ENBRIDGE LINE 5 WISCONSIN SEGMENT RELOCATION PROJECT

22-P-216493

Technical Appendix C – Hydrocarbon Route Assessment and HCA Analysis

Appendix to Operations Assessment: Oil Spill Report

Enbridge Line 5 Segment
Relocation Project
Wisconsin

Technical Appendix C

22-P-216493
Final

February 13, 2023

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Contents

Figures

Tables

1 INTRODUCTION

As described in the Oil Spill Report, Enbridge Energy, Limited Partnership (Enbridge) is proposing the Line 5 Wisconsin Segment Relocation Project (L5WSRP), which is designed to relocate the existing Line 5 pipeline (Line 5) around the Bad River Reservation ("the Reservation") in northern Wisconsin to a more southerly route in Ashland, Bayfield, Douglas, and Iron Counties, Wisconsin. The Proposed Route and each route alternative (RA) of the L5WSRP would divert a portion of the Line 5 pipeline from the existing route through the Reservation and instead route the pipeline from a starting point west of the Reservation, south around the Bad River Band Reservation, and then back to the north to reconnect at another point farther east in Iron County. Depending on the route alternative, the relocated route would add between 50.5 km (31.4 mi) and 163.4 km (101.5 mi) of new pipeline. The pipeline would carry the same products to the same ultimate Line 5 destination in Sarnia, Ontario, Canada. The Proposed Route and alternate routes RA-01 and RA-02 would bypass the Reservation to the south and pass through the upper portions of the Bad River watershed, while RA-03 would start farther west, travel farther south, and rejoin the existing line farther east, bypassing the Bad River watershed entirely (Figure 1-1).

RPS has conducted a route alternatives analysis of the Existing, Proposed, and Route Alternatives to assess the range of predicted overland and downstream movement and behavior of hypothetical hydrocarbon releases from any point along each pipeline. The intent was to use computational oil spill modeling to quantify the number and type of receptors, including Lake Superior and the Reservation, that may be susceptible to hypothetical releases of oil along the Existing Route, the Proposed Route, and each Route Alternative. OILMAPLand, a two-dimensional overland and downstream trajectory and fate model, was used to predict the movement and behavior of released oil within the environment. Hypothetical full-bore rupture (FBR) release volumes under high river flow conditions were simulated at 100-meter intervals (328 ft) and at each watercourse crossed by the pipelines (Table 1-1). This bounded the upper end of areal extent of potential effects. A second set of simulations using the same release points considered the Recent Average Release Volume (RARV, 334 bbl) under low river flow conditions to provide a lower bound for potential extent of effects. While the FBR results provide a conservative basis to make decisions for pipeline routing, smaller releases under low flow conditions were used to provide additional context to smaller volume releases with a lower potential for downslope and downstream movement. In total, 10,058 hypothetical crude oil releases were simulated (5,029 FBR releases and 5,029 RARV releases).

Trajectory results were used to quantify susceptible receptors and resources at risk to allow for direct comparison between the routes. This included an assessment that allowed for the comparison of the total length of each pipeline over which releases would have the potential to reach High Consequence Areas (HCAs) and other Areas of Interest (AOIs) identified in the project area, as well as a determination of the shortest period of time for released oil to reach the Reservation. The HCAs included in the route comparison were received from the PHMSA National Pipeline Mapping System (NPMS), as well as collected by Enbridge from other sources and using operator knowledge; while the AOIs included Lake Superior, wild rice areas (including those in the Kakagon-Bad River Slough complex), the Reservation, and various Federal and State Lands

The HCA/AOI assessment was conducted using a "could-affect" analysis that compared the individual spill trajectories with the locations of HCAs/AOIs identified in the project area. The intent was to identify all downstream HCAs that may be impacted (direct or indirect effects) from any hypothetical FBR release occurring within the simulated time frame. The could-affect pipeline segments that had the potential to reach and therefore impact various categories of HCAs (e.g., drinking water resources or populated areas) and AOIs were then identified by receptor group for comparison across the route alternatives. By comparison, the HCA/AOI assessment conducted with the smaller RARV volume was used to demonstrate the decreased potential for impacts as defined by shorter could-affect pipeline segments based upon the reduced potential for transport due to smaller release volume and less extreme river flow conditions.

Finally, a high-resolution, segment analysis was conducted to determine the length of pipeline over which potential releases might directly enter each Bad River and White River crossing for the Proposed Route and route alternatives. This analysis was conducted using OILMAPLand to simulate hypothetical FBR crude oil releases at 10-meter increments along the Proposed Route, RA-01, and RA-02, in the areas proximate to the Bad River and White River crossings of those pipelines. RA-03 was not assessed as it is outside of the watershed and therefore does not cross either river. These segment lengths were used in the Probability Assessment described in Technical Appendix A to quantify the likelihood that a release might occur at each specific watercourse crossing, and to contextualize (in the risk framework) the consequences for the releases simulated at the Bad River and White River on the Proposed Route that are provided in Technical Appendix B.

Table 1-1. Total number of hypothetical release points simulated along each pipeline route and the number of those release points that are associated with watercourse crossings.

Pipeline Route	# of Release Points (Total)	# of Release Points (New Construction)	# of Watercourse Crossings (New Construction)*
Existing Route	1,052	0	0
RA-01	1,330	552	45
Proposed Route	1,452	732	65
RA-02	1,426	1,009	75
RA-03	1,688	1,684	49

*Analyzed watercourse crossings include all crossings of the pipeline ROW (i.e., not access road or pipeyard crossings) across watercourses recorded in the NHDPlus dataset.

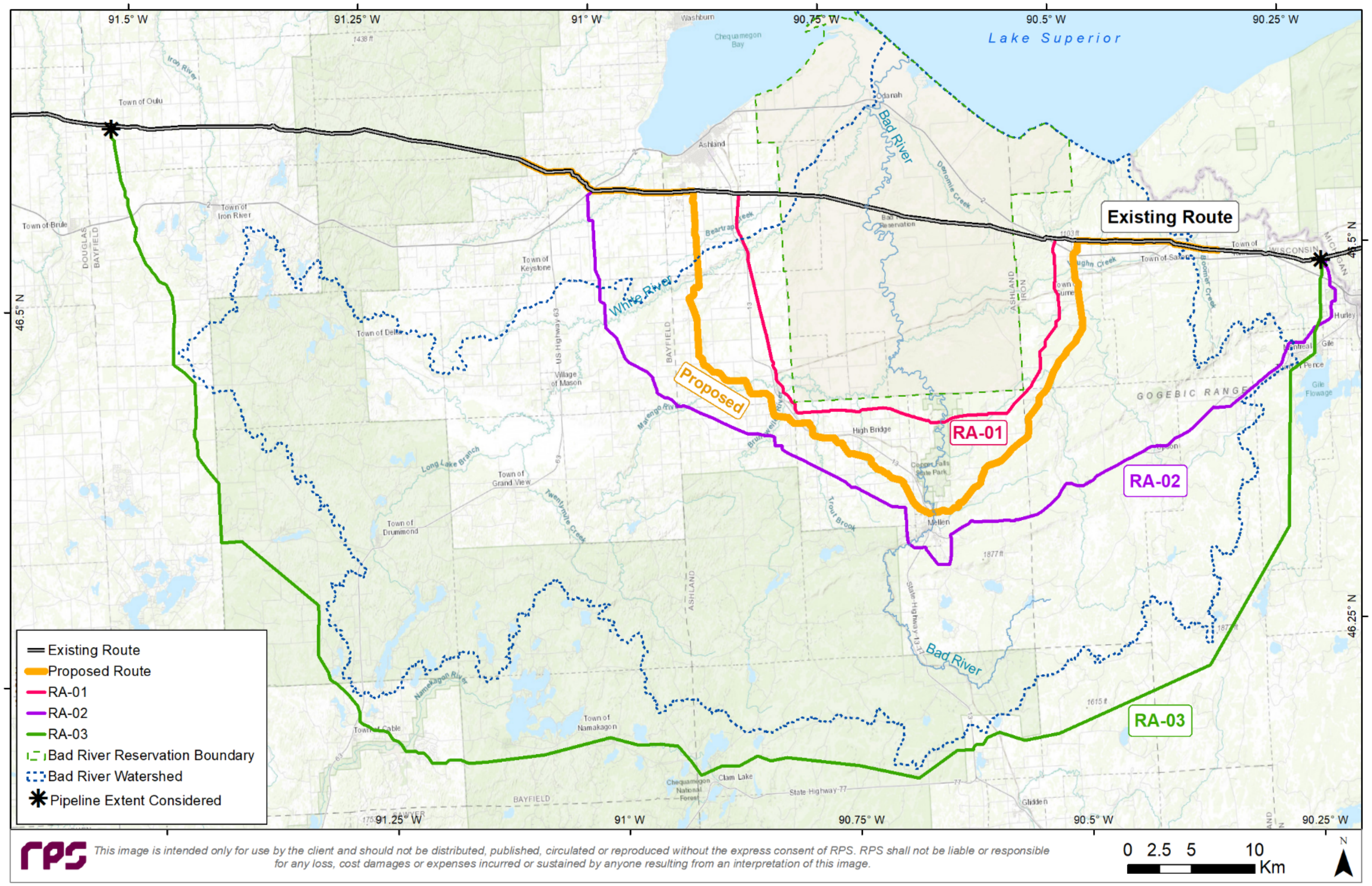

Figure 1-1. Map of the Existing, Proposed, and Route Alternatives for the Enbridge Line 5 Segment Relocation Project.

2 OILMAPLAND MODEL DESCRIPTION

The OILMAPLand model is a two-dimensional modeling system that has been developed by RPS over the last roughly twenty years to provide a conservative approximation of the overland movement of released oil or chemicals as well as the potential extent of downstream movement in the surface water network. Documentation outlining the development and past usage of OILMAPLand includes Galagan et al. (2015) and Horn and Fontenault (2018). The OILMAPLand spill modeling system is used to simulate the overland flow of crude oil releases to predict the location, volume, and timing that oil may enter a watercourse. Oil flow over land is governed by the physical characteristics and slope of the land surface. The model predicts the downslope path and calculates an oil mass balance that includes the calculated losses from oil adhesion to land over the oiled path, the formation of small puddles, oil pooling in large depressions on the land surface, and oil evaporation to the atmosphere. This is used to determine the remaining volume of oil that has the potential to reach a waterway. Once in the water, the releases are modeled as they propagate downstream, and in winter months when the waterway is predicted to be frozen, over the frozen surface until the entire amount of product is retained. Under winter conditions, snow and ice cover might significantly affect the predicted transport and fate of oil. Snow can absorb oil and has the potential to limit downslope (i.e., overland or on the ice surface) oil transport, while ice has the potential to prevent oil from entering a watercourse if the flow is from land.

When oil reaches an ice-free waterway, the water transport portion of the OILMAPLand model simulates the downstream movement of oil on the water surface at a defined velocity (by watercourse segment or reach). As oil is transported downstream, estimates of the amount of oil lost to the shore from adhesion and to the atmosphere by evaporation are made.

While OILMAPLand does provide an indication of the downstream extent of oiling and mass balance of oil, it is not able to provide detailed predictions of three-dimensional oil fate and transport. These processes, such as entrainment of oil into the water column, dissolution of soluble fractions of hydrocarbons, emulsion formation, potential biological effects from exposure to oil, and other complex interactions, are not modeled in smaller waterways, where impacts to results would be less meaningful and would not align with the overarching goal of the OILMAPLand assessment. However, these processes were modeled in SIMAP (see Appendix B) for the larger Bad River and White River watercourse crossings, where an effects assessment was conducted requiring this greater level of detail.

2.1 Overland Release Model

In OILMAPLand, the overland flow of oil or chemicals is simulated using a square land elevation grid. Starting at the release location, the model searches the eight neighboring cells to determine the steepest down-slope direction. The adjacent cell with the lowest elevation becomes the next starting location (Figure 2-1). This process repeats successively until a flat or depression area is reached. In a flat area, the model searches beyond adjacent cells to determine the minimum distance path to a next lowest cell. In a depression area, the area is assumed to fill with liquid until the elevation of the surface of the pool equals the elevation of a grid cell on its boundary. At this point, the boundary of the pool is breached, and the grid cell becomes the next starting point for further down-slope movement of oil. The lowest elevation cell becomes the next starting location.

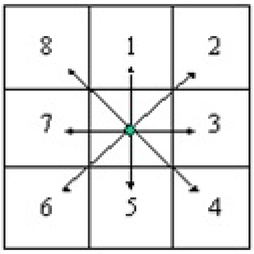

Figure 2-1. Diagram depicting how the OILMAPLand model searches the eight neighboring cells to determine the steepest down-slope gradient and resulting direction of flow.

As a release path is established, the release area is calculated and the loss of oil is computed as a function of three processes: adherence, pooling, and evaporation (Figure 2-2). Adherence, or depression storage, is the process by which oil is lost to the ground surface and vegetation as it spreads overland. Depression storage values vary by land type (as a function of surface area and roughness) and oil type (as a function of density and viscosity). Depression storage represents both the puddling of oil within small surface depressions on a scale smaller than the elevation grid and physical adhesion of oil on surfaces. Pooling is a larger-scale process by which oil is trapped within depressions in the local topography (i.e., depressions that can be resolved at the resolution of the available elevation grid). Such depressions are assumed to fill with oil before additional down-slope transport occurs. Evaporation is the process by which the volatile portion of the liquid oil becomes a gas that enters the atmosphere.

