss, and various adjustments based on gages in the region. The velocities are calculated based on the estimated flow using the Jobson Method (Jobson 1996).

The stream centerline network was originally extracted for each river from the NHDPlus network to maintain the networking and flow and velocity information found there. The stream centerlines were adjusted to be more accurately aligned using the NHD high-resolution stream centerlines, as well as aerial photography. Stream widths were measured for each stream segment based on aerial photographs. Photographs and width measurements from site visits by Stantec during July 2019 were also referenced when determining stream widths.

River velocity varied between seasons for the Little Otter Creek hypothetical release site (Figure 3-2). The mean monthly river velocities for the identified seasons/months are presented in Table 3-1. Of note, these average velocities were 0.30, 0.37, and 0.48 meters per second (m/s) for low, average, and high river flow conditions, respectively. In general, velocities were much slower (e.g., 0.1 m/s, as observed in July of 2019) throughout Little Otter Creek and at locations near the hypothetical release site. However, streamflow increases greatly within the last mile (1.5 km) of the waterway as the watercourse narrows and becomes rockier. This section of stream falls approximately 118 ft (36 m) in elevation by the time it enters the St. Louis River. Therefore, the lower portion of the creek skews the reported average velocity to slightly higher values than would be observed over large portions of the creek.

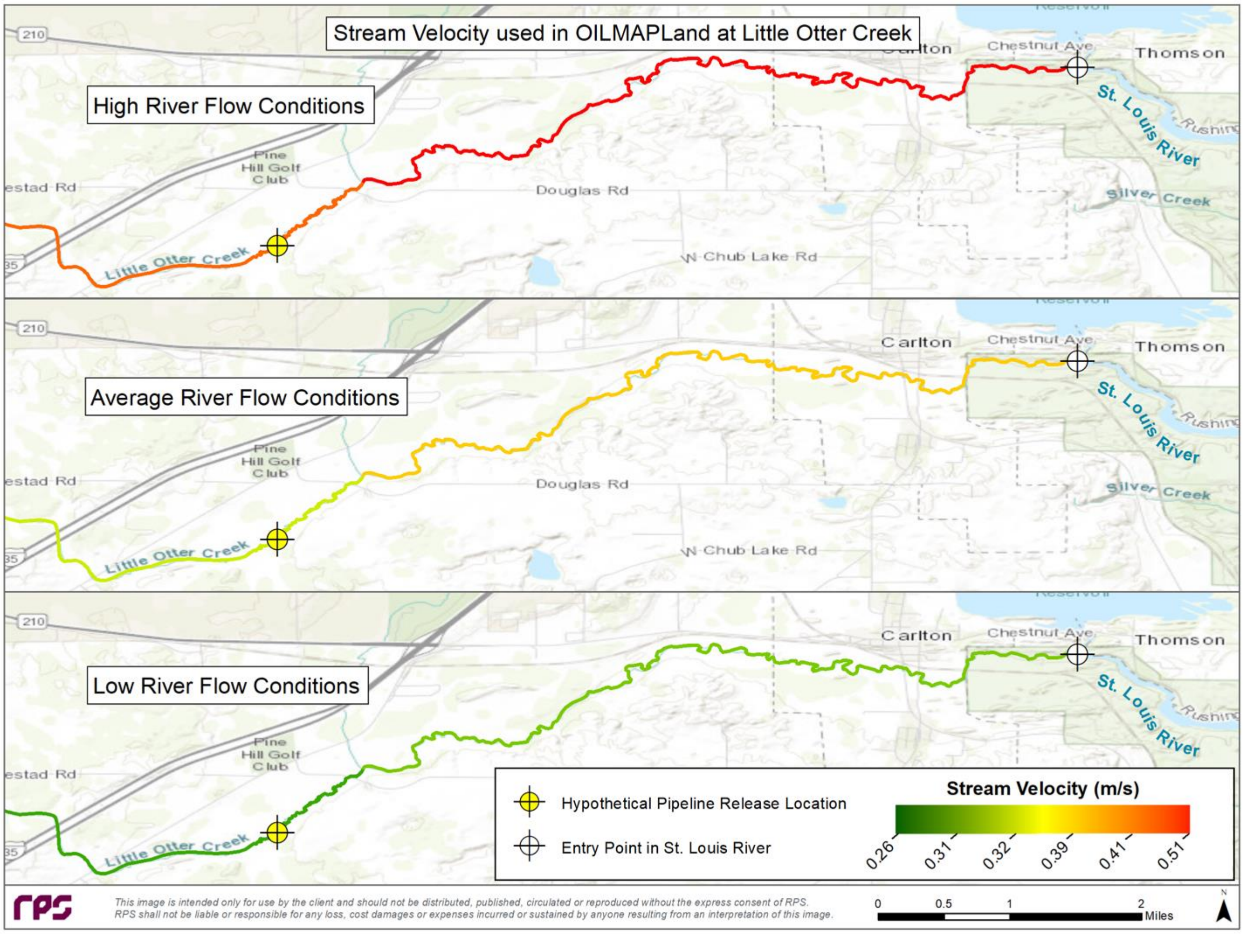

Figure 3-2 Stream Velocity Modeled Under High (top), Average (middle), and Low (bottom) River Flow Conditions for Little Otter Creek in OILMAPLand.

Table 3-1 Mean River Velocity (m/s) Used as Model Inputs for the Seasonal Scenarios Modeled at Little Otter Creek in OILMAPLand.

Case #	Release Site	River Flow	Season	Corresponding Month	Average River Velocity (m/s)
8	Little Otter Creek	Low	Winter	January	0.30
		Average	Summer	Late July/August	0.37
		High	Spring	April	0.48

3.3.1.3 Land Cover and Shoreline Type

The OILMAPLand model uses land cover data to vary the amount of oil that adheres to the land surface as oil moves down slope. The land cover data are used in a gridded format, with each grid cell value representing the type of land cover at that specific location. Land cover code values are then matched to the categories that define oil retention, so that the loss by retention can be accurately calculated as oil flows over the land surface.

The land cover data used was the National Land Cover Database ([NLCD] 2011), created by the Multi-Resolution Land Characteristics Consortium (Homer et al. 2015). The NLCD 2011 is based on a decision-tree classification of 2011 Landsat satellite data with 30-m resolution. For a full description of the mapping used to convert the NLCD 2011 land cover categories to OILMAPLand classification scheme and shoreline retention values applied for both oils and multiple shore types, please refer to Stantec et al. (2017, Section 5.2.3.2).

Stream shore types were also determined based on aerial photographs and land cover data (Figure 3-3), as well as reconnaissance surveys undertaken by Stantec in July of 2019. The average river flow scenario used the visible shore types (predominantly sand/mud and rock), while high flow scenarios assumed the shore type of the surrounding land cover above the stream bank. For low river flow conditions, the shore type was assumed to be ice. Lake polygons were derived from the high resolution NHD dataset.

Shore type modeled for Little Otter Creek is provided by season in Figure 3-4.

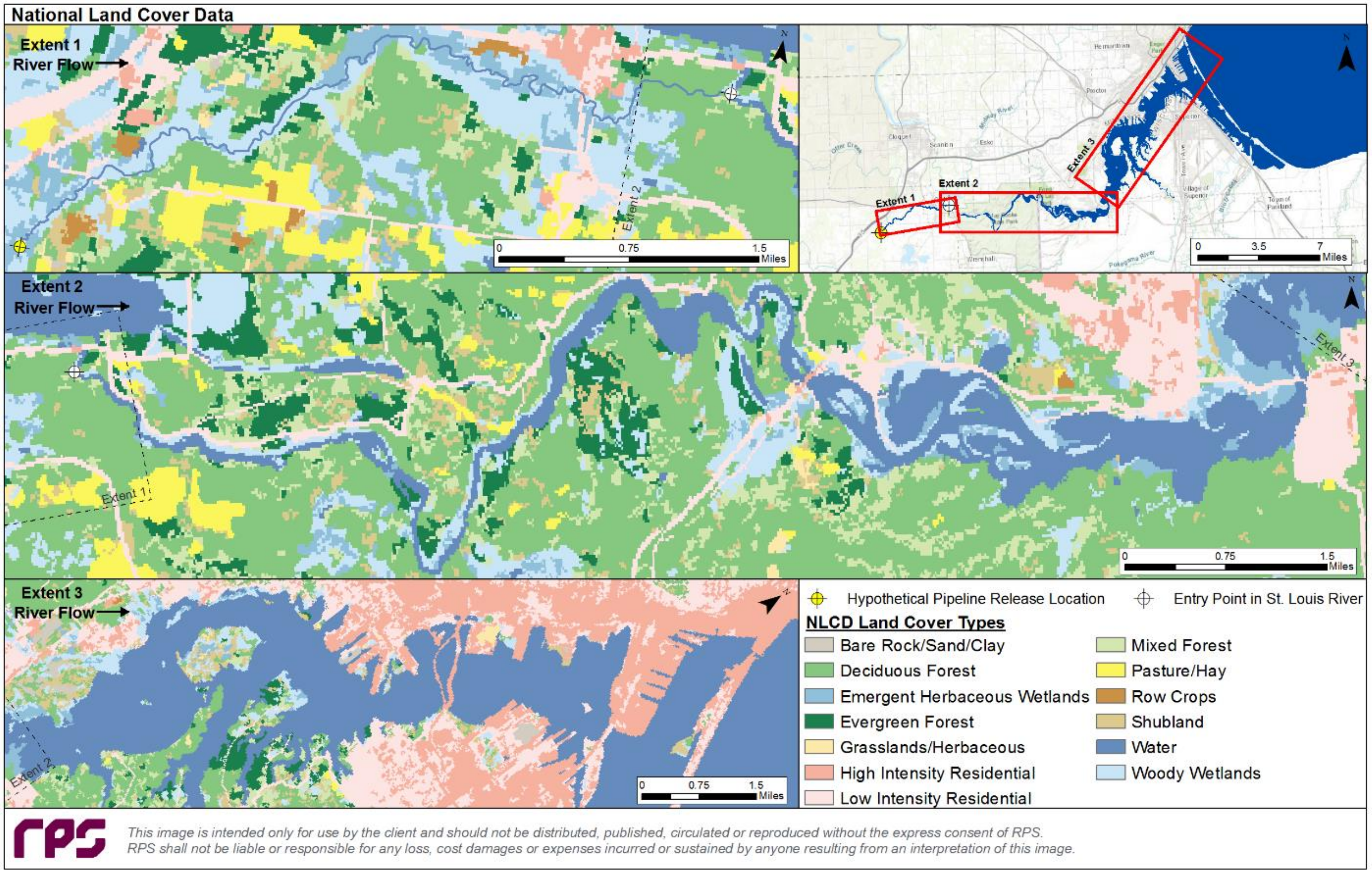

Figure 3-3 Land Cover Data used in Classifying Shore Type under High River Flow Conditions for Little Otter Creek in the OILMAPLand and SIMAP models.

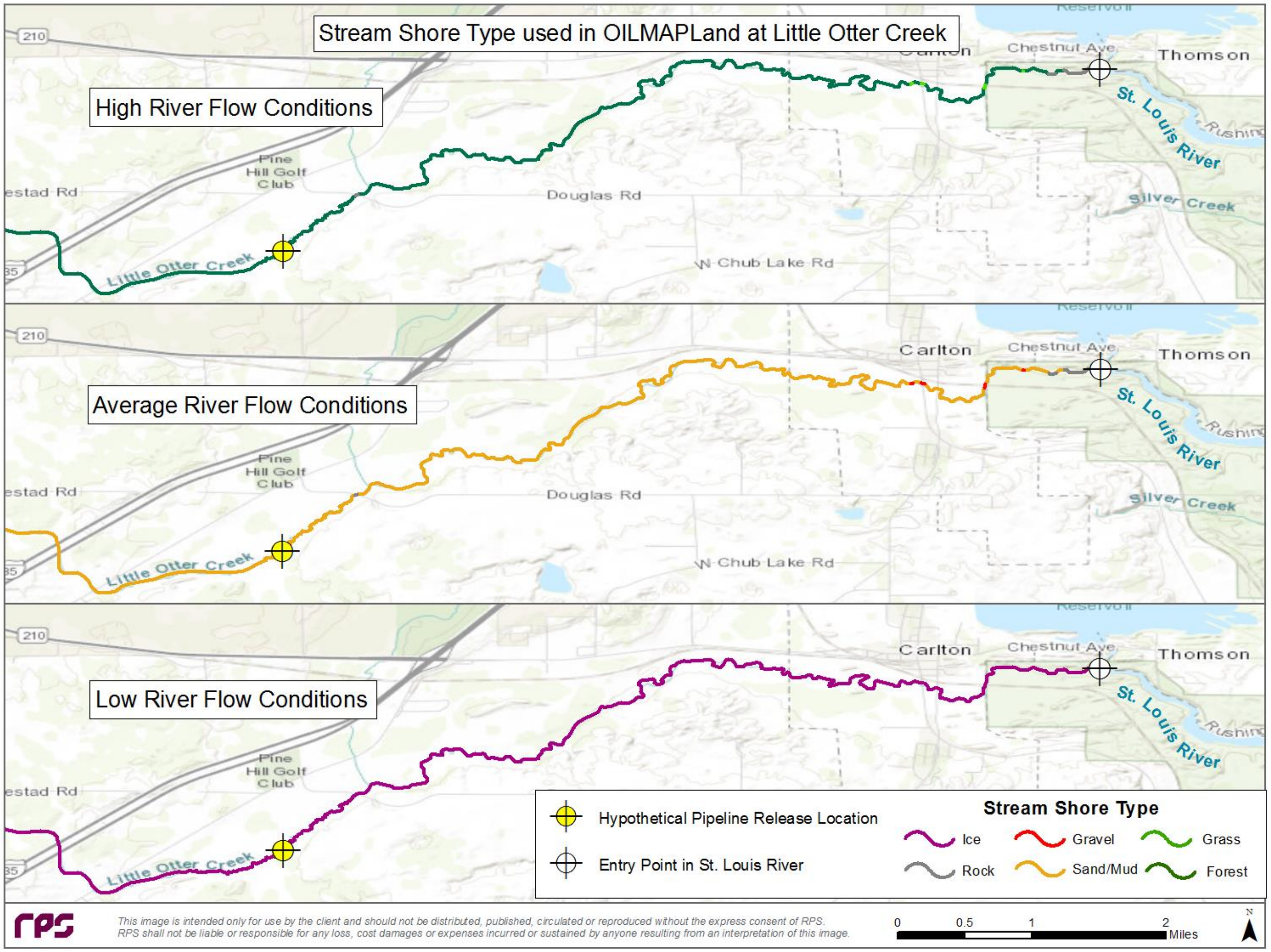

Figure 3-4 Stream Shore Type Modeled Under High (top), Average (middle), and Low (bottom) River Flow Conditions for Little Otter Creek in OILMAPLand.