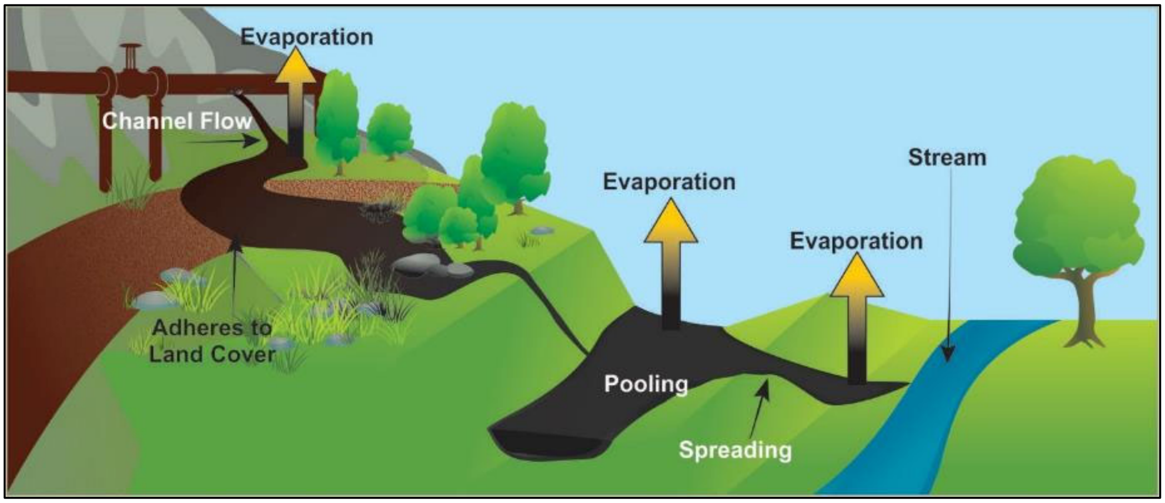

Figure 2-2. Conceptual diagram of land transport model for OILMAPLand, depicting the possible fate of oil as it moves over the land surface.

The rate of oil loss to adhesion and puddle formation depends primarily on the physical characteristics of the land surface (vegetation type, land cover, slope) and the physical and chemical characteristics of the released oil. A data grid specifying land cover type is used to determine the amount of oil retention on each grid cell. As oil traverses the land, a variable loss rate is calculated based upon changes in land cover type. Oil retention loss values vary by five orders of magnitude, between 0.02 and >200 mm, based on surface hydrologic studies (ASCE, 1969; Kouwen et al., 2002; Schwartz et al., 2002).

The second loss term includes oil lost to pooling on the land surface, known as depression storage or puddling. This is defined as the volume of oil that would be retained within depressions defined by the land elevation grid. Essentially, released oil would need to fill a depression before any additional oil would be allowed to be transported down slope. When combined, the oil lost to the ground is the sum of adhesion and pooling.

The third loss term includes the evaporation of oil into the atmosphere. Evaporative loss depends on the chemical and physical parameters of the oil, as well as the shape of the release, and environmental conditions. Some or all the remaining released product may evaporate.

The leading edge of a release travels with a specific velocity (V) as the oil is transported by gravity over the land surface. The velocity of the oil is determined using Manning's Equation, which uses the slope of the land surface and the width of the oil plume:

$$\mathbf{V = 1/n\, R^{2/3}\, S^{1/2}} \qquad (1)$$

where R is the hydraulic radius, S is the slope, and n is a dimensionless number that characterizes the flow resistance from surface roughness. The surface roughness n is 0.05 for all land types, based on USDA NRCS (2010). The hydraulic radius is a slope-dependent metric of cross-sectional area of flow divided by the wetted perimeter. It is calculated iteratively at each time step and is based upon flow rate. Typically, R is approximately 0.122 m, which corresponds with the velocity calculation that is dependent upon slope alone (USDA NRCS 2010):

$$\mathbf{V = 4.92\, S^{1/2}} \qquad (2)$$

Down-slope speed never reaches more than a few meters per second and has a minimum of 0.001 m/s. The maximum advance rate is limited by the release rate of the released oil.

In many cases, the elevation grid defining the land surface is not of sufficient resolution to define channels that direct the path of the oil. The width of the flow path increases as the slope decreases and down-slope velocity slows. Conversely, the path width decreases to a narrower channel with increasing land surface slope and increasing down-slope velocity. The model uses the land surface slope to calculate the path width of the oil, which is typically around 1 m, and cannot exceed the dimension of the land elevation grid cells.

The total volume of oil loss is equal to the sum of adherence, pooled oil, and evaporation losses. If total oil loss equals the total release volume during overland flow, then the release is terminated at this point. If the release volume is not a limiting factor, release propagation over land terminates when the leading edge encounters a surface water feature, or when the model's set duration is reached.

2.2 Surface Water Transport Model

Once the released product encounters a surface water feature, it is transported through the surface water network at a velocity defined by the speed and direction of each stream segment. As oil is transported down the surface water network, there are two potential loss terms including:

- Adhesion of the released product to the stream shoreline, and
- Loss of the released product through evaporation to the atmosphere.

A diagram is provided to illustrate the modeled portions of the downstream release model and the factors influencing a release in surface waters (Figure 2-3).

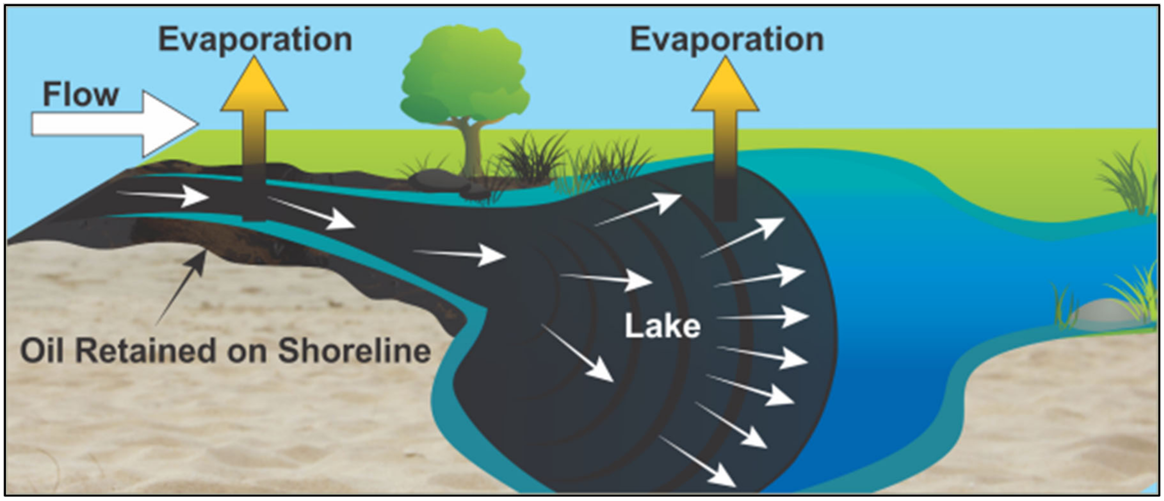

Figure 2-3. Conceptual diagram of the downstream transport model of the OILMAPLand model depicting the possible fate of oil entering the surface water network.

The distance oil is allowed to be transported downstream is limited by one of four factors, including:

- Reaching a user-specified travel time limit (i.e., model duration, which was specified as 12 hours for this study),
- Adherence of all available released product on the water surface to the stream bank as shoreline oiling,
- Loss of all available/remaining released product to evaporation, and
- Termination at specific points of interest (e.g., Lake Superior or a specific watercourse crossing).

The amount of oil adhering to the stream shoreline varies according to the stream shore type and oil type, which can be specified by the user. Five different stream shore types are defined, each with a specified bank width and range of oil retention thickness. Oil volume lost to the shoreline is calculated as the product of the length of the shoreline oiled, the specified bank width, and the oil retention thickness, which is controlled by the density and viscosity of the oil.

Oil movement across lakes was simulated based upon lake size, shape, and water flow characteristics. Oil is assumed to spread radially across the lake surface until it covers the entire lake, or until the oil slick reaches a specified minimum thickness. If the minimum thickness is reached, spreading stops and the oil is transported no farther. The minimum slick thickness is variable and is dependent upon the oil type, as density, viscosity, and other chemical and physical parameters control the behavior of oil on the water surface. Typical values for minimum slick thickness range from microns (µm) to millimeters (mm). If oil covers the entire lake surface before reaching the minimum thickness, the remaining oil is allowed to continue to move down any out-flowing streams at the velocity defined for that specific stream segment.

2.3 Evaporation

Evaporation is the process by which volatile components of the oil diffuse out of the oil and enter a gaseous phase in the atmosphere. Several simplifying assumptions are made that directly affect the amount of oil predicted to evaporate as it spreads over land and water. In general, the rate of evaporation depends on surface area, oil thickness, and vapor pressure, which are functions of the composition of the oil, wind speed, and air and land temperature. The mass of oil evaporated is particularly sensitive to the surface area of the spreading oil and the time period over which evaporation is calculated. On the land surface, the exposed surface area and evaporation time are functions of the slope, which is defined by the elevation grid. Steeper slopes cause the oil to travel faster but along a narrower path, while a lower slope slows the speed of advance and increases the width of the oiled path. In general, evaporation from surface and shoreline oil increases as the oil surface area, temperature, and wind speed increase.

In the stream network, the surface area of oiled water is a function of the total length of the oiled stream, times the average width. The total length oiled is a function of stream velocity. The surface area of the oil then defines the rate of evaporation. Oil loss to evaporation ceases once the total oil volume is released and the simulation is terminated. Termination may occur for a number of reasons, including:

- Oil loss to the ground surface, stream banks, and evaporation,
- The stream travel time is exceeded,
- The release reaches its minimum thickness on a lake surface, and
- The release reaches a dead end in the stream network or the coastline.

In reality, oil will continue to evaporate from the ground or water surface, increasing the total evaporation amount. This conservative calculation of evaporative loss is consistent with a worst-case scenario approach.

3 OILMAPLAND INPUT DATA

A number of geographic and environmental data sources were used to define inputs for the overland and downstream release scenarios simulated using the OILMAPLand model. Federal, state, and local resources were used in the modeling to capture the environmental variability of the region and to determine appropriate representative time periods to use in the modeling (Table 3-1). In addition, project-specific inputs from Enbridge including the pipeline centerlines, release volumes, and hydrocarbon product types were provided. The data types, sources, and steps taken to prepare the data for use in the modeling are discussed in the following sections.

Table 3-1. Data sources used in the OILMAPLand modeling for the Existing, Proposed, and Route Alternatives of the Line 5 pipeline.

Input Type	Source	Time Frame
Centerlines for Proposed Route and Route Alternatives	Enbridge	--
FBR and RARV Release Volumes	Enbridge and PHMSA data	--
Waterway centerline network	USGS High-Resolution National Hydrography Dataset	2018
Land elevation	WisconsinView Ashland County DEM USGS National Elevation Dataset (NED)	2015 Various
Hydrodynamics	USGS and EPA NHDPlus	1999 – 2009
Wind	NOAA National Centers for Environmental Information Ashland Kennedy Memorial Airport	1999 – 2018
Temperature		

3.1 Release Volumes

FBR release volumes were calculated by Enbridge (2022) and provided to RPS in tabular format. FBR release volumes along each pipeline route are site-specific, varying by location based upon the elevation profile of the pipeline relative to the hypothetical release location (Table 3-2; Figure 3-1). These volumes were then used to obtain or calculate the release volumes at each simulated release point along the pipeline for use in the OILMAPLand modeling. For hypothetical release locations that aligned with locations for which data were provided, the release volume provided by Enbridge was used in the simulation. For hypothetical release locations that fell between two provided data points, a linear regression between the two adjacent release volumes was calculated and used (see Section 4.1). Simulated release volumes within the provided data for all pipeline route alternatives ranged from 5,417 to 26,684 bbl with an average value of 15,972 bbl.

Table 3-2. Approximate range of total release volumes associated with hypothetical FBR releases by pipeline route.

Pipeline Route	Minimum (bbl)	Maximum (bbl)
Existing Route	5,500	27,000
Proposed Route	5,500	13,500
RA-01	5,500	21,000
RA-02	5,500	16,500
RA-03	5,500	13,500

The smaller-volume RARV was identified based on an analysis of the average release volumes of any reportable size (recorded as >5 gallons or >0.12 bbl) from 2010 to 2019 for all of Enbridge's liquids pipelines. The RARV still represents a conservatively high release volume because, since 2010, Enbridge has transported approximately 25% of the crude oil produced in North America in its pipelines and recorded only 122 total releases, of which 90% were less than 10 bbl, with both the mode and median of these release volumes being less than 1 bbl.

3.2 Elevation

The OILMAPLand model uses land elevation data to determine the overland pathways of releases occurring in the terrestrial environment (Figure 3-1). The elevation data are stored in a gridded (raster) format and the model calculates the downslope pathway by determining the direction of the 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 pathways of the liquid 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. Greater horizontal resolution is important to be able to see smaller terrain features present in the elevation data. This may include roads, ditches, and other smaller-scale features. Each horizontal grid cell is assigned a single elevation value, so small-scale features would be flattened or smoothed in a larger grid cell and have limited effects on the elevation. 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 for the study were obtained from United States Geological Survey (USGS) National Elevation Dataset (NED) (USGS 2022a). Elevation in the NED is available at many horizontal resolutions, though not all resolutions are available in all areas. The best resolution available for the region surrounding the pipeline was the 1/3-arc second data, which has an approximately 10-meter horizontal resolution, and a vertical resolution of less than 0.1 centimeters (Figure 3-1).

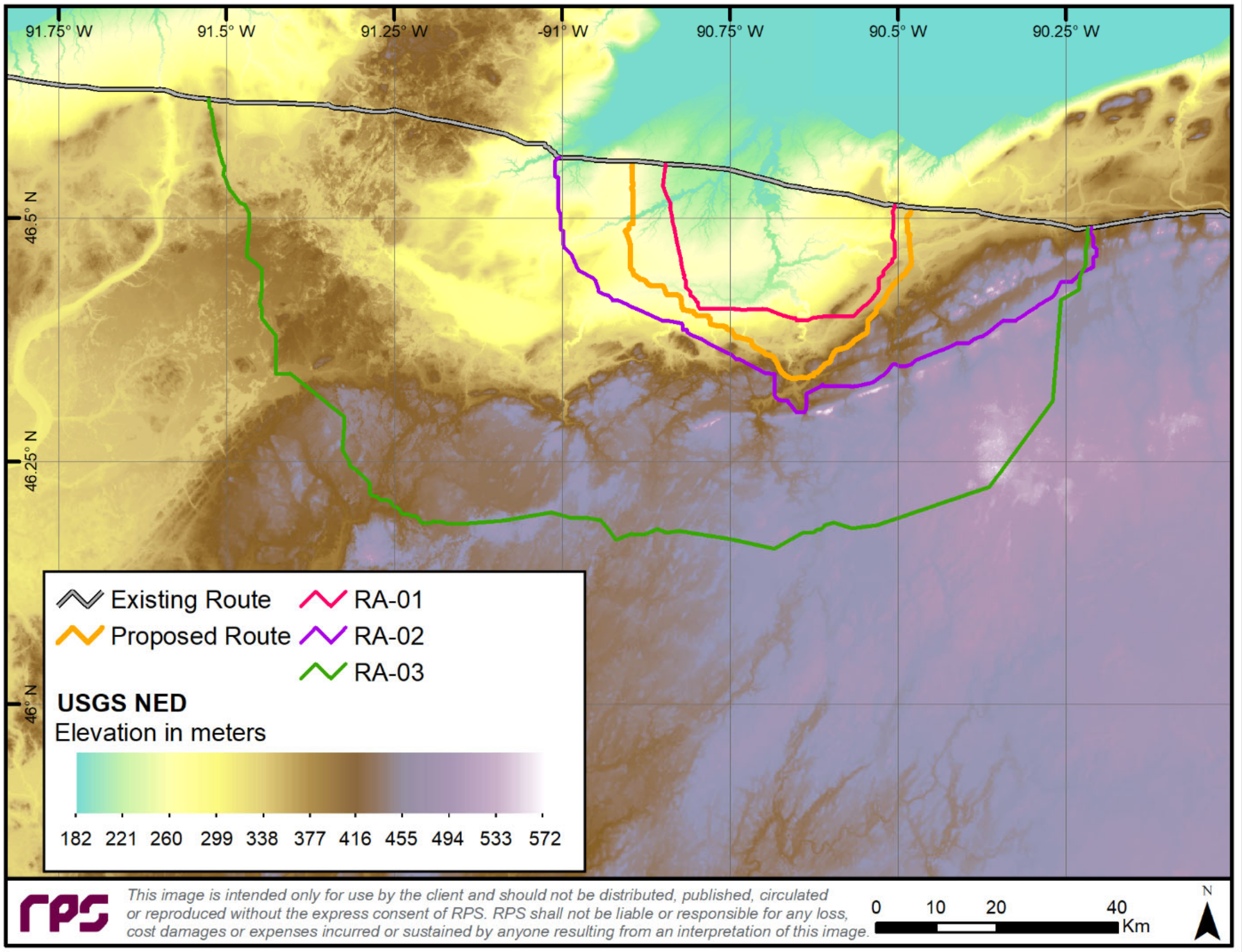

Figure 3-1. Elevation data in the vicinity of Line 5 routes and the Bad River Reservation.

For the Segment Analysis, a higher-resolution dataset was used to improve the accuracy of the model for the higher-resolution (10 m; 32.8 ft) spill distance interval. Elevation data for this part of the analysis were obtained from the WisconsinView Data Portal (2022). The WDNR created Digital Elevation Models (DEMs) derived from county-produced LiDAR covering multiple counties. Elevation data available for the relevant areas had a 1-meter (3.28 ft) horizontal resolution, and a vertical resolution of less than 0.1 centimeters (0.39 in). These data were resampled to a horizontal resolution of 2-meters (6.56 ft) to facilitate efficient operation of the model.

3.3 Hydrological Network

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

Surface water data were derived from USGS high resolution National Hydrography Dataset (NHD HR) (USGS 2022b) (Figure 3-2). It provides geospatial vector data describing hydrographic features such as lakes, reservoirs, rivers, streams, and canals in the form of a linear drainage network that is used by the model to route spills downstream. The NHD is available to the public from the USGS National Map web site (www.nhd.usgs.gov), but it requires some processing and QA/QC steps to make it usable by the OILMAPLand model. The dataset is comprised of data from federal, state, and local levels coordinated by the USGS. The NHD is a vector data product primarily designed to allow hydrographic network analysis. It is intended for water flow analysis, water and watershed management, and environmental and hydrographical applications.

Stream current velocities are used by the model to determine downstream transport speeds. The high resolution NHD data does not include stream flow and current velocity information, so it is necessary to obtain this information from the United States Environmental Protection Agency's (EPA) National Hydrography Plus (NHDPlus) dataset. NHDPlus combines the USGS's medium resolution NHD, the 1/3 arc-second resolution NED, and National Watershed Boundary Dataset (WBD) in order to estimate stream flow and velocity for every stream segment (McKay, 2012). The NHDPlus dataset provides an estimated average stream velocity for each calendar month, for nearly every stream segment in the database.

Because the high resolution NHD and the lower resolution NHDPlus do not contain the same stream features it is necessary to calculate a current speed for streams in the high resolution NHD grouped at some geographic unit, in this case a drainage basin. A method has been developed to calculate a single stream current velocity for a drainage basin and apply that velocity to all stream segments within that basin. The individual stream segment velocities were analyzed within the drainage basin in the region surrounding the pipeline. The basins were defined using the level 5 (10 digit hydrologic unit code) watershed boundaries contained in the WBD. Minimum, maximum, mean, and standard deviation current speeds were calculated for each month for each watershed. For the high river flow FBR releases, the month representing the maximum average velocity for the year was identified for each watershed. The monthly mean velocity represents the average velocity of all the stream segments in the watershed. Slower moving streams in the watershed can reduce the overall mean and result in slower current velocities for the faster streams in the watershed. A more conservative estimate of stream velocity within the watershed is to use the 95th percentile velocity. This is the velocity in the watershed that is exceeded by only 5% of the stream segments in the watershed (assuming a normal distribution). This velocity was estimated by taking the monthly mean velocity and adding 2 standard deviations. The 95th percentile velocity for the five watersheds in the region ranged from 0.53 m/s to 0.62 m/s (Figure 3-3). The velocity was applied to all of the individual stream segments within each watershed and was used by the model to calculate downstream transport speeds.

For the low river flow RARV release, the month representing the minimum average monthly velocity for the year was identified for each watershed. The lowest monthly mean velocity was used directly for the five watersheds in the region. This provided a conservative low river flow estimate for the lower bound modeling predictions. The low river flow velocities for the five watersheds in the region ranged from 0.12 m/s to 0.25 m/s.

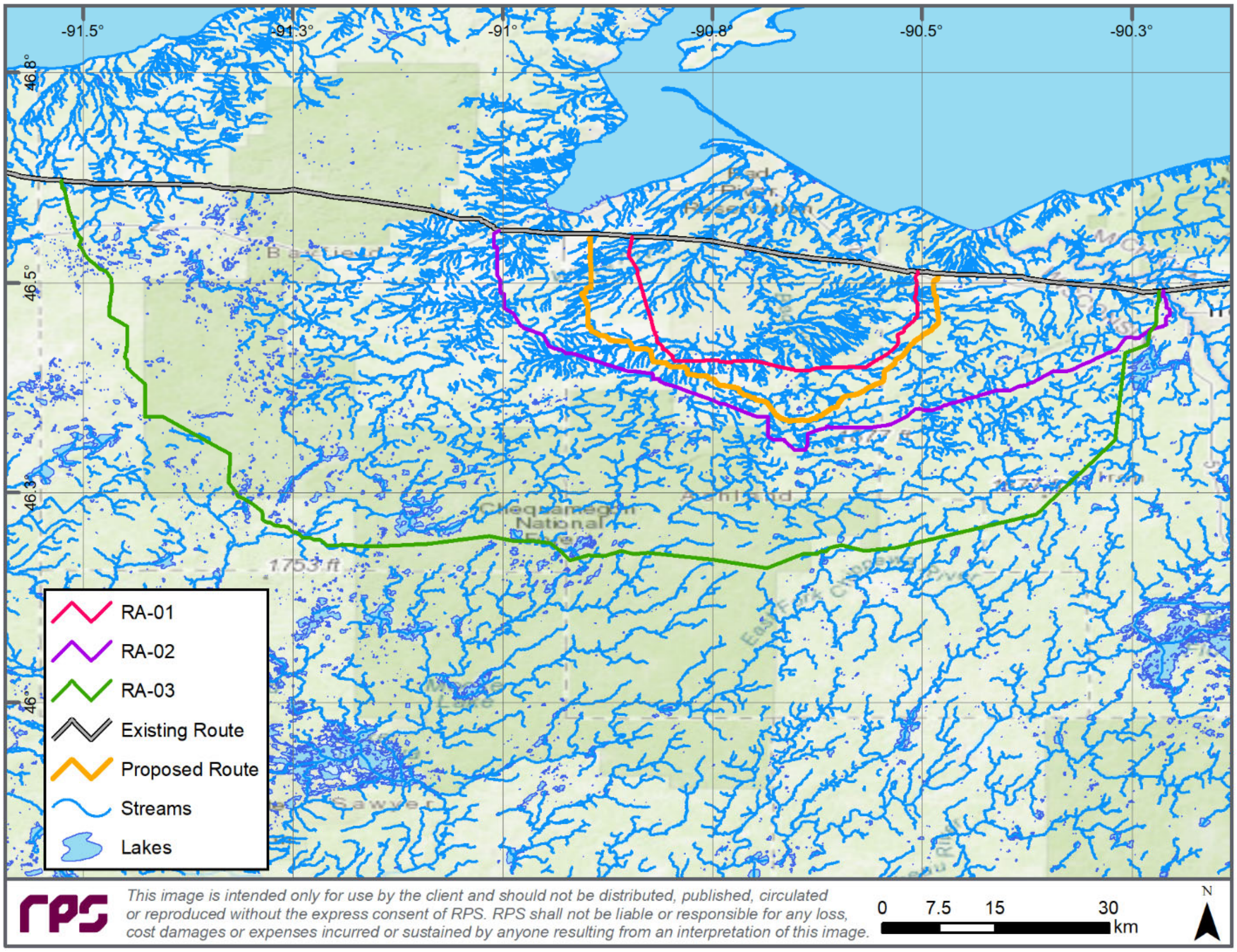

Figure 3-2. NHD HR stream and lake data used in the OILMAPLand assessments.

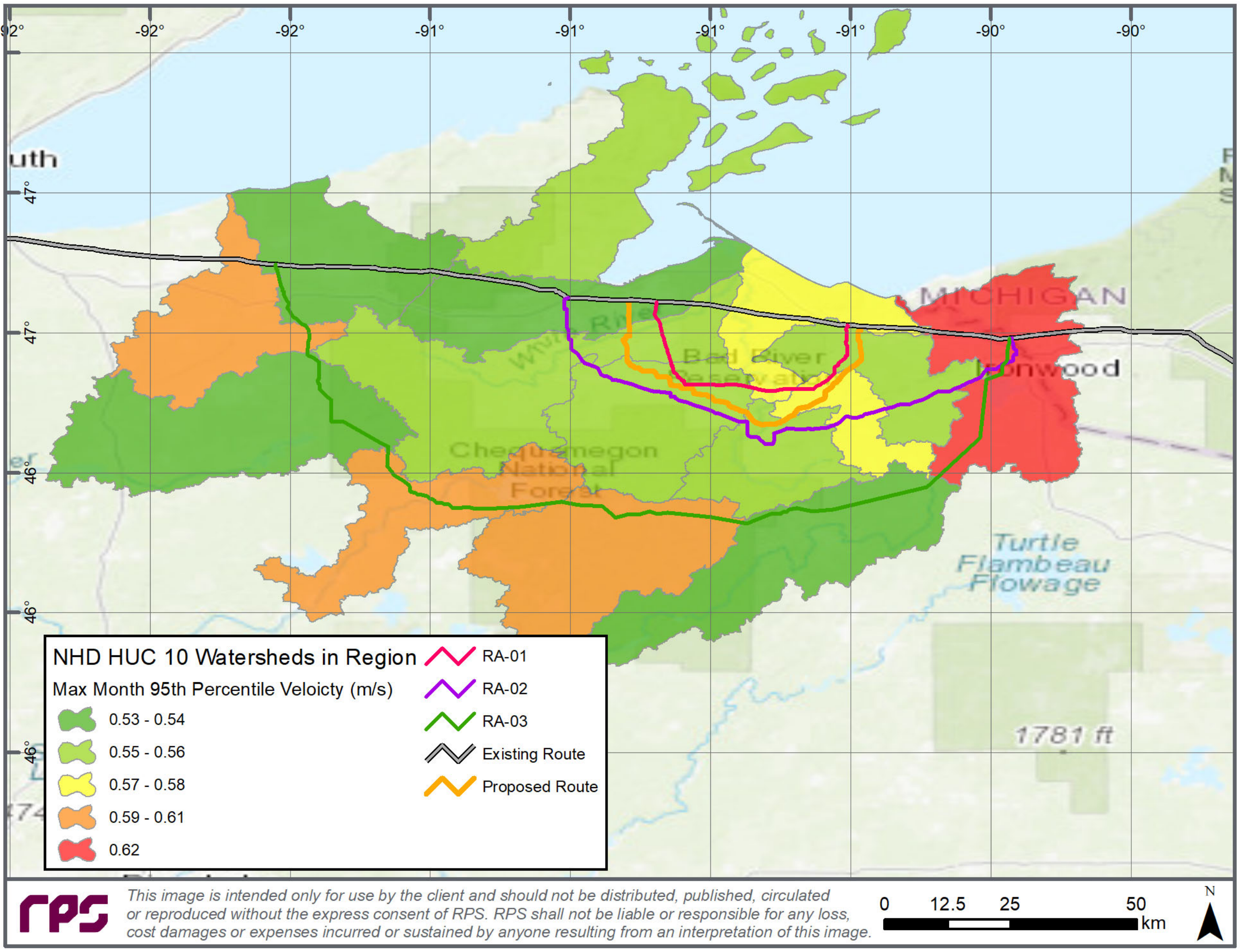

Figure 3-3. Watersheds within the L5WSRP project area and their corresponding 95th percentile stream current velocity used in the OILMAPLand modeling.