3.3.1.4 Wind and Temperature Data

Daily climatological statistics consisting of wind speed and air temperature were obtained from the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information website (NOAA 2016a). The preliminary climate datasets consist of two parts:

- Site information: the station location (latitude/longitude) and the month and year of the report
- Monthly averages and totals for the month

The available data for both air temperature and wind speed between 2010 and 2015 were averaged by month. Release scenarios were simulated under different meteorological conditions (i.e., different wind speed and air temperature for each flow condition/season), which cover the range of monthly average conditions at Little Otter Creek and provide a conservative approach to assessing potential outcomes of a release (i.e., trajectories, fates and effects). Table 3-2 depicts the temperatures and wind speeds used for different seasonal scenarios in the model.

Table 3-2 Air Temperature (ºCelsius [C] and ºFahrenheit [F]) and Wind Speed (meters/second [m/s]) Values Used as Model Inputs for the Seasonal Scenarios Modeled at Little Otter Creek in OILMAPLand and SIMAP.

Case #	Release Location	River Flow	Season	Month	Air Temp. (ºC)	Air Temp. (ºF)	Wind Speed (m/s)
8	Little Otter Creek	Low	Winter	January	-12.1	10.2	4.74
		Average	Summer	Late July / August	18.8	65.8	3.80
		High	Spring	April	4.2	39.6	4.96

3.3.1.5 Thickness of Oil Under Ice

Ice coverage is important to consider as it may affect the ultimate trajectory and fate of oil within the winter environment. Ice may reduce the quantity or prevent oil from entering a water body altogether. Furthermore, it may affect the potential downstream transport and potential for pooling of oil under ice. Fates processes such as evaporation may be affected as well.

Ice cover was considered at the modeled location. During winter conditions, complete coverage (100% ice cover) of the water surface is assumed. If a release were to occur into the watercourse from the underground/underwater crossing, then all oil would enter into the water column itself. For the purpose of modeling, oil is assumed to rise through the water column and be trapped by the ice cover at the surface. The model assumes that evaporation is prevented completely (0% evaporation) due to the layer of ice on the water surface. The downstream transport of oil is modeled within river sections at the local water velocity; however, oil pools under the ice in lakes. As modeled in the ice-free conditions, complete shoreline oiling occurs in the complete ice cover season as well. However, rather than referring to true shoreline oiling, this term in the winter would more appropriately be named edge-oiling. Shorelines are set to ice-edge and shoreline retention values are lower than those found during the ice-free seasons. The retention of oil along the banks during winter seasons refers to the oil that would be trapped below the ice surface along the edge of the river in the narrow region between the ice and the bottom. These conservative approximations maximize the extent of potential oiling.

The equilibrium thickness of oil under ice has been measured in many environments. However, the main focus has been in the marine environment, where thicknesses may range from 1-30 centimeters (cm) (Dickins et al. 2008). Freshwater environments, particularly rivers, are quite different than the open ocean, notably with the level of energy within the environment (e.g., waves and other turbulent processes). Assuming that new ice formed in calm conditions and the underside was flat and smooth, the oil will spread beneath ice to an equilibrium thickness based upon the balance between surface tension and buoyancy (Barnes et al. 2013). The equilibrium slick thickness may be determined using the equation of Cox et al. (1980):

$$\delta = -8.5(\rho_w - \rho_o) + 1.67$$

Where δ is the thickness of oil under ice in cm and $(\rho_w - \rho_o)$ is the density difference between oil and water. Under the smoothest ice conditions, thicknesses of 5.2–11.5 mm (0.20-0.45 in) are typical for oils with densities in the range of crude oils (Cox et al. 1981). The minimum stable drop thickness for crude oil under ice is approximately 8 mm (0.31 in) (Lewis 1976). The equilibrium thickness of CLWB was determined to be 0.4 in. (10.6 mm), while the thickness for Bakken was calculated to be 0.07 in. (1.9 mm). The CLWB (heavy crude oil) is therefore predicted to be over five times thicker than the Bakken (light crude oil) under the ice.

3.3.2 SIMAP

3.3.2.1 Geographic and Habitat Data

For geographical reference, SIMAP uses a rectilinear grid to designate the location of the shoreline, the water depth (bathymetry), slope, bottom roughness, and the shore or habitat type. The grid is generated from a digital shoreline or other geographical information using the ESRI Arc/Info compatible Spatial Analyst program. The cells are coded for depth and habitat type; the model then identifies the shoreline using this grid. Thus, in model outputs, the land-water map is only used for visual reference; it is the habitat grid that defines the actual location of the shoreline in the model.

Geographical data including digital shoreline basemap, river geometry, and habitat mapping were obtained from multiple sources. The river polygon that was used to define river area and land/water boundary was obtained from the USGS NHD high-resolution dataset, with slight improvements (e.g., refined shoreline and land/water boundary) based upon aerial imagery. Habitat data, obtained from the NOAA Environmental Sensitivity Index (NOAA ESI) maps, NLCD, and aerial imagery, were used to define the types of habitats present within the study area. Habitat grids were used to define the bottom type and vegetation found in watered areas, areas of extensive mud flats and wetlands, and the shore type.

Shore types were characterized based on NOAA ESI, NLCD, aerial imagery, photographs posted by Google Earth, and a site visit conducted by Stantec in July of 2019. For average river flow conditions, the shore type was based upon NOAA ESI and visible bank type. For low river flow conditions, the shore type was assumed to be ice along natural shorelines and man-made structures (e.g., concrete) where present. For high river flow conditions, the shore types were assigned based upon the land cover data (NLCD) above the riverbank, except for man-made structures. In general, this corresponded with shore widths of approximately one meter for high-flow scenarios, approximately 10 cm for average-flow scenarios, and ice edge for the low-flow scenarios. The ice edge has a much lower holding capacity for oil than the ice-free bank types. These assumptions are realistic for this type of environment and season, but also conservative, in that they will tend to maximize downstream transport of crude oil. The bottom type was defined as silt and mud with some regions characterized as rock from imagery and the Stantec site visit.

River depth was characterized based on NOAA Electronic Navigation Charts (NOAA ENC). Sounding points and contour lines were digitized from lake contour maps produced by the Minnesota Department of Natural Resources. Contour lines were interpolated using the Topo to Raster tool in ArcGIS, creating a gridded output, that was then converted to points. These points, in addition to the NOAA ENC sounding points were interpolated using inverse distance weight interpolation to create the final depth profile of the river. River depth (Figure 3-5) and habitat are presented for the St. Louis River to Lake Superior for high (Figure 3-6), average (Figure 3-7), and low (Figure 3-8) river flow conditions that were modeled the different seasons.

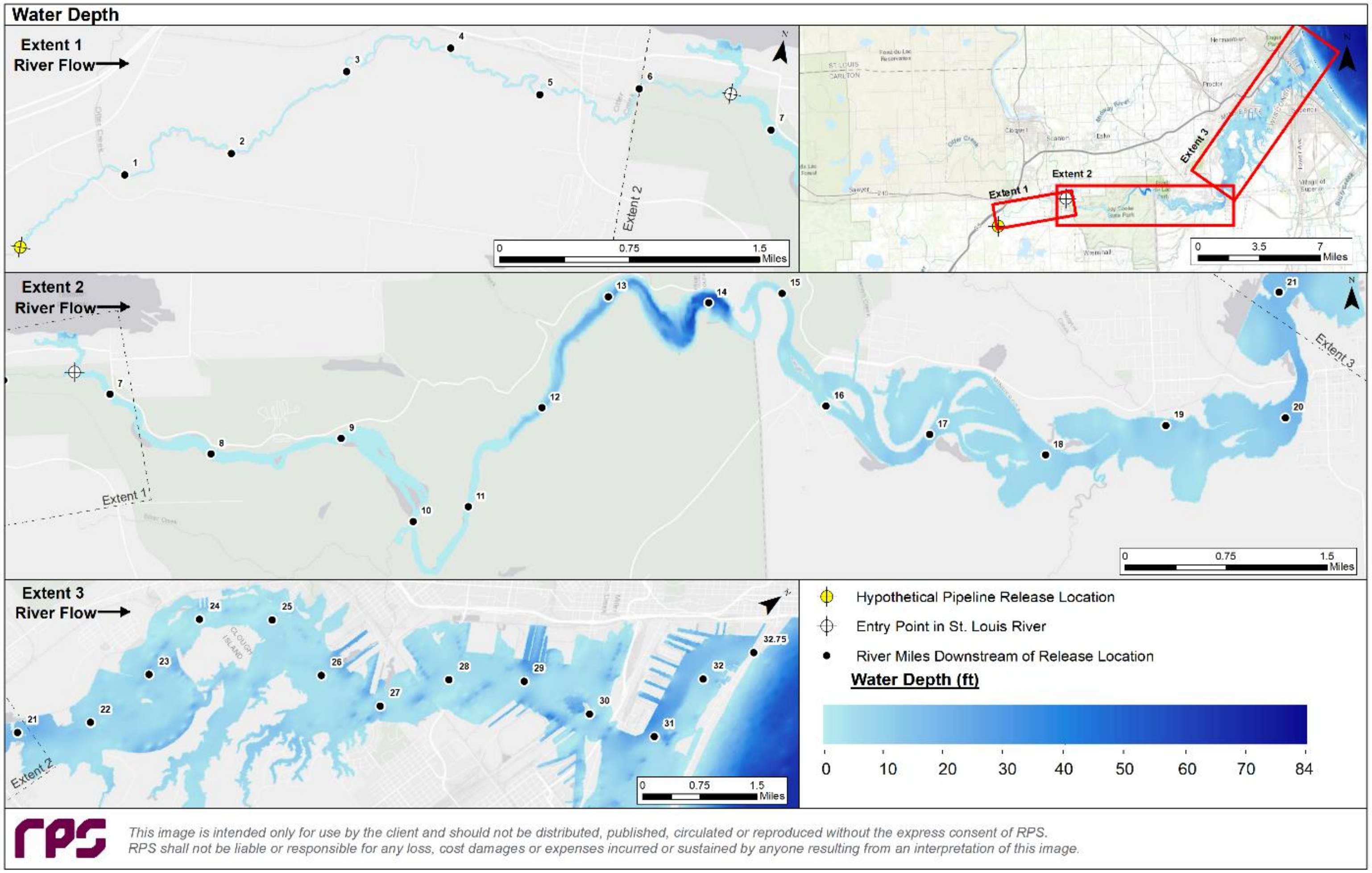

Figure 3-5 River Depth for the St. Louis River to Lake Superior used in SIMAP. Points indicate downstream distance (miles) from hypothetical release location.

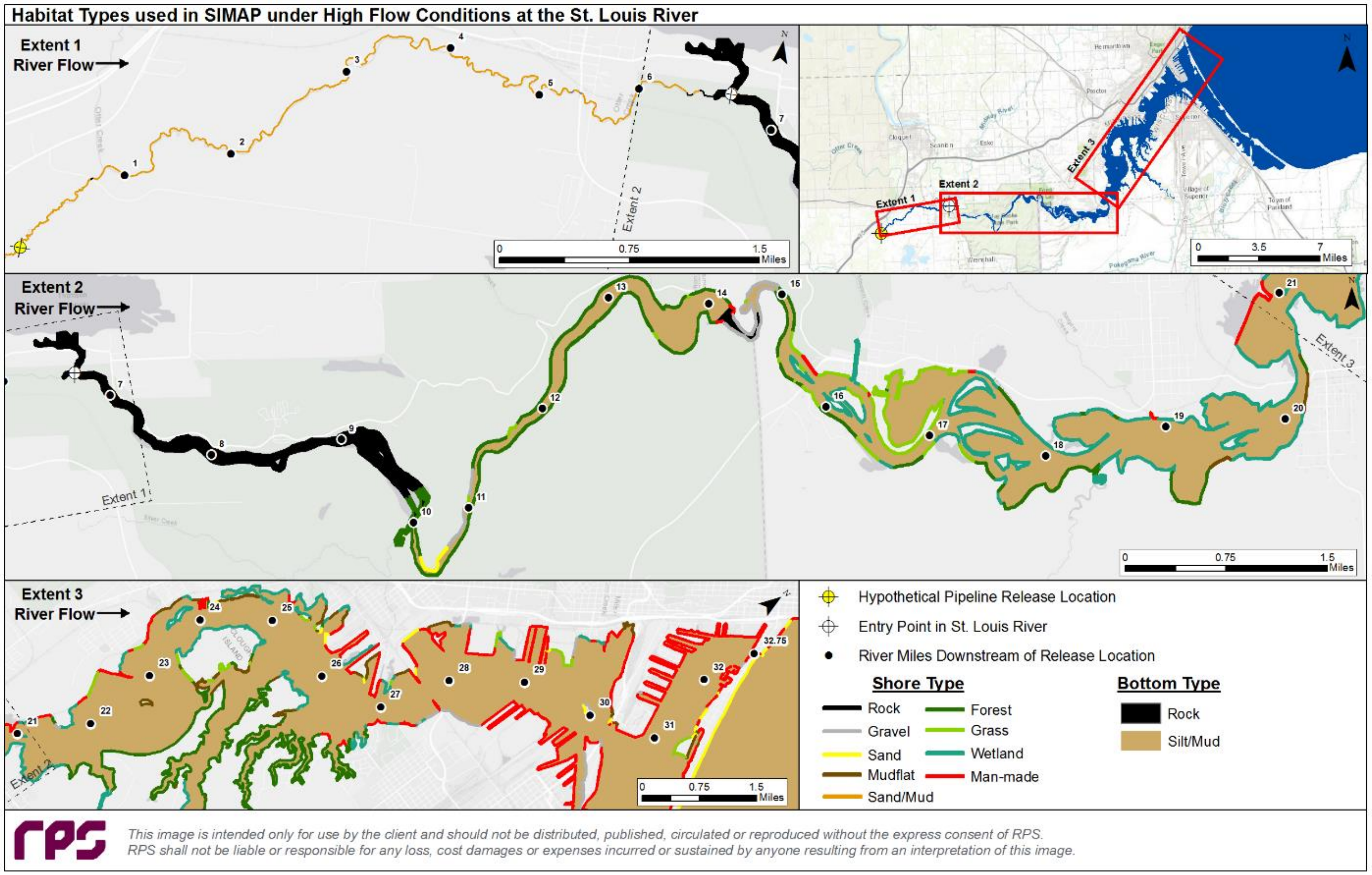

Figure 3-6 Habitat Types for the St. Louis River to Lake Superior Under High Flow Conditions used in SIMAP. Points indicate downstream distance (miles) from hypothetical release location.

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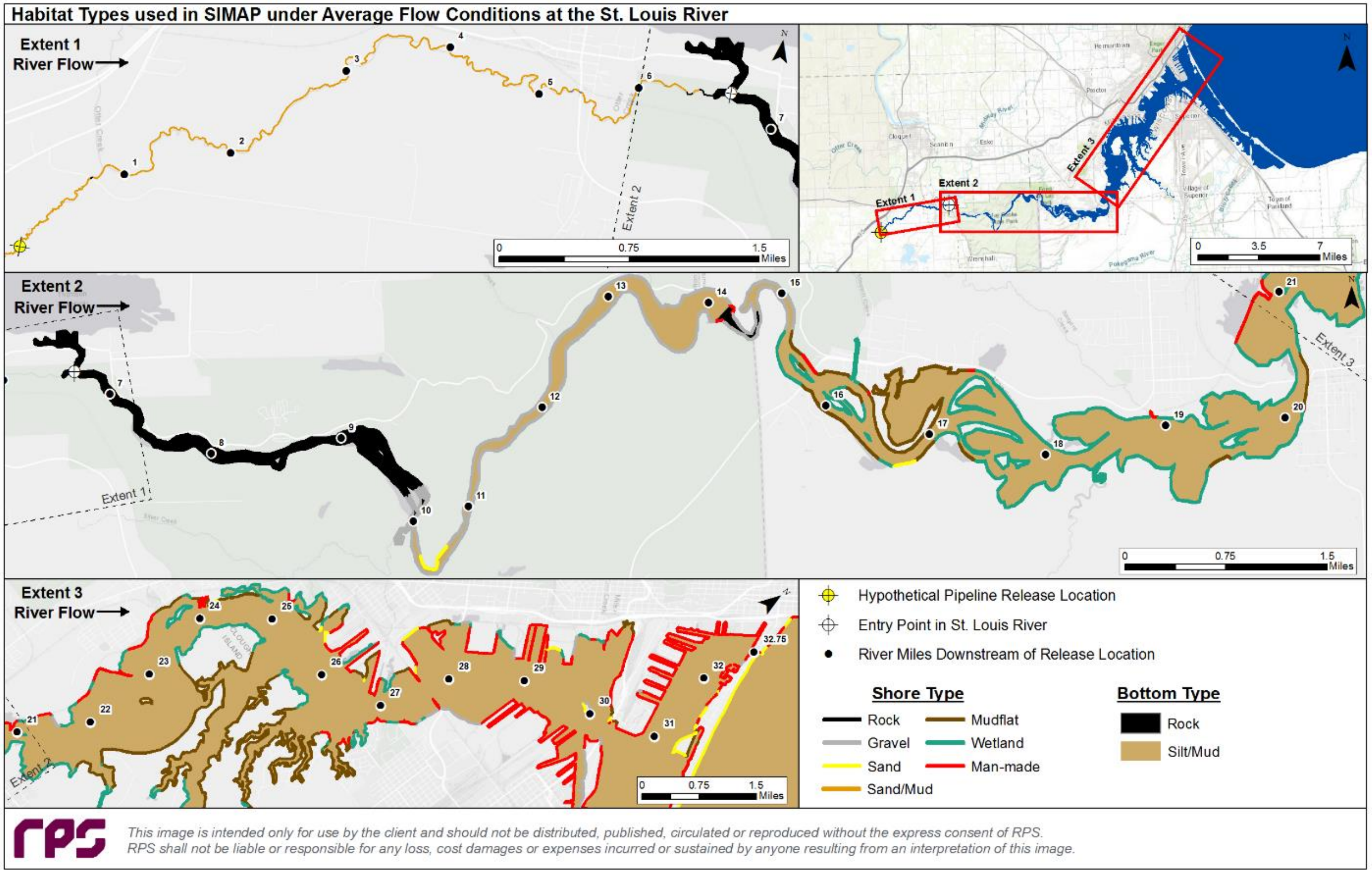

Figure 3-7 Habitat Types for the St. Louis River to Lake Superior Under Average Flow Conditions used in SIMAP. Points indicate downstream distance (miles) from hypothetical release location.

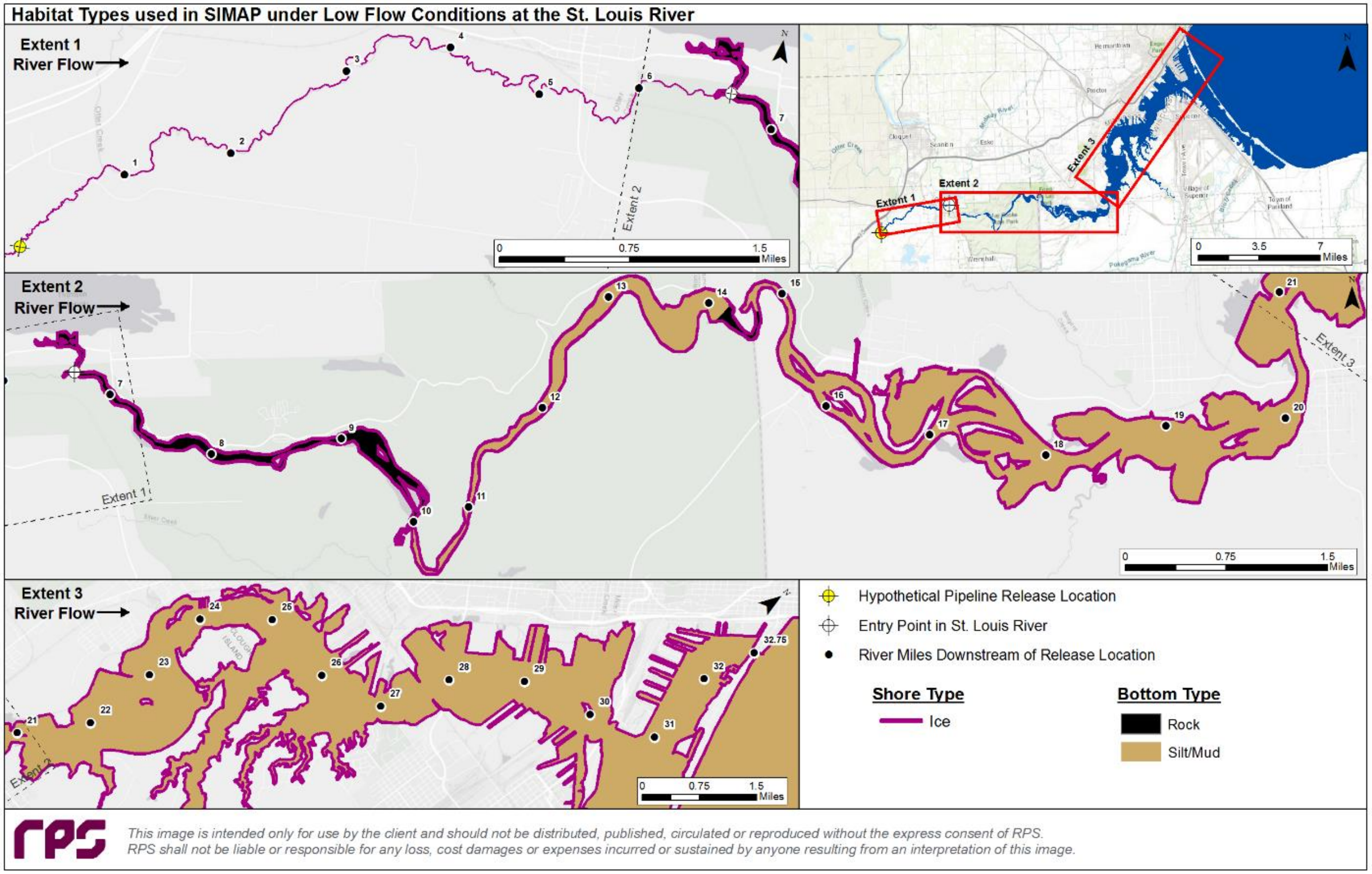

Figure 3-8 Habitat Types for the St. Louis River to Lake Superior Under Low Flow Conditions used in SIMAP. Points indicate downstream distance (miles) from hypothetical release location.

3.3.2.2 Environmental Data

The types of environmental data used in the SIMAP modeling for Little Otter Creek were the same as those used for the other seven representative sites. Location-specific and season-specific environmental data was used to develop model inputs for the SIMAP model as described below.

3.3.2.2.1 River Currents

Currents have an important influence on the trajectory and fate of the oil and are critical data inputs. The SIMAP modeling system uses spatially varying current fields throughout a gridded domain of the river within a study area to force oil throughout the domain. For this modeling exercise, the current fields were generated using BFHYDRO, a hydrodynamic model created by RPS. The model was used to first generate a boundary fitted grid mapped to the wetted domain, as defined by the NHD. It was then used to generate a spatially varying current field for three different environmental conditions representing low, average, and high monthly average river flows and associated current speeds in the St. Louis River. For a full description of the hydrologic analysis, hydrodynamic modeling system, and development of solution, please refer to Section 5.3.3.2 of Stantec et al. (2017).

NHDPlus is a geo-spatial, hydrologic framework dataset built by the USEPA Office of Water, assisted by the USGS. The NHDPlus data set was queried to determine the variability in monthly flows and river reach speeds within the study area. NHDPlus includes an estimated monthly and annual average stream flow rate and velocity for each stream segment. Flow is estimated using EROM. This method determines river flow based on estimates of accumulated runoff based on the elevation data, evaporative loss, and various adjustments based on gages within the region. The velocities are calculated based on the estimated flow using the Jobson Method (Jobson 1996). A summary of the monthly flows and average current speeds within the St. Louis River to Lake Superior are presented in Table 3-3. Based on analysis of this data, it was determined that the month representing low river flow conditions was January/February, average river flow conditions was end of July, and high river flow conditions was April.

Hydrodynamic modeling was performed to generate river current speeds that matched the average reach speeds in the NHDPlus data set for the designated months. The BFHYDRO model was used to generate current fields that matched the NHDPlus average reach estimates. The NHDPlus estimates are simplifications that assign constant current speeds for a reach. In reality, there are variations across and along each reach due to bottom elevation changes, river cross-section changes, and other local features. River current speeds are provided for the St. Louis River for high (Figure 3-5), average (Figure 3-6), and low (Figure 3-7) river speeds. In addition, the locations of rapids, waterfalls, and dams used in the SIMAP model are provided (Figure 3-8). These locations are areas of enhanced vertical mixing and will result in the entrainment of surface oil into the water column due to this turbulence.