3.4 Land Cover

The OILMAPLand model uses land cover data to calculate the amount of oil that may adhere to the land surface as oil moves downslope. 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 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) 2016, created by the Multi-Resolution Land Characteristics Consortium (Homer et al., 2020) (Figure 3-4). The NLCD 2016 is based on a decisiontree classification of 2016 Landsat satellite data with 30-meter horizontal resolution and was transformed to the geographic coordinate system (North American Datum of 1983) used in the modeling. The dataset required reclassification of land cover classes to assign them to oil retention thickness for use in OILMAPLand (Table 3-3).

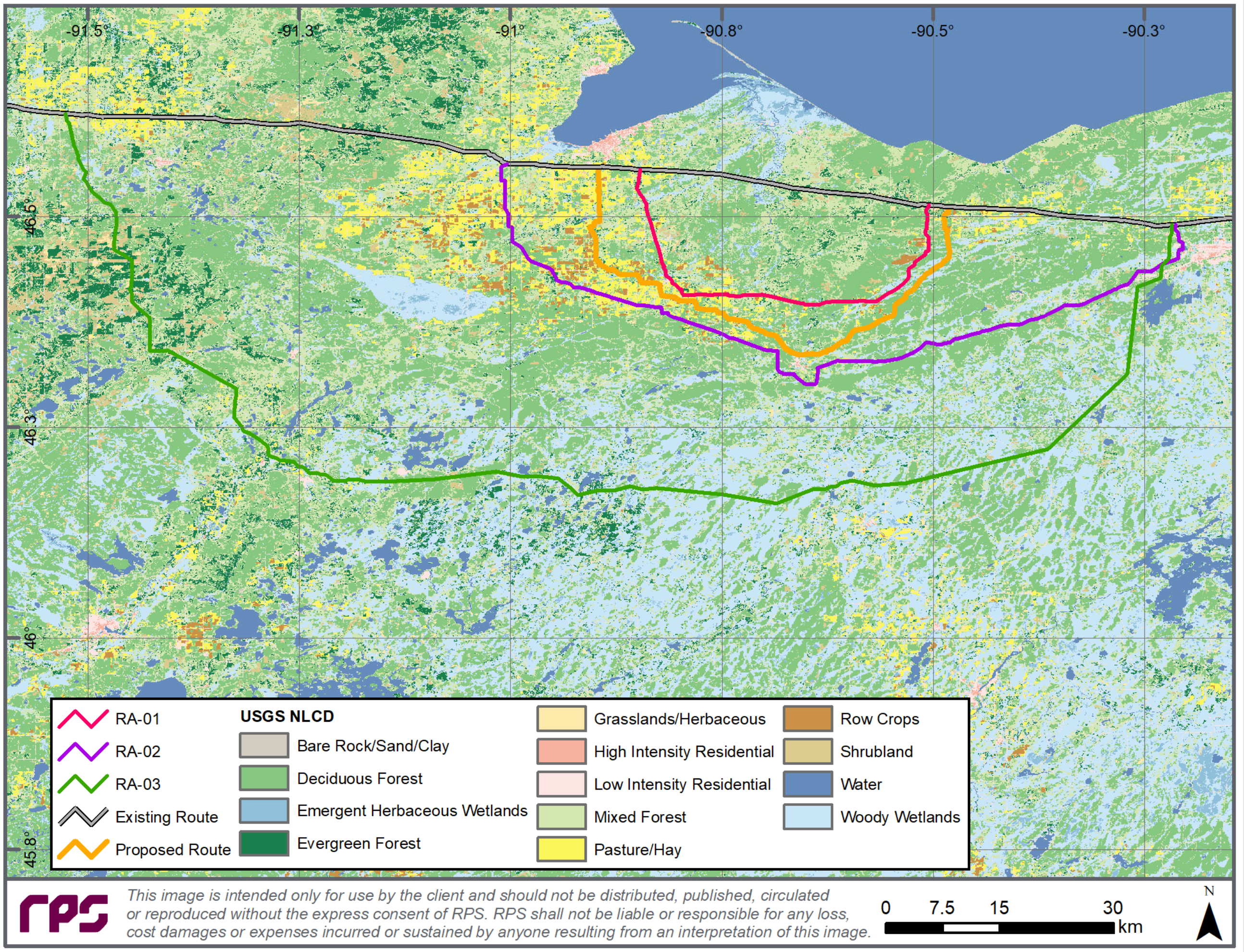

Figure 3-4. Land cover data used in the OILMAPLand spill assessment.

Table 3-3. Land surface retention values used in the OILMAPLand overland modeling.

Land Cover Type	Oil Retention Thickness (mm)
Bare Rock/Sand/Clay	0.7
Deciduous Forest	2.0
Emergent Herbaceous Wetlands	33.8
Evergreen Forest	2.0
Grasslands / Herbaceous	0.6
High Intensity Residential	0.6
Low Intensity Residential	1.7
Mixed Forest	2.0
Pasture/Hay	0.6
Row Crops	0.6
Shrubland	0.6
Woody Wetlands	33.8
Water	0.1

3.5 Wind and Temperature Data

Daily climatological statistics consisting of wind speed, wind direction, and air temperature were obtained from the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information website (NOAA, 2015). The preliminary climate datasets consist of three parts:

- Site information (includes the station location coordinates and the month and year of the report),
- Daily climatological data, and
- Monthly averages.

Monthly averages for both air temperature and wind speed for the 19-year period between 1999-2018 were obtained from the Ashland Kennedy Memorial Airport station. Release scenarios were simulated under different meteorological conditions (i.e., different wind speed and air temperature corresponding with each river flow condition/season), which cover a range of weather conditions at the hypothetical release locations and provide a conservative approach to assessing potential outcomes of a release (i.e., trajectories, fates, and effects). Table 3-4 depicts the temperatures and wind speeds that correspond with environmental conditions at the time of the targeted high and low river flow conditions that were used for the OILMAPLand scenarios. Use of these conditions added environmental realism and consistency, while conservatively attempting to maximize downstream transport.

Table 3-4. Air temperature and wind speed values that correspond with targeted high and low river flow conditions used in the OILMAPLand modeling.

Season / River Flow	Month	Air Temp. (°C)	Air Temp. (°F)	Wind Speed (m/s)
Spring / High	April	4.3	39.8	3.8
Winter / Low	January	0.1	32.2	3.8

4 MODEL APPLICATION

4.1 OILMAPLand Modeling

An interval-based approach was used in OILMAPLand to assess releases along the entirety of each pipeline route that move over the land surface and down the surface-water network. The OILMAPLand model was used to generate release point locations spaced at 100-meter intervals (328 ft) along each pipeline route, as well as at every watercourse crossing identified in the NHDPlus dataset. A total of 5,029 individual release points were simulated from the Existing, Proposed, and Route Alternatives using the OILMAPLand model, with between 552 and 1,684 hypothetical release points per pipeline route (Table 1-1). Each release point was simulated for both FBR release volumes (location specific) and the RARV release volume (the same at each point), for a total of 10,048 release simulations. Hypothetical release locations included in the assessments for each pipeline route began and ended at the same westernmost and easternmost points where RA-03 diverted from the existing line (i.e., the Pipeline Extent Considered in Figure 1-1 denoted by the asterisk). This means that portions of the existing Line 5 were used in the analysis of multiple Route Alternatives. These portions were included to allow for commensurable comparisons of each route alternative between the same upstream and downstream endpoints.

Site-specific spill volumes were assigned to each hypothetical release location based on predicted FBR release volumes provided by Enbridge (2022) or the RARV (334 bbl for all locations). The FBR spill durations were calculated in a Python geoprocessing script that used drained volume, pipeline diameter, pipeline shutdown time, and elevation profile of the pipeline. For the RARV, a duration of 0.01 hours was used for all release locations. The methodology used is described below.

Volume outflow at a given location was calculated using a relatively simple linear interpolation. The first step was to spatially identify the records in the release volume spreadsheet that occurred before and after each spill location. The spill volume was determined using a simple linear regression based on the two bounding volume records. In cases where one of the bounding volume records included a valve location, the spill volume was set to be equal to the non-valve bounding record.

The duration calculation used a more complicated approach. The portion of the spill volume that would be released before the pipeline was shutdown was subtracted from the total spill volume, which resulted in a remaining volume that is referred to as the gravity flow volume. The maximum elevations along the pipeline in both the upstream and downstream directions, before the next valve, were then determined. A friction factor was also calculated based on the inside diameter of the pipeline and a roughness value based on non-new commercial steel pipe. Based on these various calculated values, a series of equations were solved to determine the spill duration for each location.

The velocity of oil that would drain down through the pipeline was calculated for both upstream and downstream portions of the pipeline, relative to the spill location, as follows (Equation 1):

$$v = \sqrt{\frac{2ghd}{f_D L}} \tag{1}$$

where v = velocity, g = acceleration due to gravity (9.81 m/s^2), h = change in elevation, d = pipeline inside diameter, f_D = friction factor, and L = distance

The flow rate for the upstream and downstream sections were then calculated as follows (Equation 2):

$$Flow = Velocity \times Pipeline\ Area \tag{2}$$

The gravity flow volume was divided between the upstream and downstream sections of the pipeline as follows (Equations 3 and 4):

$$Gravity\ Flow\ Upstream = Total\ Gravity\ Flow\ Volume \times \frac{Length\ Upstream}{(Length\ Upstream + Length\ Downstream)} \tag{3}$$

$$Gravity\ Flow\ Downstream = Total\ Gravity\ Flow\ Volume \times \frac{Length\ Downstream}{(Length\ Upstream + Length\ Downstream)} \tag{4}$$

The total spill duration was then calculated using the following method (Equation 5):

$$Duration = Maximum\left(\frac{Gravity\ Flow\ Vol\ Upstream}{Flow\ Rate\ Upstream}, \frac{Gravity\ Flow\ Vol\ Downstream}{Flow\ Rate\ Downstream}\right) + Time\ to\ Valve\ Closure \tag{5}$$

In addition to requiring individual spill volumes and durations for each location, the OILMAPLand model uses input datasets to define the environment around the pipeline. The elevation data, hydrology, and land cover data used in the modeling are described in Sections 3.2, 3.3, and 3.4, respectively. The temperature and wind speed condition inputs that were selected were based on monthly averages as described in Section 3.5. In addition, several other important model input parameters used in this modeling are provided in Table 4-1.

Table 4-1: OILMAPLand model settings used for spill trajectory simulations.

Setting Name	Value Used	Setting Description
Buffer Size	15 meters	Buffer applied to the spill pathway to account for uncertainty in the overland path and to add width to stream centerlines.
Stream Shore Type	Sand/Gravel	Shore types influence the quantity of oil that is able to be retained on the shoreline based upon what is referred to as a shoreline holding capacity.
Stream Width	3 meters	Widths of the streams are used in the evaporation calculation as they are required to define the surface area of the wetted surface.
Maximum Stream Travel Time	12 hours	Time limit for oil to travel downstream from the start of the spill. It was assumed that after this identified point, mitigation measures would have been in place for a sufficient amount of time to have impacted downstream transport (via oil containment) and the amount remaining (via oil collection).

4.2 Route Comparison

To enable comparisons between the different potentials for impact from hypothetical releases along each pipeline route, the OILMAPLand-predicted trajectories from simulated release points were overlaid upon maps of HCAs and AOIs. The HCAs analyzed included the five types defined by PHMSA in 49 CFR § 195.450 and 49 CFR § 195.6: commercially navigable waterways (CNW), high population areas (HPA), other populated areas (OPA), drinking water resources (DW), and ecological resource unusually sensitive areas (ESA). While AOIs are not defined regulatorily, receptors of interest to various stakeholders are frequently considered in addition to defined HCAs. For this assessment, AOIs included Lake Superior, the Reservation, wild rice areas, and Federal, State, and County/Local Land[1] (WDNR, 2022 and Esri, 2022) (Figure 4-1). The wild rice areas included those in the vicinity of the Kakagon-Bad River Slough complex (i.e., within the Reservation; from Bad River Tribe, 2020), as well as elsewhere throughout the region (from WI DNR, 2020; 2023).

Both the HCA and AOI analyses within the route comparison identified "direct" could-affect segments, where segments of the pipeline centerline directly intersected an HCA/AOI, and "indirect" could-affect segments, where releases from points along the pipeline segment would be predicted to reach an HCA/AOI following overland and/or downstream transport. Reported portions of the pipeline that directly impact an HCA/AOI were also always considered to indirectly impact the HCA/AOI.

Conservative approaches were used to maximize the calculated total length of an HCA/AOI could-affect segment and the number of HCAs/AOIs that might be affected. If a liquid plume output simulated in OILMAPLand was predicted to reach any portion (or only the edge) of an HCA/AOI, that entire HCA/AOI was considered impacted. If a liquid plume output from a given release point was predicted to reach an HCA/AOI, the entire segment from the nearest upstream point to the nearest downstream point was categorized as an indirect could-affect segment, regardless of whether the upstream or downstream point itself resulted in the potential for an HCA/AOI impact. Spray radius impacts were also considered. Portions of the pipeline where an HCA/AOI was within a spray radius of 260 meters (853 ft; based on historical Enbridge releases that have had spray) were also considered indirect could-affect segments. The lengths of these could-affect segments were calculated and summarized individually, by category, and by overall length for each pipeline route.

Note that the route comparisons (HCA and AOI analyses) were performed using the combined portions of new construction and relevant portions of the existing Line 5, thus covering the full Pipeline Extent Considered for each route, to enable commensurable comparisons (Figure 1-1).