Table 3-3 Summary of Monthly River Flows and Average Current Speeds for the St. Louis River Modeled in SIMAP.

Month	St. Louis River Flow (m^3/s)	St. Louis River Current Speed (m/s)
January	40.02	0.43
February	39.17	0.43
March	53.32	0.49
April	187.74	0.86
May	142.34	0.76
June	92.10	0.62
July	96.27	0.64
August	50.82	0.48
September	63.51	0.53
October	83.04	0.59
November	77.33	0.57
December	50.25	0.48
Low	39.17	0.43
Average	81.33	0.57
High	187.74	0.86

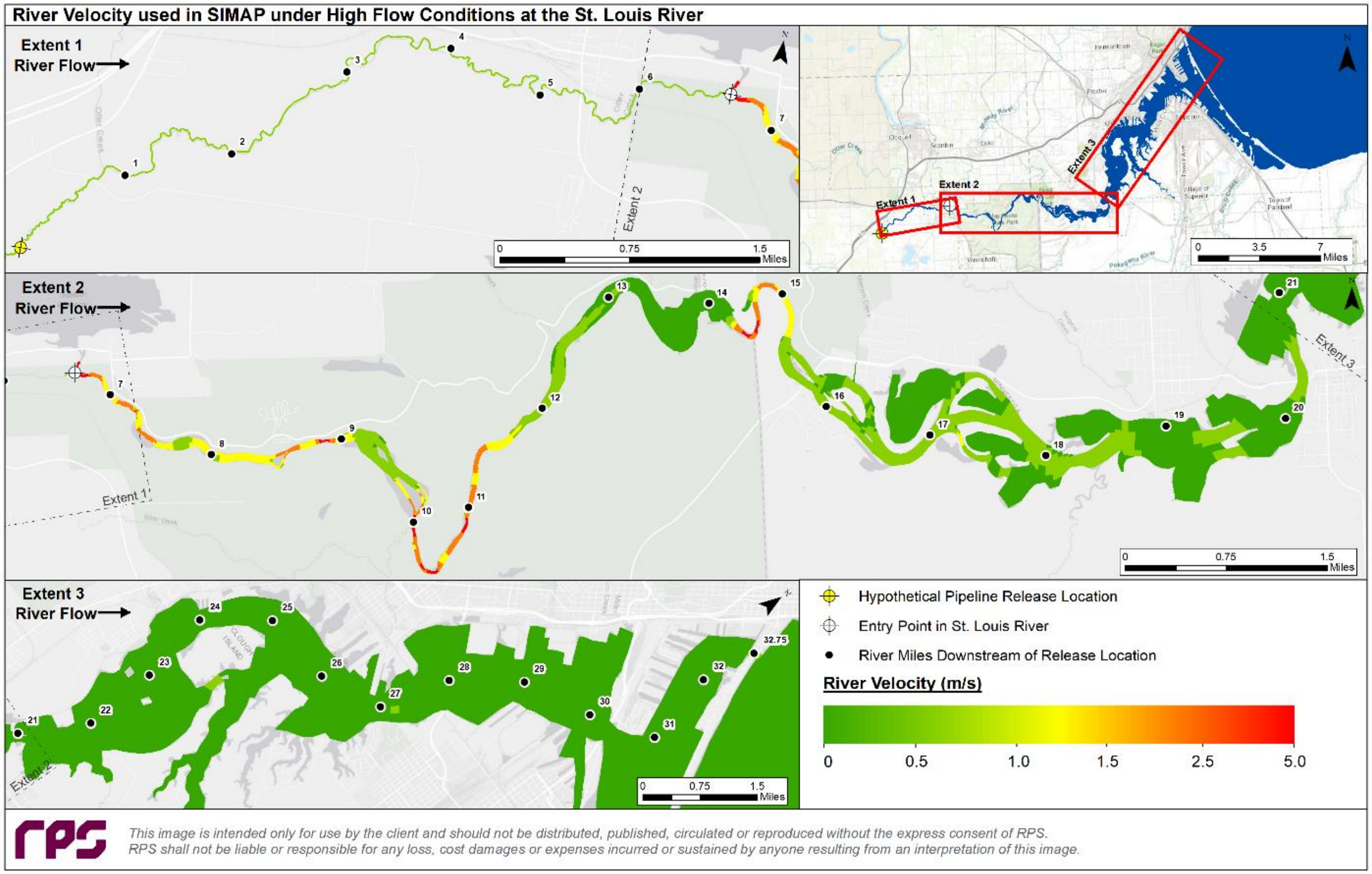

Figure 3-9 Spatial Variability of Downstream Current Speeds for High River Flow Conditions in the St. Louis River used in SIMAP. Note that the range of river velocities and associated color-ramp values within the legend differ between depicted river flow conditions. Points indicate downstream distance (miles) from hypothetical release location.

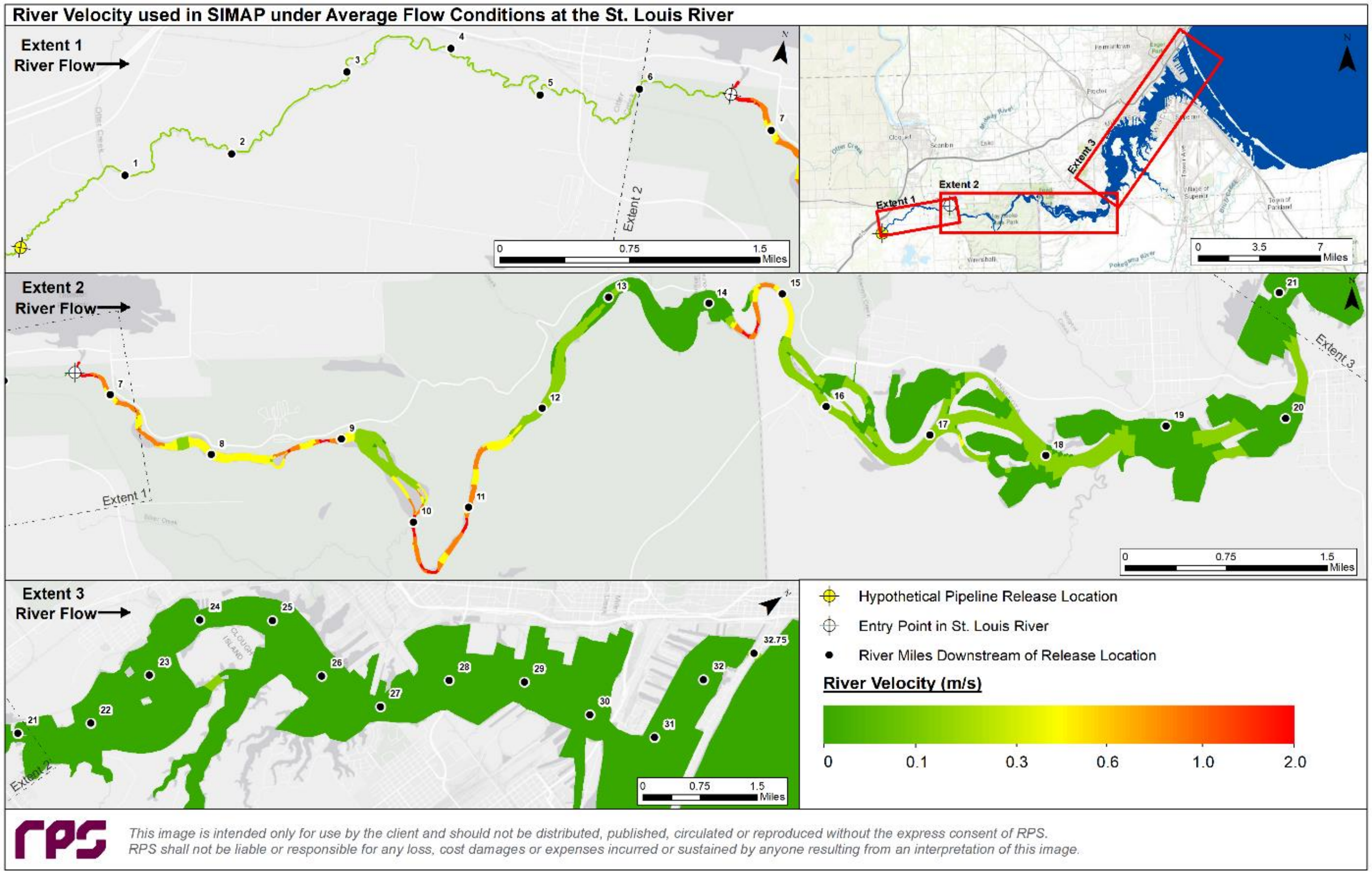

Figure 3-10 Spatial Variability of Downstream Current Speeds for Average River Flow Conditions in the St. Louis River used in SIMAP. Note that the range of river velocities and associated color-ramp values within the legend differ between depicted river flow conditions. Points indicate downstream distance (miles) from hypothetical release location.

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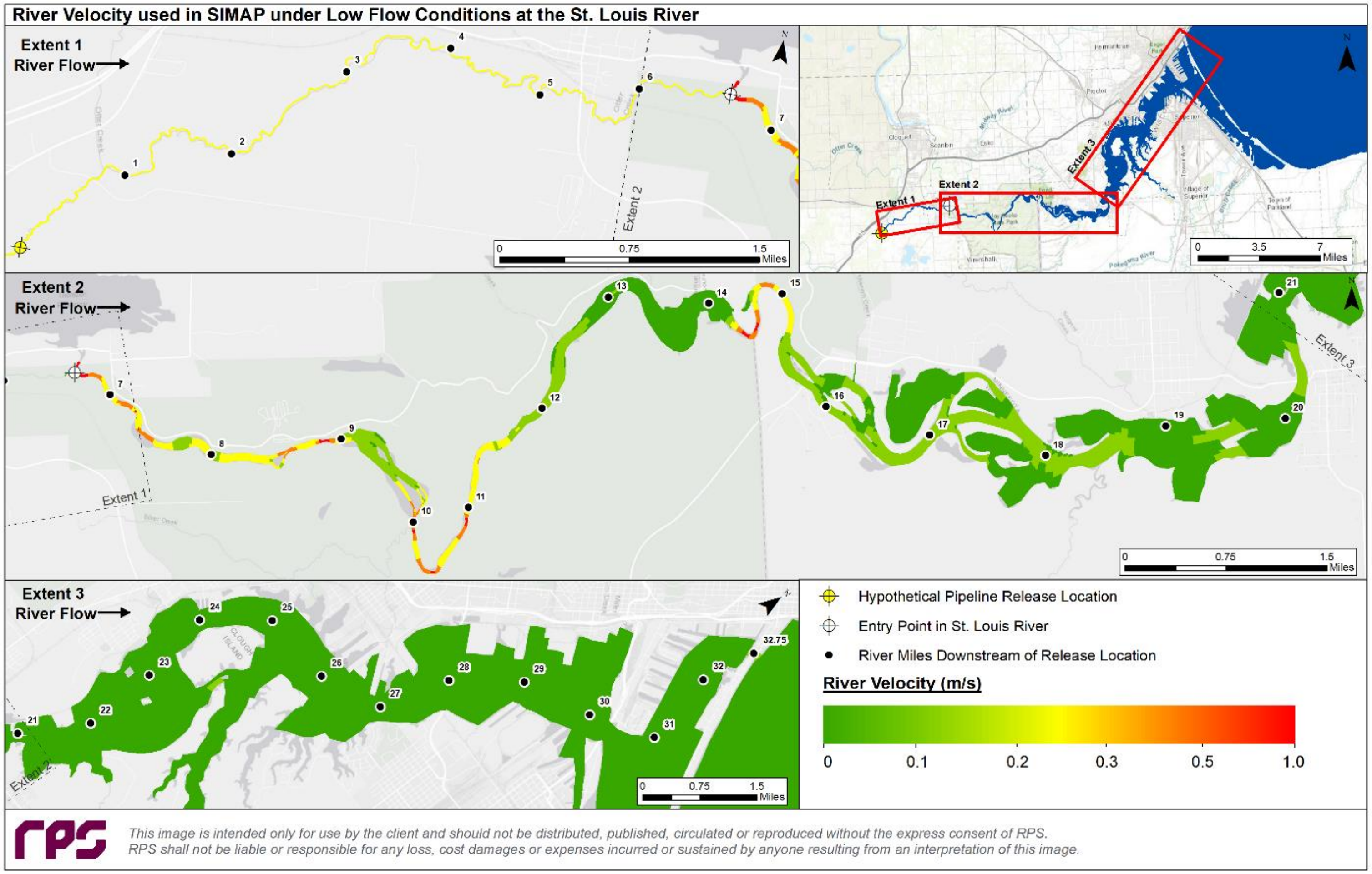


Figure 3-11 Spatial Variability of Downstream Current Speeds for Low River Flow Conditions in the St. Louis River used in SIMAP. Note that the range of river velocities and associated color-ramp values within the legend differ between depicted river flow conditions. Points indicate downstream distance (miles) from hypothetical release location.

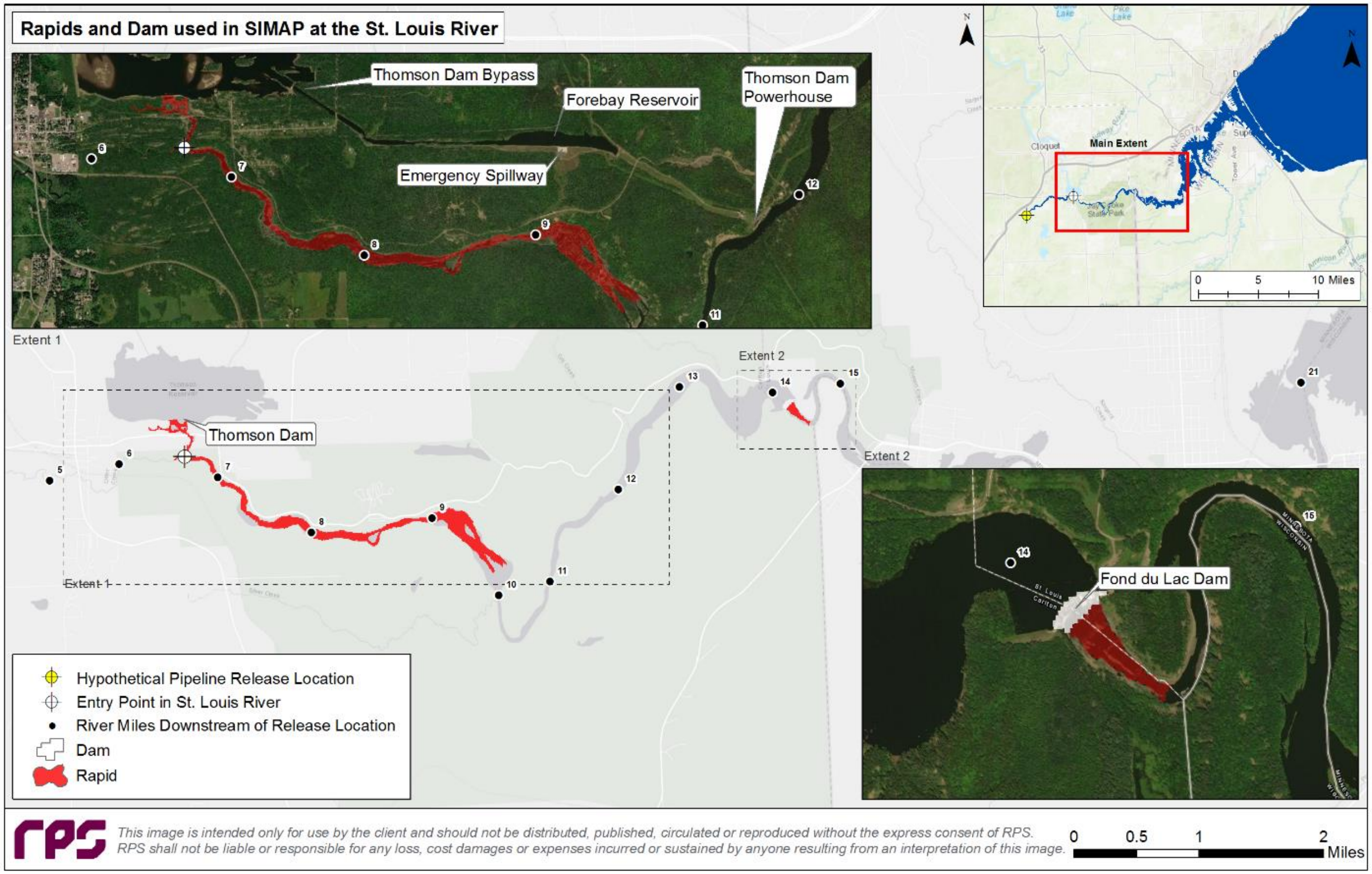


Figure 3-12 Spatial distribution of rapids, waterfalls, and dams within the St. Louis River as Well as Other Points of Interest. Points indicate downstream distance (miles) from hypothetical release location.

3.3.2.2.2 Wind and Temperature

The same wind and temperature data sources for that were used as inputs for the OILMAPLand scenarios (Section 3.3.1.4) were also used to develop wind and temperature information for the SIMAP modeling of the St. Louis River portion of the Little Otter Creek release scenario.

Winds may physically transport oil on the water surface and wind speed and direction at the water surface may make a difference between limited (especially in windy sections of river) or extensive transport. The wind data available is for open areas at some distance from the Little Otter Creek site, as opposed to in the forested stream areas modeled; thus, local winds at each point downstream from the release site may be different than the reported wind speed and direction. Because of these uncertainties and the expected variability in direction, the SIMAP model conservatively assumed wind drift transport as zero (i.e., winds did not laterally transport oil or push it ashore). The modeled wind was therefore not a true vector as it had magnitude, but no direction. Because of this assumption, winds may add to the evaporation of surface oil in the model output and could enhance the vertical mixing of the surface water, in some instances keeping subsurface oil entrained or entraining more oil under higher wind speeds.

3.3.2.2.3 Total Suspended Solids

The amount of sediment transport can change by several orders of magnitude based on location and river flow conditions, with extensive sediment transport and turbid water during high river flow conditions (especially storm events), and very low sediment transport and clear water during low river flow conditions (e.g., under winter ice cover). During peak storm events, it is not uncommon to have values exceeding hundreds of mg/L in some locations within the model domain, such as the Pokegama River.

For modeling purposes, the sedimentation rate was set to 1 mm/day for high flow scenarios and 0.1 mm/day for low flow scenarios. Sediment loads of 99, 25, and 10 mg/l were assumed to be present at constant values for the high, average, and low river flow conditions. These values are identical to the assumptions used in the previous AAR (Stantec et al. 2017). At a suspended sediment concentration of approximately 100 mg/L, sedimentation of oil and polycyclic aromatic hydrocarbons (PAHs) becomes substantial (i.e., following an oil release, suspended sediment particles may adhere to oil droplets, and the resulting oil-particle aggregate may settle out to the bottom). Therefore, low and average river flow conditions were unlikely to result in large amounts of oil settling to the bottom, while high river flow conditions would result in the potential for substantial settling of oil in quiescent regions.

3.3.2.2.4 Ice Cover

Oil interactions with mobile and immobile ice involve several processes that affect the transport and fate of oil. Oil released under water may become trapped under the ice in ridges and keels or build up along and become trapped (Drozdowski et al. 2011). Many of these interactions and processes are at a finer scale than can be captured in oil spill models using inputs from the available large scale meteorological, hydrodynamic and coupled hydrodynamic-ice models. SIMAP simulates the influence of ice on net transport and fate processes by considering potential reduction in the surface area of the oil and the water in contact with the atmosphere, which changes the effects of the wave environment, spreading, movements, dissolution, volatilization, and mixing on the released oil.

In SIMAP, when oil encounters ice at the surface of the river, it is assumed to trap along the ice edge and remain immobile until ice retreats/melts. For modeling during the winter season, it was assumed that there was 100% ice coverage on the watercourses and along banks. As the oil was released from the bottom of the river, the oil would be transported downstream within the water column until it came into contact with the water-ice interface (surface or sides) at which point it would "stick."

Ice also can shelter oil from the wind and waves (Drozdowski et al. 2011), and slow weathering processes such as evaporation and emulsification, as well as spreading and entrainment (Spaulding 1988). Effects of ice cover on wave-damping, spreading, and temperature appear to be the primary factors governing observed spreading and weathering rates (Sørstrøm et al. 2010). Given the assumption of 100% ice coverage during winter (used for this site and the other seven representative sites), the processes of evaporation, emulsification, entrainment, volatilization, and spreading were stopped within the SIMAP modeling.

4 TRAJECTORY AND FATE RESULTS

4.1 Description of Model Outputs

The expected downstream transport of each hypothetical release of crude oil was simulated using OILMAPLand within Little Otter Creek and SIMAP in the St. Louis River and downstream locations. High, average, and low river flow conditions were modeled for CLB (either Winter or Summer) and Bakken Crude oil and the associated trajectory, fate, and mass balance information for each simulation were predicted.

OILMAPLand was used to predict the downstream trajectory and fate of released oil between the release point on Little Otter Creek and the confluence of Otter Creek with the St. Louis River. The model calculates the amount of released oil that would evaporate, adhere to the shoreline, and remain on the water surface. In an actual oil release, other processes such as dissolution and dispersion would come into play.

SIMAP was used to predict the trajectory and fate of released oil from the point where it enters the St. Louis River, downstream towards Lake Superior. This model includes oil fate processes such as oil spreading (gravitational and by shearing), evaporation, transport, randomized dispersion, emulsification, natural entrainment, dissolution, volatilization of dissolved hydrocarbons from the surface water, adherence of oil droplets to suspended sediments, adsorption of soluble and sparingly-soluble aromatics to suspended sediments, sedimentation, and degradation. If there was oil on the river surface after 24-hours, it would continue downstream, further oiling shorelines, until it either evaporated and stranded, or was captured by emergency response operations (which were not modeled).

Results of each modeled hypothetical release are provided to of the predicted timing, downstream extent, and magnitude of contamination for each release. In the summary maps for each simulation, symbols with different color/shape combinations denote the predicted location and time in hours (6-hour intervals) of the farthest downstream movement of released crude oil for each set of scenarios. In addition, mass balance information is provided for the entire model run as well as tabular summaries of mass balance at 24-hours. Components of the oil are tracked as entrained droplets of oil within the water column, dissolved hydrocarbons, floating surface oil, stranded oil on shorelines, oil in the sediment, and oil constituents which evaporate or decay (i.e., photo-oxidation and biodegradation). The mass balances are also provided, summarizing how much of the oil was predicted to remain on the river surface, evaporate to the atmosphere, or strand on the riverbanks.

The SIMAP hydrocarbon trajectory provides a history of oil transport throughout the modeled domain in both time and space. Summary figures of the trajectory and fate (see below) are provided for each location, season, and release volume.

1. **Mass Balance Plots**: Provide an estimate of the weathering and fate of oil for the entire model duration as a fraction of the oil spilled up to that point. Components of the oil tracked in SIMAP over time include the amount of oil on the water surface, the total entrained hydrocarbons in the water

column, the amount of oil on shore, the oil evaporated into the atmosphere, the oil in sediments, and the amount of oil that has decayed.

2. **Hydrocarbon Trajectory Maps:** Show the history of each individual particle of oil throughout the modeled domain in both time and space. Components of the oil were tracked within SIMAP as entrained droplets of oil, dissolved aromatic constituents, floating surface oil, and stranded shoreline oil. Trajectory maps are provided for 6, 12, and 24 hours after the initial release.
3. **Surface Oil Thickness Maps:** Depict the predicted footprint of maximum floating surface oil and the associated oil thicknesses (mm) of each individual SIMAP spill simulation at 24 hours.
4. **Water Column Concentration Maps:** Depict the predicted footprint of the vertical maximum water column concentration of dissolved hydrocarbons (µg/l or ppb) at 24 hours for each simulation. Dissolved hydrocarbons are the portion of the oil having the greatest potential to affect water column biota. Water column contamination figures show only concentrations ≥ 1 ppb. Concentrations below 1 ppb are considered low and result in little water column impact. The footprints for dissolved hydrocarbons are typically smaller than the extent of total oil contamination in the water column.
5. **Shoreline and Sediment Impact Maps:** Depict the predicted total mass of oil deposited onto the shoreline and on sediments for each individual SIMAP spill simulation. Note that 1 µm thickness is roughly equivalent to 1 g/m^2.

4.2 Unmitigated Hypothetical Release Case 8—Little Otter Creek

The Little Otter Creek scenarios represent a small watercourse within the Lake Superior watershed that flows into a larger and more high energy environment (the St. Louis River) containing rapids, waterfalls, and a hydro-electric dam. As the St. Louis River transitions into the St. Louis River Estuary, the releases could enter Spirit Lake, St. Louis and Superior bays, and potentially Lake Superior.

Several pipeline route alternatives cross the Little Otter Creek at a common location approximately 5 miles (8 km) south southwest of Cloquet, Minnesota and 3.5 miles (5.6 km) southwest of Carlton, Minnesota. At this location, Little Otter Creek is approximately 6-13 ft (2-4 m) in width, as it travels through a convoluted channel lined with grassland and forest for nearly 1 mile (1.6 km) enters Otter Creek, continues for another 1.5 miles (2.4 km) to the northeast and then east for 2 miles (3.2 km) passing to the south of Carlton, Minnesota before entering the St. Louis River 0.25 miles (0.4 km) south of the Thomson Reservoir Dam. The Little Otter Creek portion of the simulation was modeled in OILMAPLand and included approximately 6.5 river miles (10.5 river km).