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[1] While Federal and State lands are traditionally used in these assessments, additional lands associated with county/local government, as well as Forest Crop Law lands were included in the segment length analysis as a further conservative consideration, following consultation with Federal, State, and Tribal representatives. These lands were included because they are important to community, cultural, and ecological functions. Individual county and local land parcels that could be impacted, however, were not listed individually as unique AOIs because of the wide variety of land types and the overlapping nature of these resources between each dataset (e.g., contained within Federal and State lands).

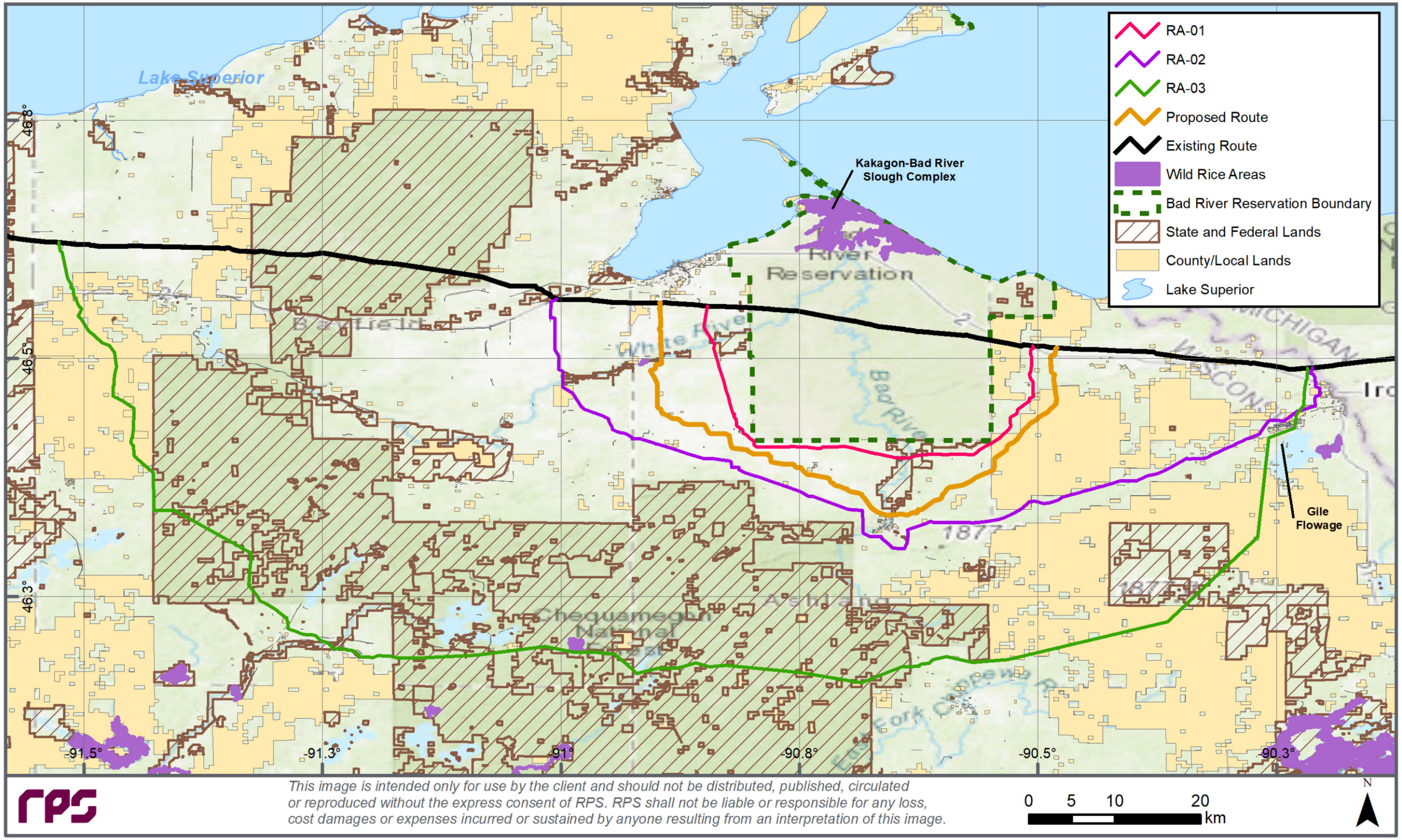

Figure 4-1: AOIs in the area of the route alternatives.

4.3 High-Resolution Segment Analysis

To address the probability of large crude oil releases, quantitative estimates of rupture frequency were determined in the Probability Assessment (Appendix A) for each of the Bad River and White River crossings on the Proposed Route, RA-01, and RA-02. For linear infrastructure such as pipelines, the probability of failure over a given time period is proportional to segment length, with longer segments being associated with greater probabilities. Given that each watercourse crossing has unique local topography and land conditions, there is variability in the total length of the pipeline segment at each crossing that would have the potential to impact the waterway.

The length of the pipeline segment that had the potential to impact each watercourse crossing was determined in a high-resolution segment analysis using a high-resolution outflow and overland spill modeling assessment conducted with OILMAPLand. Simulations were modeled at hypothetical release locations spaced at 10-m intervals along the pipeline on either side of the White River and Bad River crossings, up to the point that the coarser and previously conducted 100-m interval (328 ft) results clearly depicted the oil traveling away from the river crossing or through a separate hydrologic route that entered the river a significant distance (e.g., >500 m or >1,640 ft) from the crossing itself. A total of six segment analyses were performed, including one for each of the Proposed Route, RA-01, and RA-02 crossings of both the White River and Bad River. RA-03 is not in the watershed and therefore does not cross the White River or the Bad River, and thus was not included in this analysis. A higher resolution elevation dataset (the Ashland County DEM) was used to improve the accuracy of the assessment. Inputs were otherwise the same as those described in Section 4.1. The site-specific and bank-specific endpoints located inland from each riverbank varied by bank, watercourse, and route alternative. The total length of the pipeline segment that was predicted to have the potential to enter each watercourse crossing was calculated as the sum of each inland segment from both banks. This total length or “potential impact segment” then served as the basis for estimating the failure probability of each watercourse crossing in Appendix A.

5 OILMAPLAND MODEL RESULTS

Hypothetical releases of crude oil were simulated from points on land originating along the Existing Route, Proposed Route, and three route alternatives of the Line 5 pipeline using the OILMAPLand model. Simulations were performed to assess the trajectory and fate of oil overland and through the surface water hydrologic system in order to determine the potential impact of hypothetical releases on downstream receptors, including HCAs and specific AOIs (see Section 4.2). Depictions of the predicted overland and downstream pathway of hypothetical releases that were modeled along each pipeline route are provided for each route analysis. These results include route-specific and site-specific pathways for each individual release simulated along the pipeline routes. The trajectories were then used to evaluate and compare the potential for impacts to receptors from each pipeline route alternative within the Pipeline Extent Considered.

OILMAPLand simulations were performed for the Existing Route, Proposed Route, RA-01, RA-02, and RA-03, each within boundaries of the Pipeline Extent Considered. Release locations were modeled at 100-m intervals (328 ft) and at every watercourse crossing, with 552-1,684 release locations per pipeline extent (Table 1-1). Both FBR releases under high river flow conditions and RARV releases under low river flow conditions were simulated at each location.

The OILMAPLand-predicted plume trajectories for the FBR releases on each pipeline route are depicted in bright orange (Figure 5-1 to Figure 5-5). The trajectories for the RARV releases on each pipeline route are depicted in Figure 5-6 to Figure 5-10. For pipeline route alternatives that include portions of the existing pipeline within the Pipeline Extent Considered (that still apply to each separate route alternative scenario), the trajectories from the existing pipeline are depicted in a muted orange. These full results, combining the release trajectories for the new construction and relevant portions of the existing Line 5, were then compared to evaluate the range of potential impacts between the route alternatives.

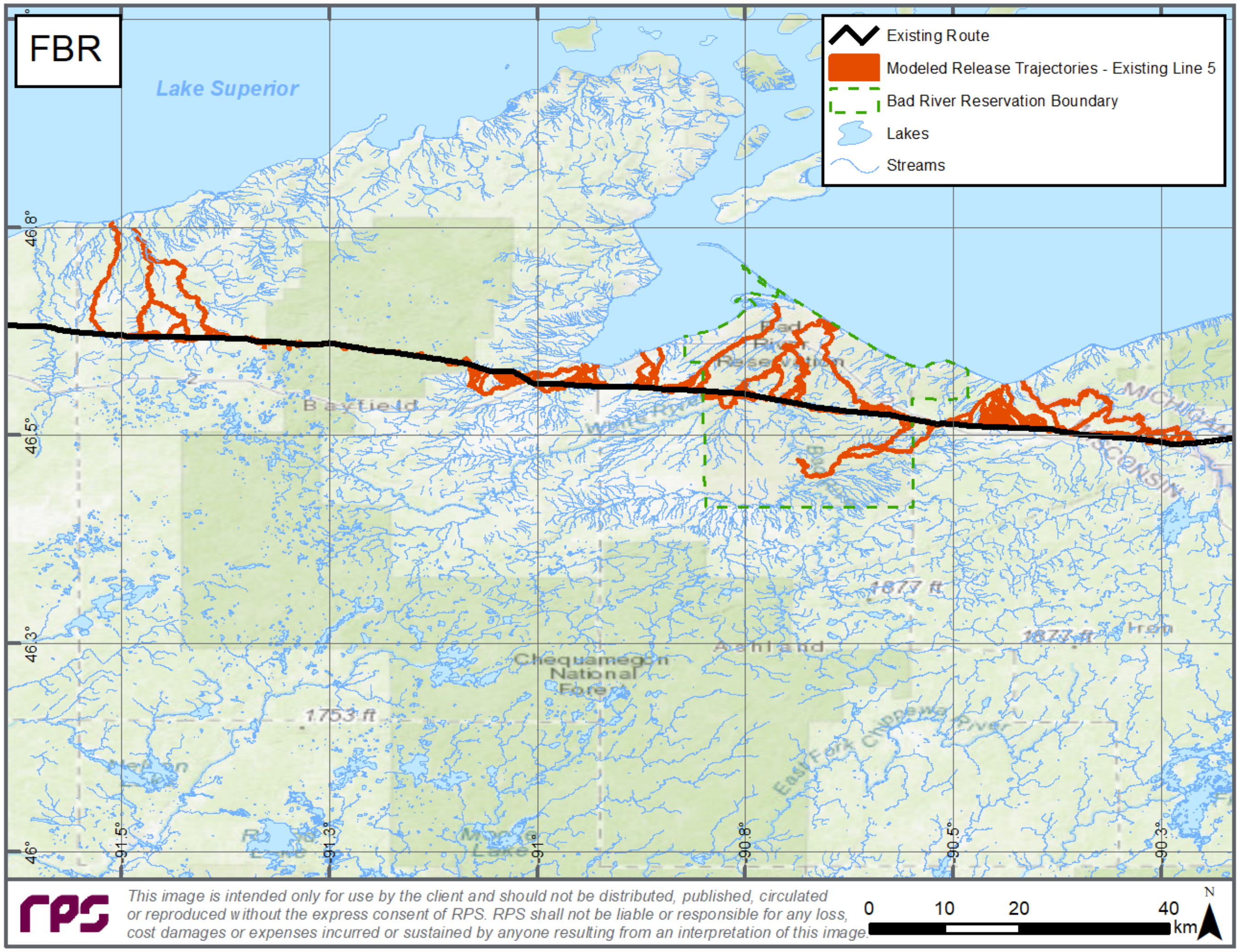

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Figure 5-1: Modeled FBR release trajectories under high river flow conditions along the Existing Route.

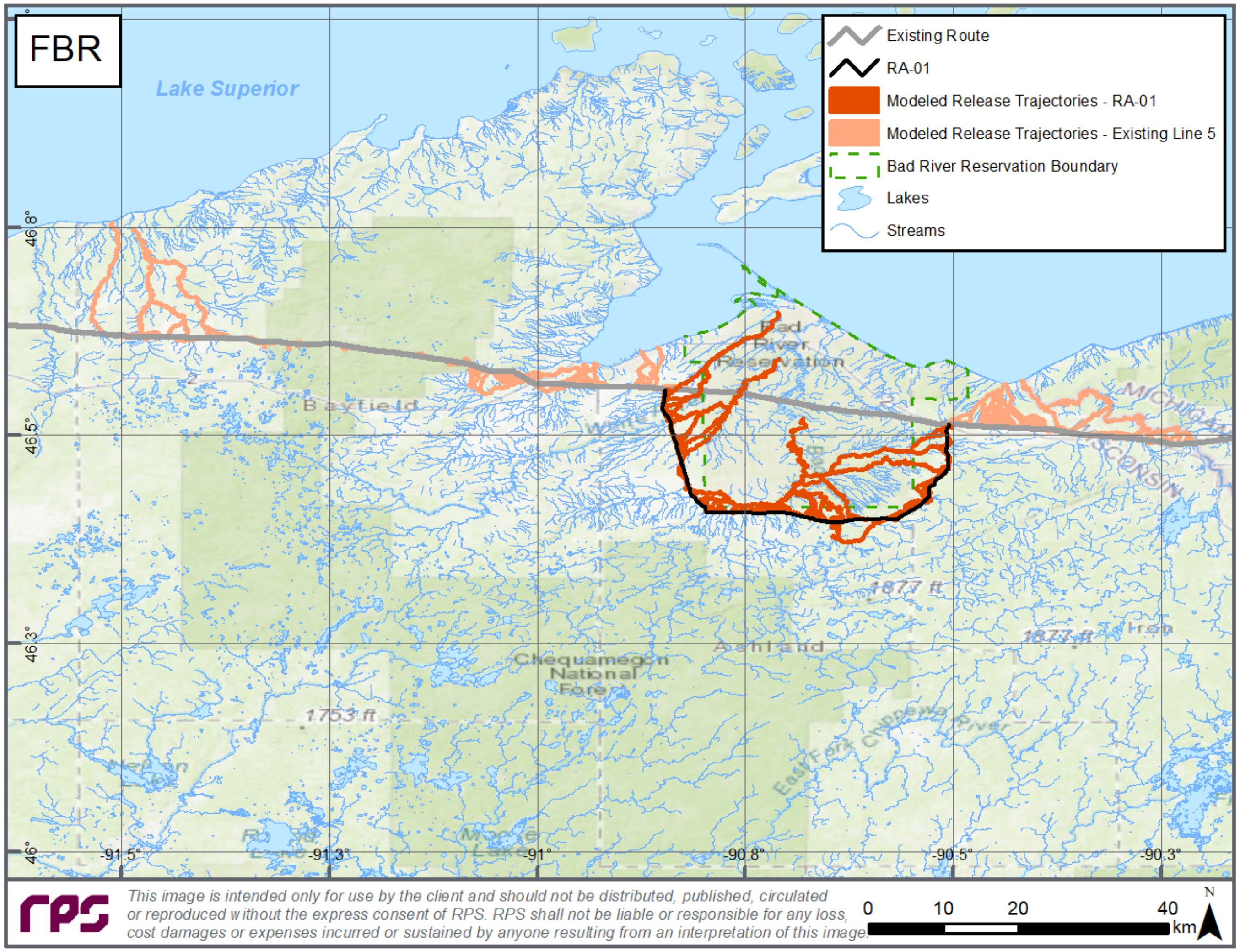

Figure 5-2: Modeled FBR release trajectories under high river flow conditions along RA-01.