The St. Louis River portion of the simulation was modeled in SIMAP and included approximately 14 river miles (22.5 km) before reaching Spirit Lake and then a further 12.3 miles (19.8 km) of relatively open water within St. Louis and Superior bays before reaching Lake Superior. The upper section of the St. Louis River is a high energy rocky environment (Figure 3-1) with rapids and waterfalls (Figure 3-12). The Thomson Dam Powerhouse is located approximately 11.5 miles (18.5 km) downstream of the hypothetical release point with a large amount of turbulent flow exiting the Powerhouse on the northern shore. The Fond du Lac Dam, approximately 14.3 miles (23 km) downstream of the hypothetical release point, is approximately 78 ft (23.8 m) tall. Located within Jay Cooke State Park, the Fond du Lac Dam was constructed in 1924 and is the first hydro project on the St. Louis River when heading upriver from Duluth. This concrete dam has a number of chutes or spillways that can create tremendous turbulence as water passes over. The St. Louis River has predominantly rocky shorelines immediately below the Fond du Lac Dam, giving way to lower energy areas in the estuary downstream, with wetlands and shallow lake environments. Jay Cooke State Park extends from river mile 5 (8 km) to 14.5 (23.3 km). Wetlands, mudflats, and man-made structures make up the majority of the shore types within the section of the St. Louis River below the Fond du Lac Dam.

Ultimately, a hypothetical release of oil at the crossing of Little Otter Creek would need to be transported downstream nearly 33 river-miles before entering Lake Superior.

4.2.1 Cold Lake Blend Scenarios

A full bore rupture of 13,007 bbl (2,068 m^3) of CLB was simulated into Little Otter Creek using OILMAPLand.

Table 4-1 provides a summary of the mass balance predictions from OILMAPLand at the point where oil would enter the St. Louis River. Table 4-2 provides the predicted volume and associated timing of this entry. The fate of oil that was predicted to enter the St. Louis River was modeled using SIMAP. Table 4-3 provides mass balance information at the end of the 24-hour simulation for the portion modeled within SIMAP. It is important to note that the combined simulation lengths for OILMAPLand and SIMAP totalled 24-hours.

Figure 4-1 provides the furthest predicted downstream extent of crude oil at the end of the 24-hour simulation period. Hypothetical releases of CLB under high river flow conditions resulted in the leading edge of floating oil being transported downstream 6.5, 13.6, 16.3, and 20.0 miles (10.5, 21.9, 26.2 and 32.2 km) after 6, 12, 18, and 24 hours, respectively (Figure 4-1, Figure 4-3, Figure 4-4, and Figure 4-5). Under average river flow conditions, the leading edge of floating oil was located approximately 13.7 miles (22.0 km) downstream after 24 hours (Figure 4-1, Figure 4-13). During low river flow conditions, the majority of the release was predicted to be trapped at the ice-water interface with the leading edge of floating oil located approximately 8.2 miles (13.2 km) downstream of the hypothetical release point, based upon the calculated equilibrium thickness of the oil under ice (Figure 4-20; Section 3.3.1.5).

Table 4-1 Mass Balance Summary of the Percent of the Total Volume of CLB (CLSB or CLWB) Simulated in OILMAPLand for the Little Otter Creek and Otter Creek Portion of the Release up to the Point Oil Was Predicted to Enter the St. Louis River.

Scenario	Evaporated (%)	River Surface (%)	River Banks (%)
CLSB—High Flow (Spring)	1.1	79.3	19.6
CLSB—Average Flow (Summer-Fall)	1.7	78.1	20.3
CLWB—Low Flow (Winter)	<0.01	>99.9%*	

*Value represents percent of oil remaining under the ice.

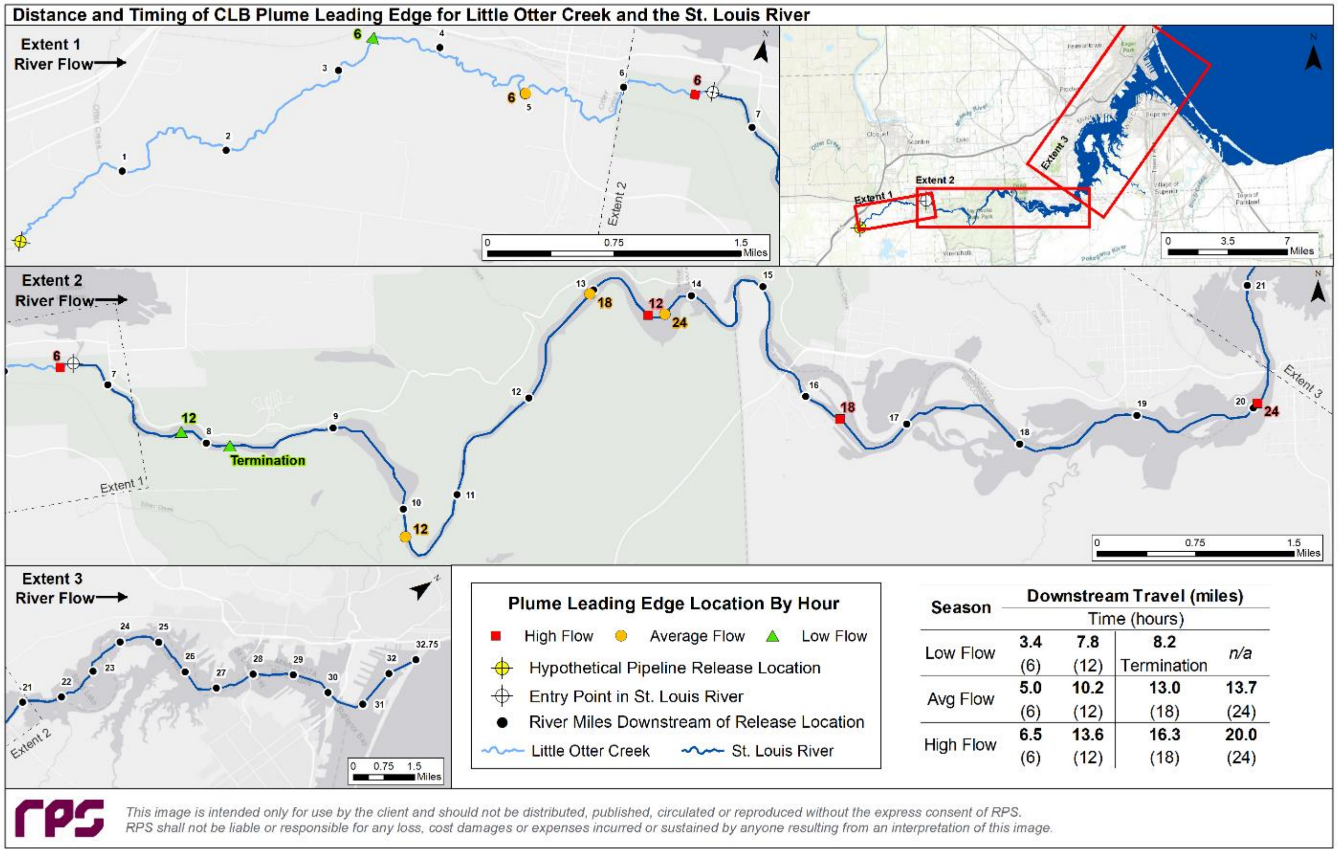
Table 4-2 Predicted Volumes and Associated Timing of CLB (CLSB or CLWB) leaving Otter Creek and entering the St. Louis River from the OILMAPLand Simulations.

Scenario	Volume Entering the St. Louis River (m^3)	Volume Remaining in the St. Louis River (m^3)	Volume Evaporated (m^3)	Time Into Release (hr)
CLSB—High Flow (Spring)	1,639	406.3	22.7	6.12
CLSB—Average Flow (Summer-Fall)	1,614	418.8	35.2	7.93
CLWB—Low Flow (Winter)	820	1,248	0	9.92

Table 4-3 Mass Balance Summary of the Percent of the Total Volume of CLB (CLSB or CLWB) Simulated in SIMAP for the St. Louis River to Lake Superior Portion of the Release at the End of the 24-Hour Simulation.

Scenario	Surface (%)	Evaporated (%)	Water Column (%)	Sediment (%)	Ashore (%)	Decayed (%)
CLSB—High Flow (Spring)	60.9	17.6	2.5	0.3	18.2	0.5
CLSB—Average Flow (Summer-Fall)	78.4	19.3	0.2	0.1	1.5	0.5
CLWB—Low Flow (Winter)	99.2*	<0.01	0.5	<0.01	<0.01	0.3

*Value represents percent of oil remaining under the ice.



Season	Downstream Travel (miles) Time (hours)			
Low Flow	**3.4** (6)	**7.8** (12)	**8.2** Termination	*n/a*
Avg Flow	**5.0** (6)	**10.2** (12)	**13.0** (18)	**13.7** (24)
High Flow	**6.5** (6)	**13.6** (12)	**16.3** (18)	**20.0** (24)

Figure 4-1 Predicted Downstream Transport of CLB Oil at the Little Otter Creek Release Location within the St. Louis River and Estuary to Lake Superior. Points indicate downstream distance (miles) from hypothetical release location.

During high and average river flow conditions, almost 80% of the total CLB release volume was predicted to be transported downstream within Little Otter Creek and Otter Creek to the point where it entered the St. Louis River (Table 4-1). Under high river flow conditions, with the highest river velocities, this was predicted to take approximately 6.12 hours (Table 4-2). Under average and low river flow conditions, this predicted travel time was increased to 7.93 and 9.92 hours, respectively. Because of the small surface area of the creek, the large volume of CLB released, and the low volatile content contained within the CLB, <2% of the release was predicted to evaporate by the time the oil reached the St. Louis River.

At the point where Otter Creek enters the St. Louis River, approximately 20% of the release was predicted to adhere to the shorelines along Little Otter Creek and Otter Creek. Under low river flow conditions, approximately 60% of the CLB was predicted to be trapped at the ice-water interface to a thickness of 0.4 in. (1.06 cm) (Table 4-1; Section 3.3.1.5).

At the junction of Otter Creek with the St. Louis River, the velocity and turbulence of the water increases as a long section of rapids extends from 6.5-10.0 miles downstream of the hypothetical release site to the east through Jay Cook State Park (Figure 4-1). In this section of the St. Louis River, the majority of the CLB was predicted to entrain within the water column, denoted by a large purple peak in the mass balance between 6-10 hours (0.25-0.4 days) into the release for high river flow (Figure 4-2) and 9-12 hours into the release for average river flow (Figure 4-10). For the high river flow conditions at 9-12 hours into the release, the majority of the oil was predicted to be below the rapids (Figure 4-4). As the water slows and becomes more quiescent (i.e., low vertical turbulence), entrained oil was predicted to resurface, spreading more broadly over the Fond du Lac Headpond, which therefore enhanced evaporation. Additionally, in these quiescent waters below regions of enhanced mixing (i.e., below rapids, waterfalls, dams), oil-particle aggregates that may form within the water column would no longer remain in suspension, and some of the oil-particle aggregates may sink to the river bed. Under average river flow conditions, the CLB was predicted to not move beyond the waters above the Fond du Lac Dam after 24 hours (Figure 4-13).

Hydrocarbon contamination is predicted for downstream portions of the St. Louis River. Surface oil thickness of CLB within the St. Louis River was predicted to be in the form of predominantly heavy black oil (>1mm) and black oil (0.1-1 mm). At hour 24 within the high river flow case, discontinuous patches of CLB were predicted from mile 14-20 (22.5 to 32.2 km) within the St. Louis River prior to entering Spirit Lake (Figure 4-6). For the average river flow case, a relatively continuous patch of CLB is predicted to be retained behind the Fond du Lac Dam as thick black oil (>1mm) (Figure 4-14).

For the high river flow scenario, CLB was predicted to go over the Fond du Lac Dam (0.65-1 day into the release), becoming re-entrained within the water column, and transported downstream to river mile 20 (Figure 4-5). The large increase or “hump” in entrained oil at 0.65-1.0 day reflects this entrainment as the oil is forced into the water column. Entrained oil droplets in the water column subsequently rise back to the surface over subsequent timesteps in the more quiescent regions below the dam. Figure 4-9 depicts the dissolved and total hydrocarbon concentrations within the water column at the Fond du Lac Dam at a time when portions of the release were both above and below the dam. Above the dam, there are low predicted total hydrocarbon concentrations within the water column, as most of the oil is floating on the water surface. A portion of this surface oil is dissolving into the surface water column, but as the rate of evaporation is much higher than dissolution, the dissolved hydrocarbon concentration above the dam is low. (<100 ppb) However, immediately downstream of the dam, both the total hydrocarbon concentration (>15,000 ppb) and the dissolved hydrocarbon concentration (100–1,000 ppb) increase, as surface oil passing over the dam would be entrained into the water column as small droplets, allowing the soluble portions to dissolve into the water more readily. The total hydrocarbon concentration in the water column decreases downstream of the dam due to the buoyant rise of oil droplets to the surface in the relatively quiescent waters.

Maximum total dissolved hydrocarbon concentrations are predicted to be greatest near the leading edge of the release, where entrained oil droplets and surface slicks have had a chance to become dissolved into the water column. For each model run, dissolved hydrocarbons are likely to exceed 5,000 ppb within much of the river, as an instantaneous maximum over 24 hours. However, peak concentrations typically pass quickly (minutes to hours) followed by larger regions of water predicted to experience dissolved hydrocarbon concentrations at lower levels, <250 ppb and typically <100 ppb (Figure 4-7). For the average river flow scenario, concentrations were predicted to be higher than the high river flow scenario above the Fond du Lac Dam, as most of the released oil entering the St. Louis River would be mixed into the water column in the extensive rapids between the Thomson Reservoir and Fond du Lac Headpond. As the entrained oil enters the more quiescent waters of the Headpond, the dissolve aromatic hydrocarbon concentrations were predicted to be >5,000 ppb (Figure 4-15). When considering effects, it is important to note the concentration, as well as the duration of exposure. Therefore, average concentrations over a period of time (e.g. one hour) are likely to be much less than the instantaneous maximums that may exceed 5,000 ppb.

Extensive shoreline oiling is predicted under the high and average river flow scenarios with shoreline retention of oil exceeding 500 g/m^2 down to approximately 18.5 and 13.5 miles (29.8 and 21.7 km), respectively (Figure 4-8; Figure 4-16). Because of the high turbulence within the rapids, and the termination of the run at 24 hours as oil was just reaching the Fond du Lac Headpond, only a small amount of sedimented oil was predicted for the average river flow scenario between mile 11.0-13.5 (17.7 to 21.7 km) at levels predominantly <0.01 g/m^2 and, in some cases, between 0.1-0.5 g/m^2. Because of the enhanced flow, mixing, and sediment load under high river flow conditions (Section 3.3.2.2.3), a similar amount of sedimented oil was predicted between mile 11.0-13.5 (17.7 to 21.7 km). However, under high river flow conditions, the release travelled further down river, with a greater amount of and more extensive sediment oiling (but still patchy) predicted with values between 0.1-0.5 g/m^2 between mile 12-20 (19.3 to 32.2 km), with localized pockets exceeding 500 g/m^2 in quiescent regions at mile 16 and 17.2 (25.7 and 27.7 km).

For the low river flow (winter) scenario, all of the oil was predicted to remain trapped beneath the ice and was therefore either in the water column (purple) or rising to the “surface” (blue) where it would be trapped beneath the ice (Figure 4-17). The hydrocarbon trajectory at the end of the 24-hour simulation extended 8.2 miles (13.2 km) from the hypothetical release site (Figure 4-20) as a continuous slick of heavy black oil 0.4 in (1.06 cm) thick at the ice-water interface (Figure 4-21). While the whole oil fraction remained trapped under the ice, the soluble portion of hydrocarbons was free to move downstream within the water as a dissolved fraction (Figure 4-22). Concentrations exceeding 5,000 ppb may be possible near the leading edge of the plume, which is transported downstream approximately 11.5 miles (18.5 km) within the 24-hour model simulation. However, concentrations were predominantly 500-750 ppb in the waters below the trapped oil and upstream of the leading edge. No sediment oiling was predicted for the low river flow scenario due to the low sediment load within the water column (Figure 4-23).

There was very little decay of hydrocarbons predicted for any of the three hypothetical releases within the 24-hour timeframe modeled (Table 4-3).

4.2.1.1 Trajectory and Fate Results for High Flow (Spring)

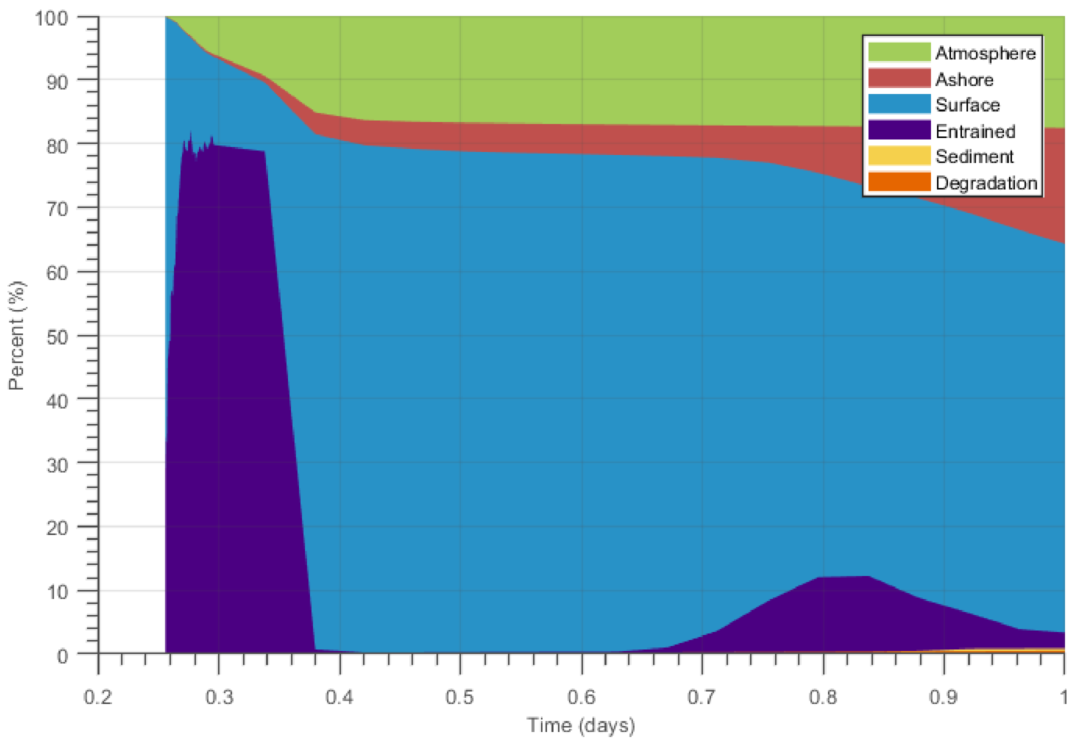


Figure 4-2 High River Flow (Spring) Season - Oil Mass Balance Graph from SIMAP for the Release of CLB at the Little Otter Creek Release Site. Note that the SIMAP simulation begins after the initial release (time zero) as the downstream transport of oil was first modeled within Little Otter Creek and Otter Creek using OILMAPLand. Please refer to Table 4-1 for OILMAPLand mass balance information.

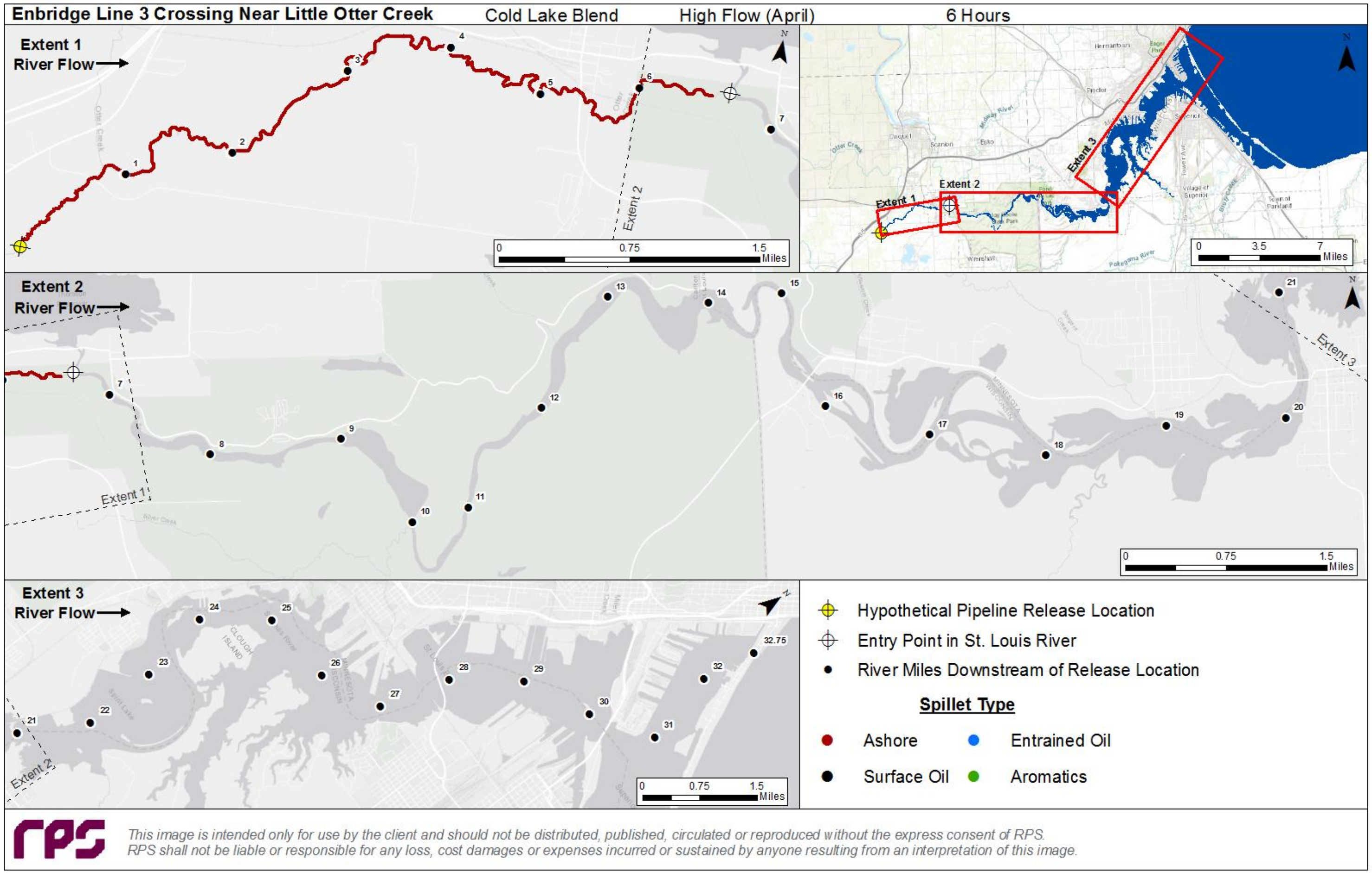


Figure 4-3 High River Flow (Spring) Season - Oil Trajectory at 6 Hours for the Release of CLB at the Little Otter Creek Release Site from SIMAP. Note that all of the oil is still within Little Otter Creek and Otter Creek. Data provided came from OILMAPLand outputs. Points indicate downstream distance (miles) from hypothetical release site.

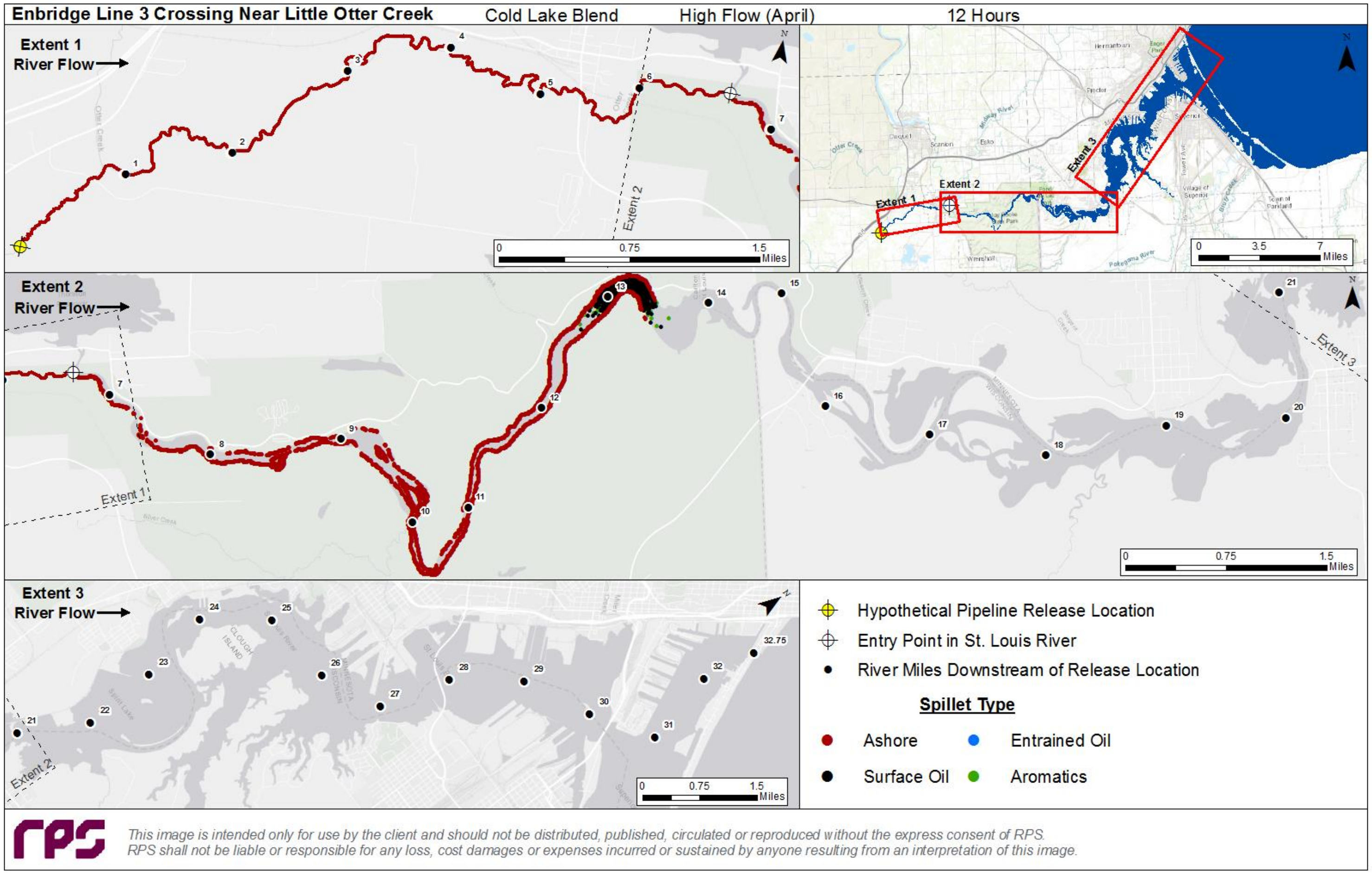


Figure 4-4 High River Flow (Spring) Season - Oil Trajectory at 12 Hours for the Release of CLB at the Little Otter Creek Release Site from SIMAP. OILMAPLand results for Little Otter Creek and Otter Creek are also provided. Points indicate downstream distance (miles) from hypothetical release site.