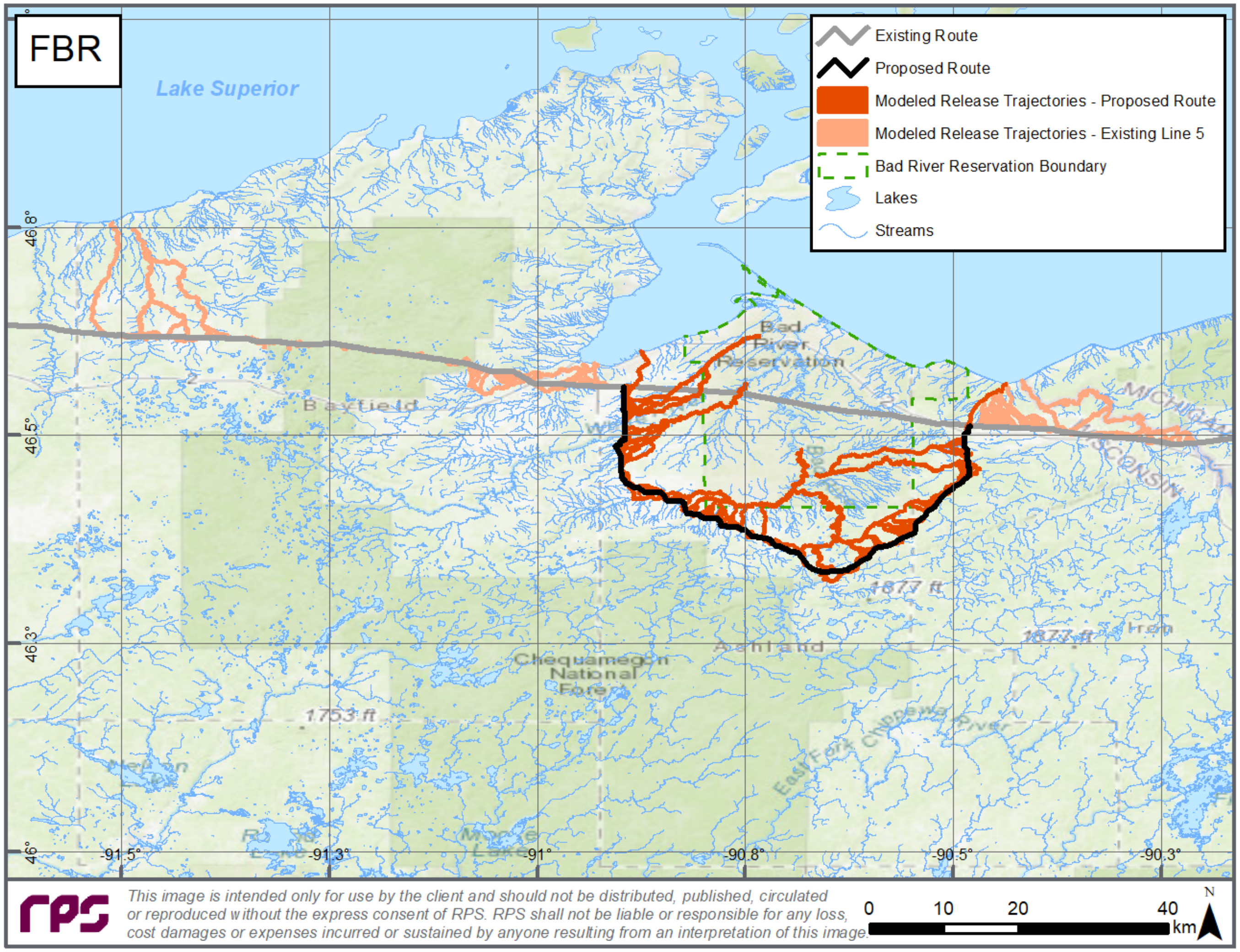

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Figure 5-3: Modeled FBR release trajectories under high river flow conditions along the Proposed Route.

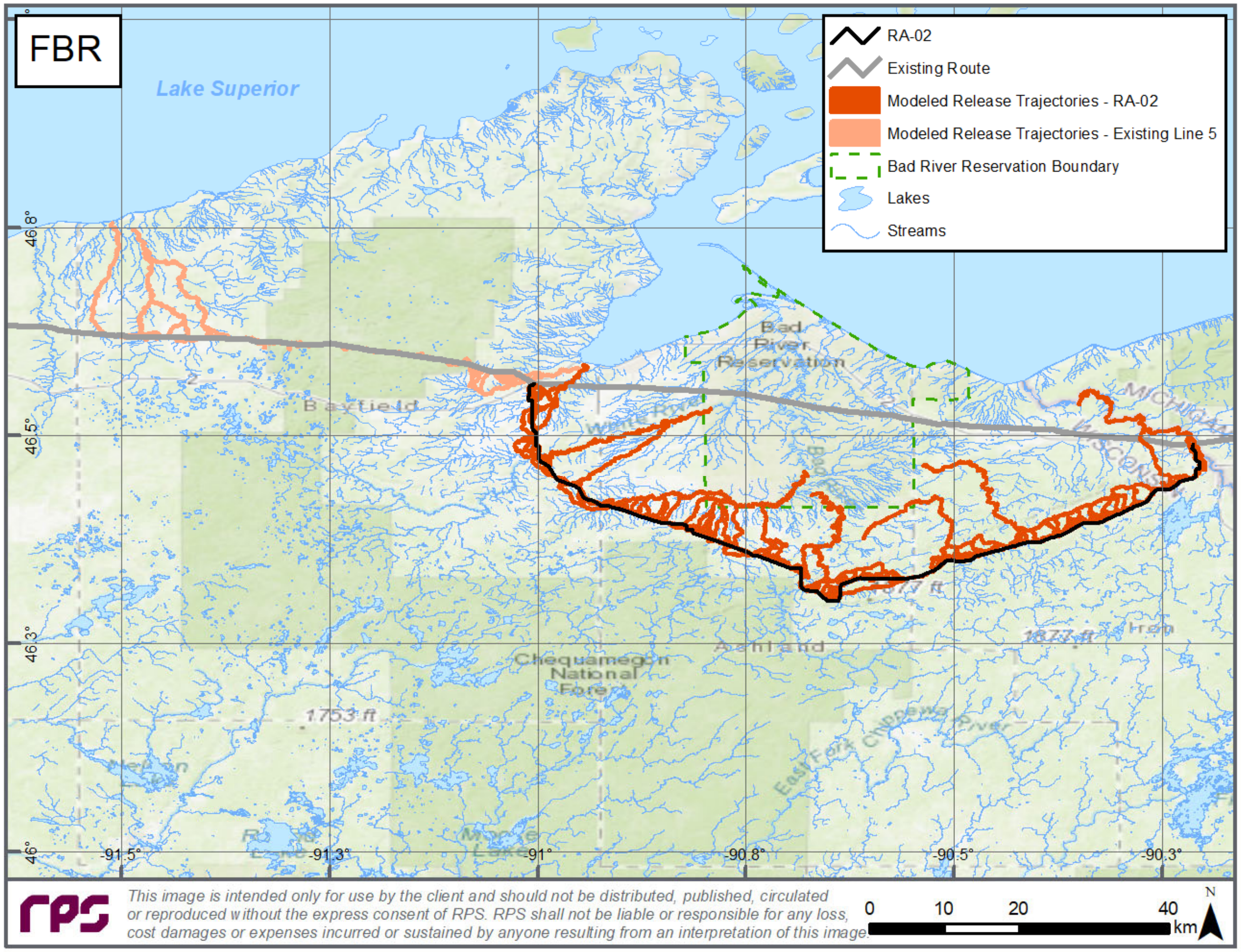

Figure 5-4: Modeled FBR release trajectories under high river flow conditions along RA-02.

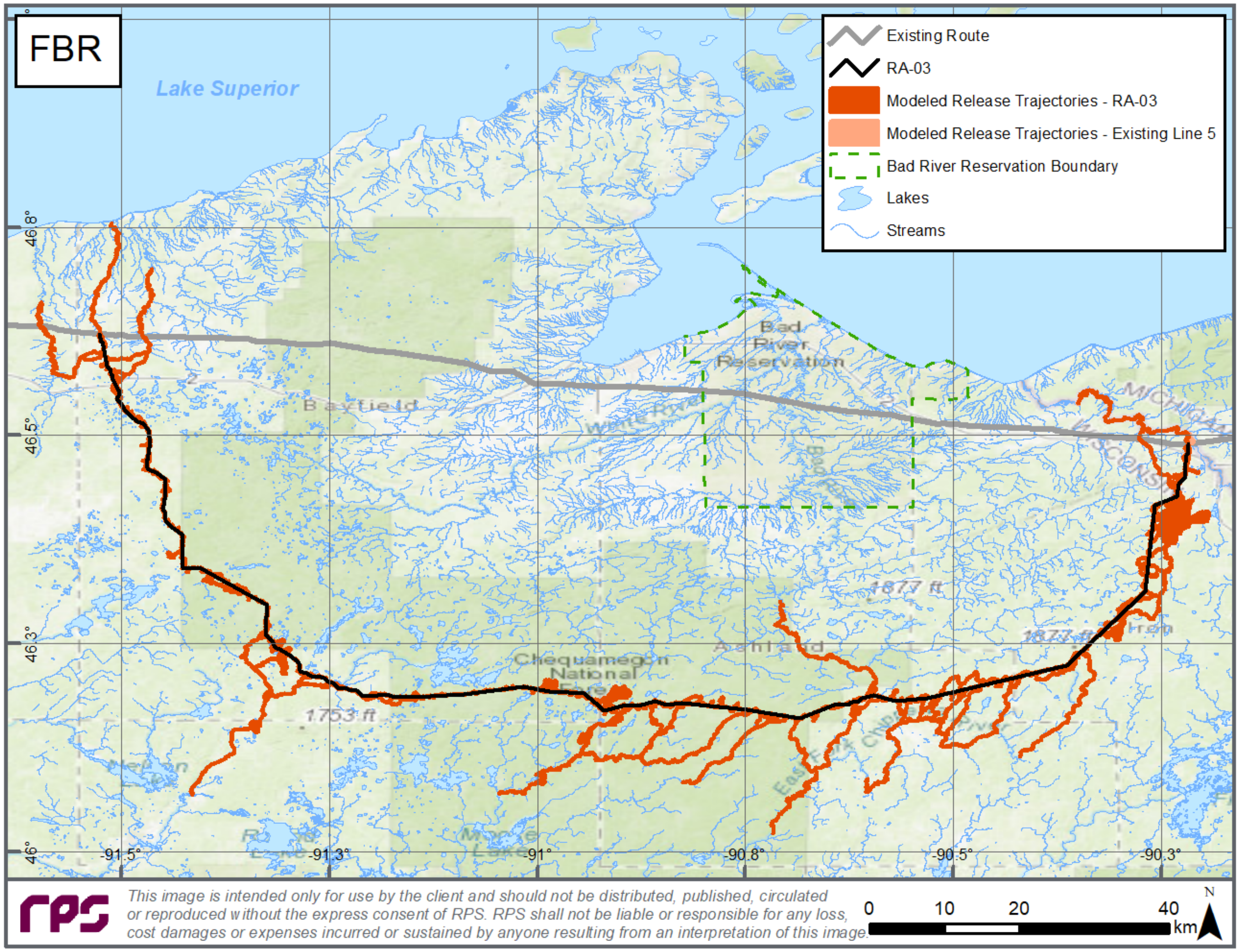

Figure 5-5: Modeled FBR release trajectories under high river flow conditions along RA-03.

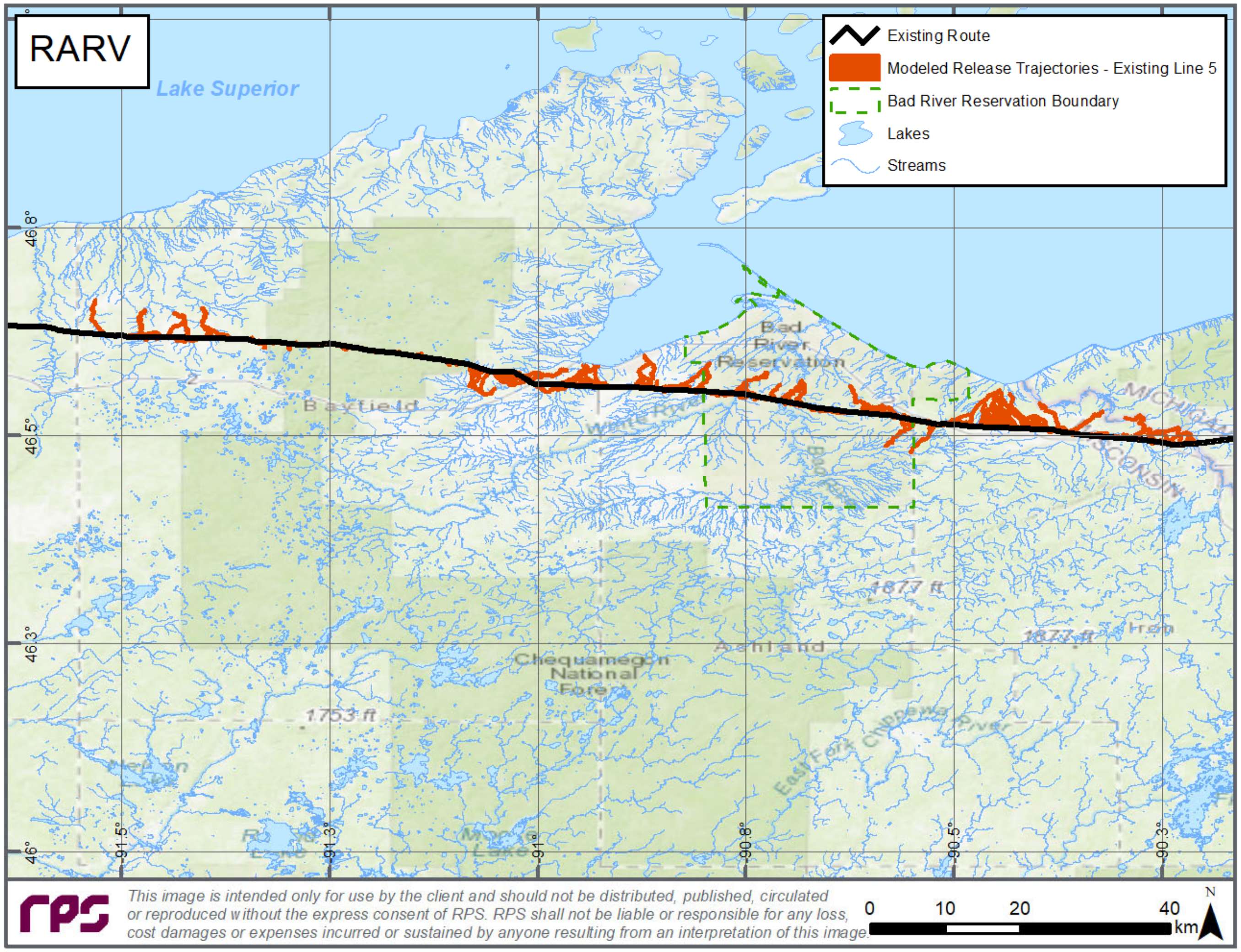

Figure 5-6: Modeled RARV release trajectories under low river flow conditions along the Existing Route.

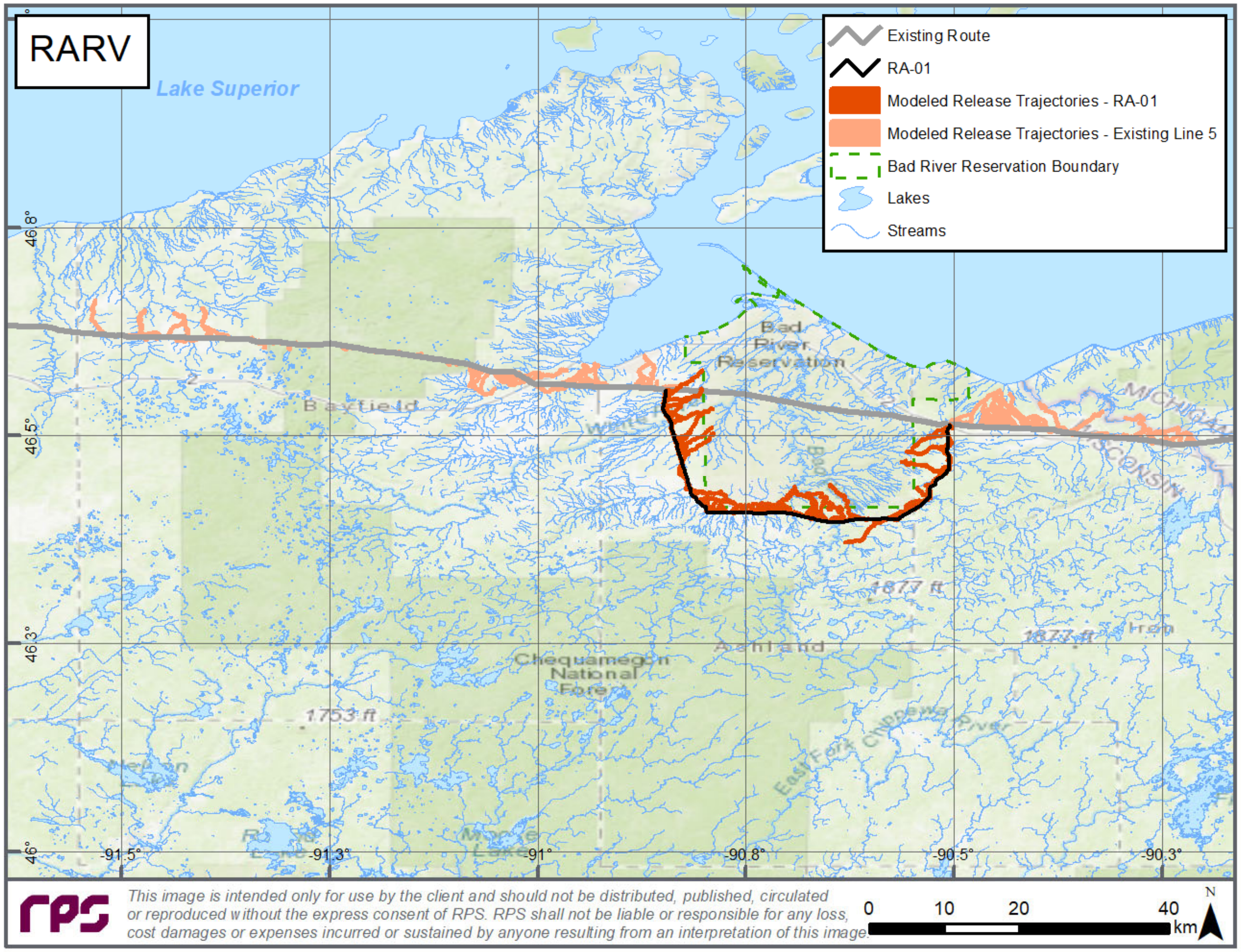

Figure 5-7: Modeled RARV release trajectories under low river flow conditions along RA-01.

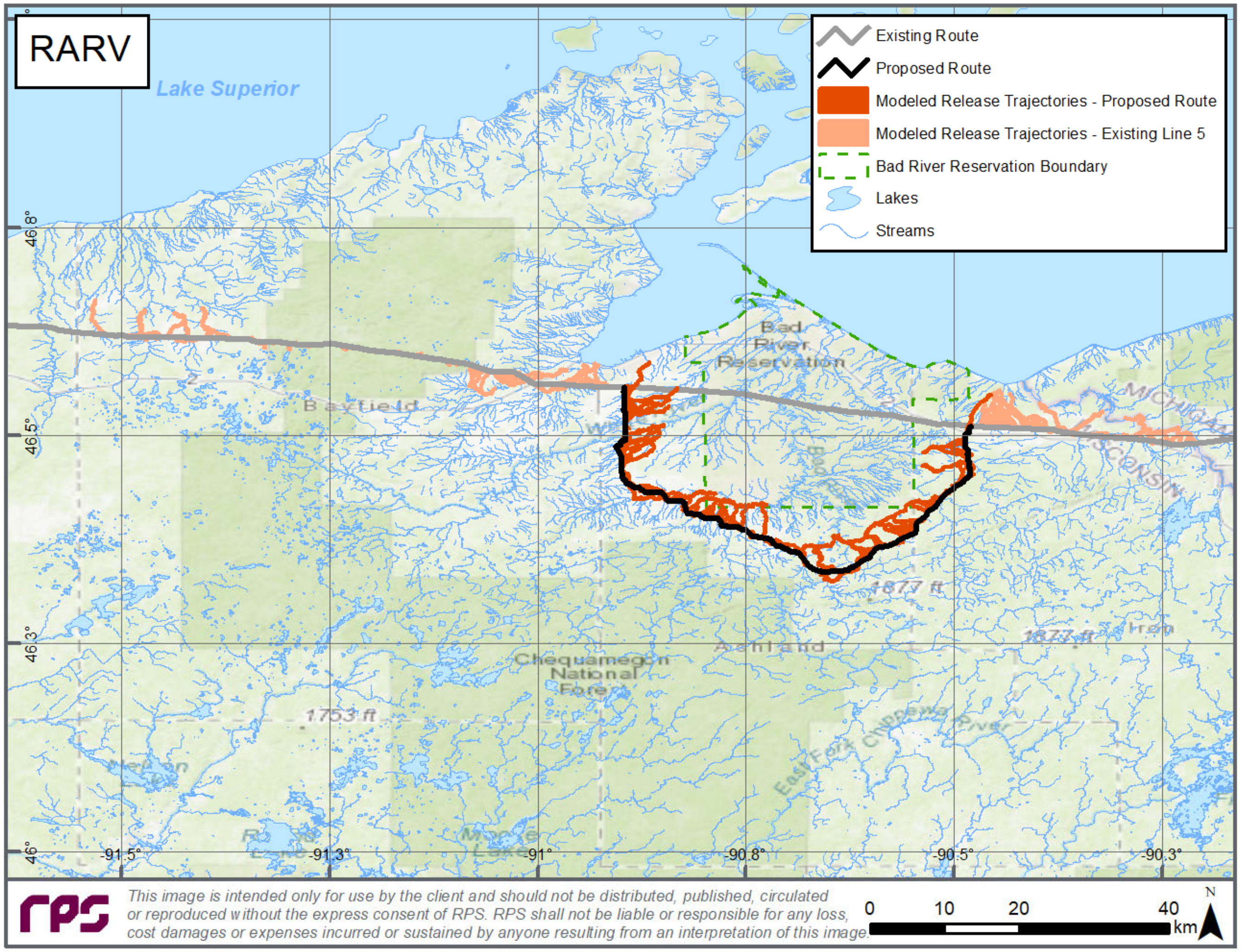

Figure 5-8: Modeled RARV release trajectories under low river flow conditions along the Proposed Route.

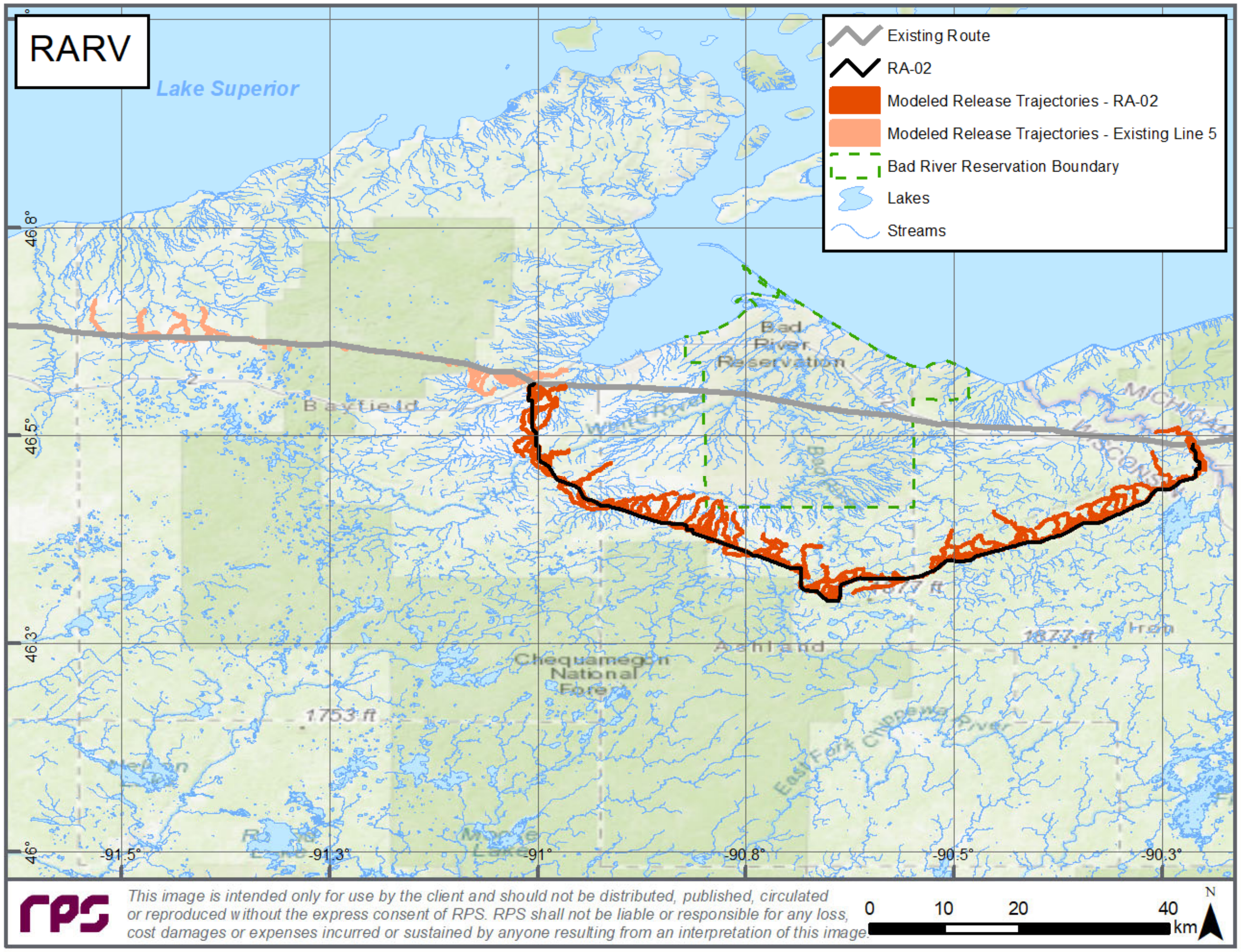

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Figure 5-9: Modeled RARV release trajectories under low river flow conditions along RA-02.