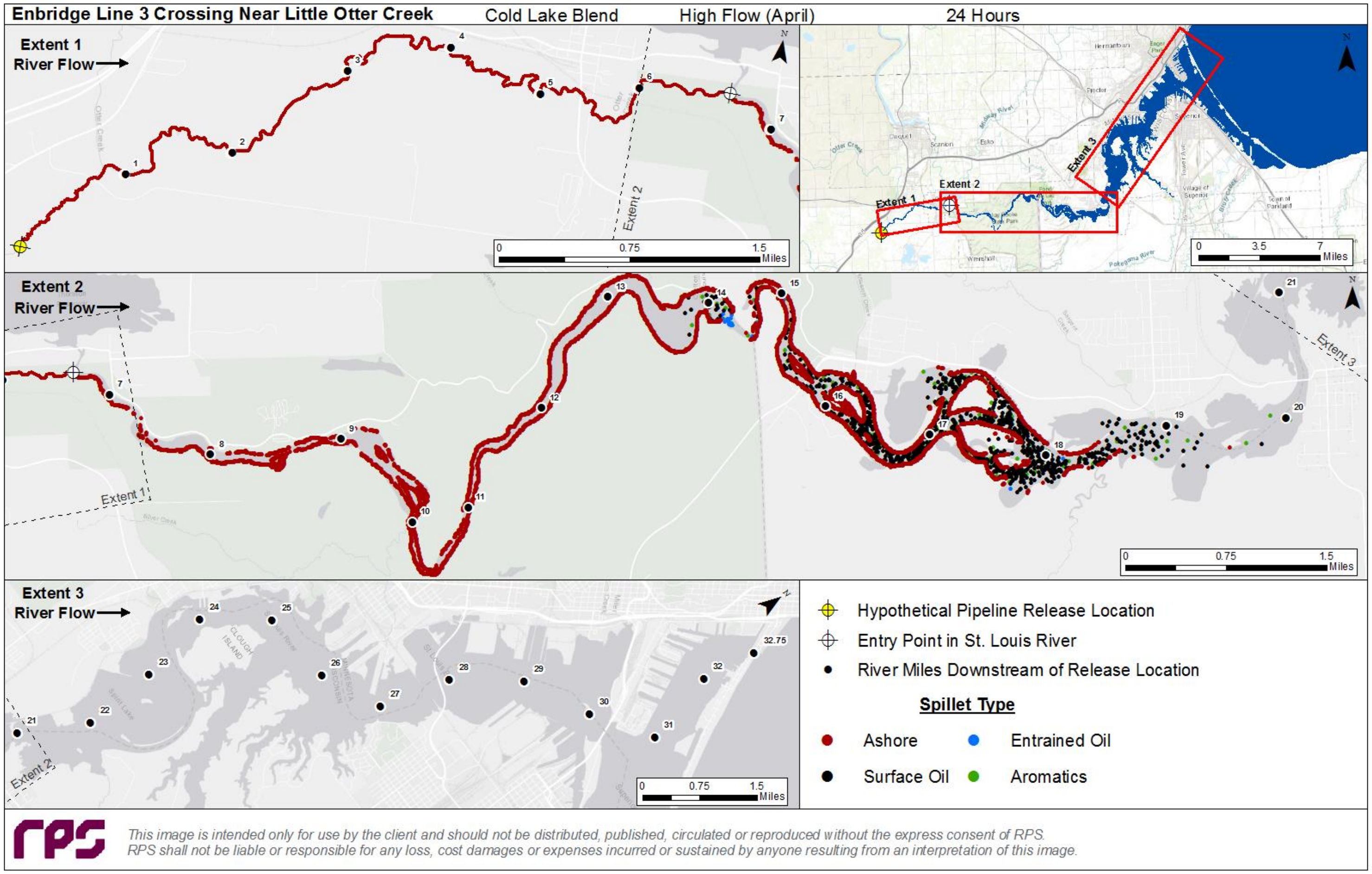


Figure 4-5 High River Flow (Spring) Season - Oil Trajectory at 24 Hours for the Release of CLB at the Little Otter Creek Release Site from SIMAP. OILMAPLand results for Little Otter Creek and Otter Creek are also provided. Points indicate downstream distance (miles) from hypothetical release site.

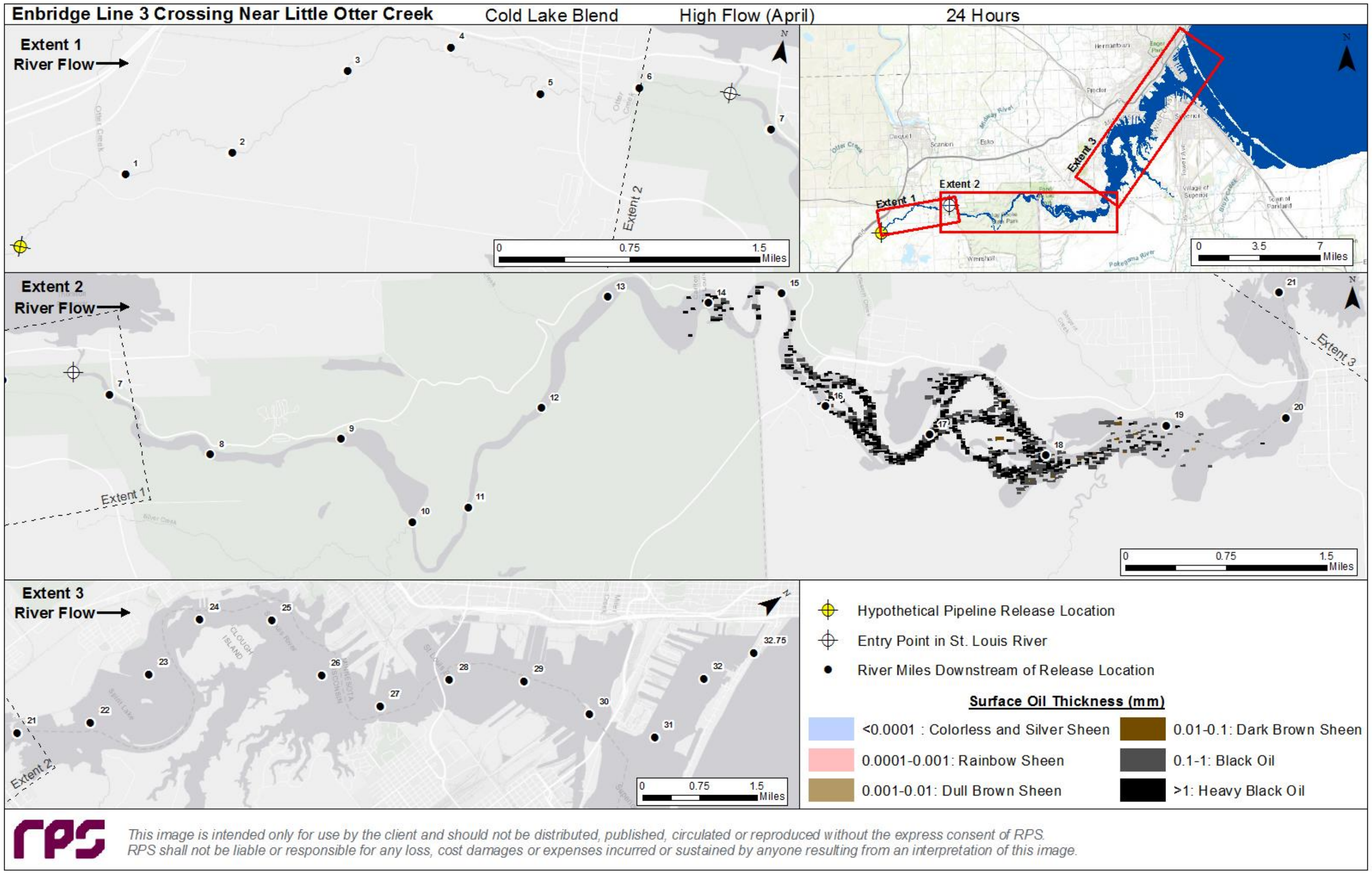


Figure 4-6 High River Flow (Spring) Season - Maximum Floating Surface Oil at 24 Hours for the Release of CLB at the Little Otter Creek Release Site from SIMAP. Points indicate downstream distance (miles) from hypothetical release site.

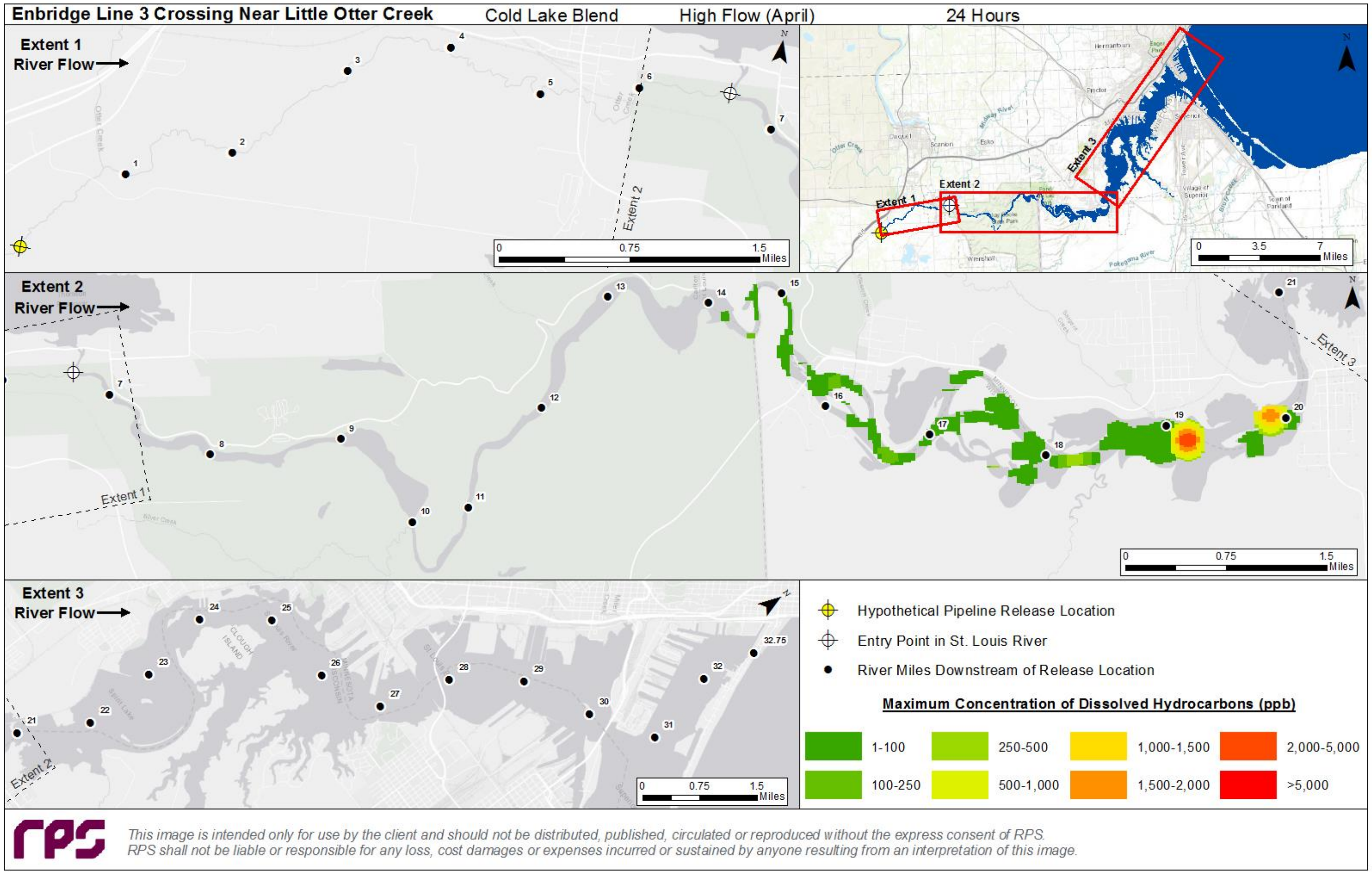


Figure 4-7 High River Flow (Spring) Season - Maximum Total Dissolved Hydrocarbon Concentrations at 24 Hours for the Release of CLB at the Little Otter Creek Release Site from SIMAP. Points indicate downstream distance (miles) from hypothetical release site.