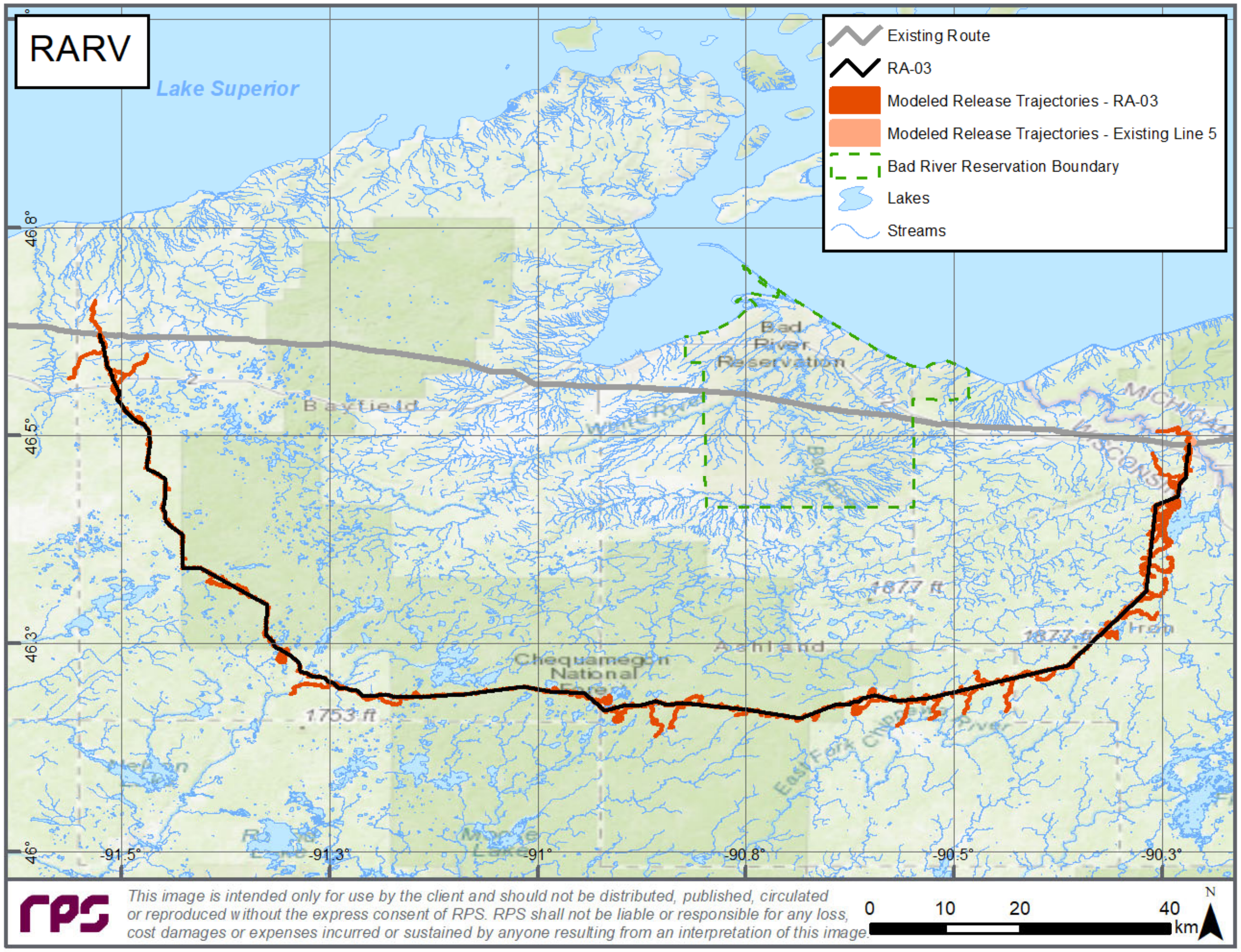

Figure 5-10: Modeled RARV release trajectories under low river flow conditions along RA-03.

5.1 Route Comparison (HCA & AOI Analysis)

Pipeline length is a key factor for determining the likelihood of a release occurring (i.e., greater total length of pipe to release) and the potential to impact a greater number of receptors (i.e., greater land area exposed to the potential for both direct and indirect effects). Several metrics were used to compare the modeling results from each pipeline route alternative to one other and to the Existing Route. To ensure that a commensurable comparison could be made, the pipeline routes were analyzed over the same Pipeline Extent Considered, meaning the start and end point of each assessment was the same for all routes (Figure 5-11, Figure 5-12). The comparative length and potential trajectories associated with each route were then determined. The total pipeline lengths over the Pipeline Extent Considered varied between 103.5 and 163.8 km (64.3 and 101.8 mi) for the different routes, including 0.4 to 103.5 km (0.2 to 64.3 mi) of the existing Line 5 and 0.0 and 163.4 km (0.0 and 101.5 mi) of new pipeline construction (Table 5-1).

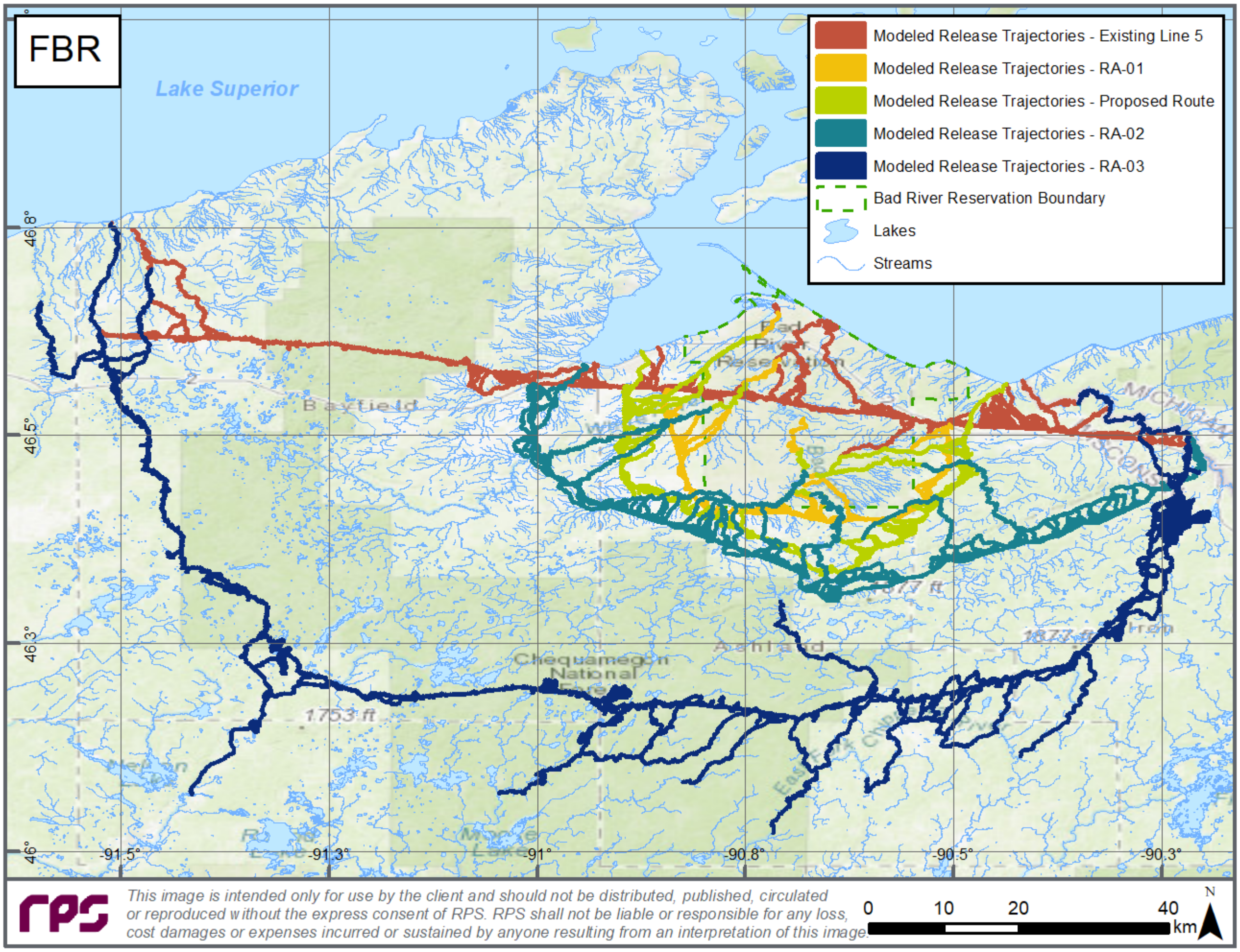

Figure 5-11: Modeled FBR release trajectories under high river flow conditions for all pipeline routes. Note that some trajectories may not be visible as they are underneath trajectories for another route.

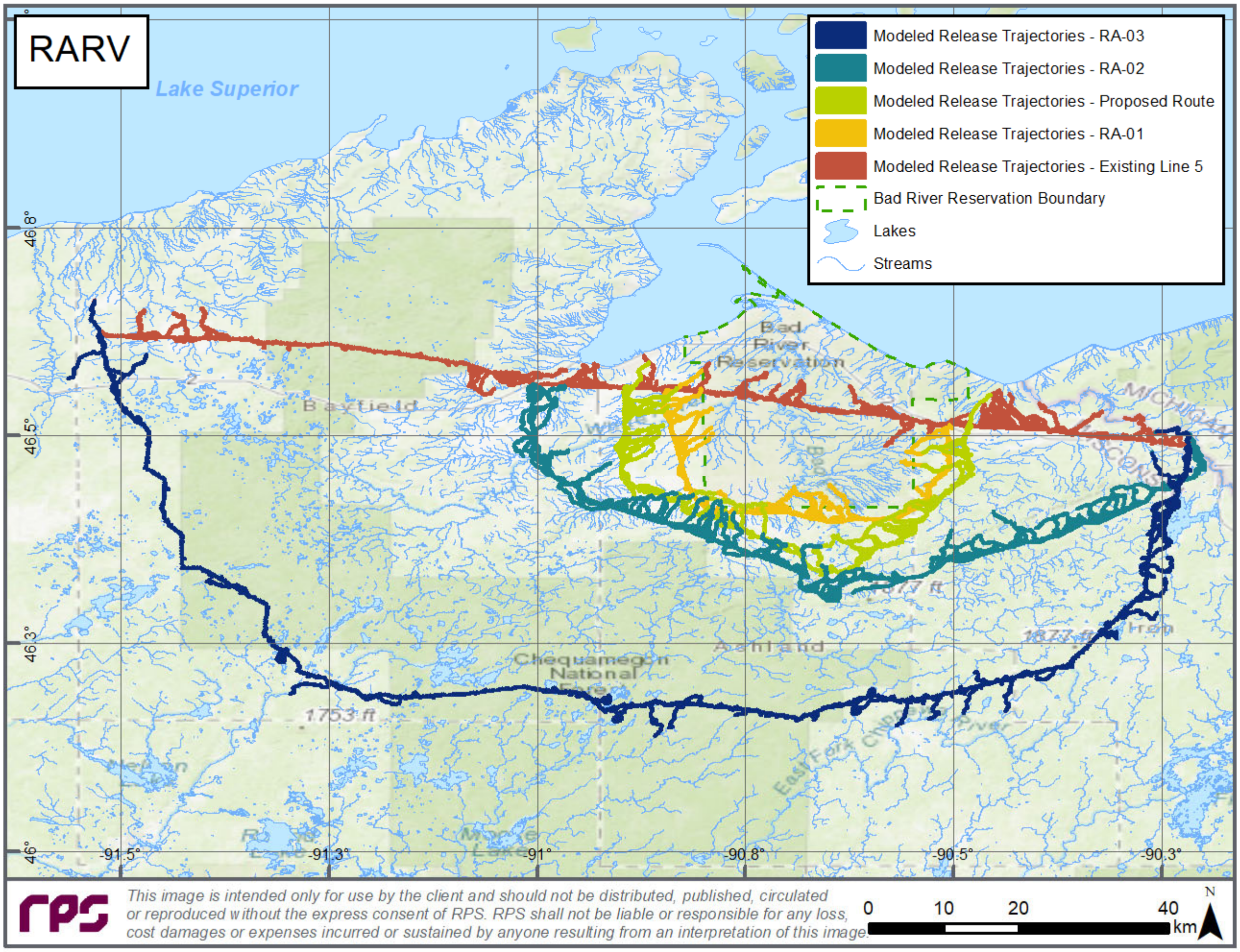

Figure 5-12: Modeled RARV release trajectories under low river flow conditions for all pipeline routes. Note that some trajectories may not be visible as they are underneath trajectories for another route.

Table 5-1: Comparative length of existing pipeline and new pipeline construction within the Pipeline Extent Considered for each route.

Route	Total Pipeline Length (km)	Length of Existing Line 5 (km)	Length of New Construction (km)
Existing Route	103.5	103.5	0.0
RA-01	127.2	76.6	50.5
Proposed Route	136.8	70.7	66.0
RA-02	135.0	41.6	93.4
RA-03	163.8	0.4	163.4

5.1.1 AOI Analysis

Using the trajectory results from the OILMAPLand model simulations, hypothetical releases for each route were analyzed to determine the total length of each pipeline route over which a modeled release could reach the study AOIs (Table 5-2 for FBR releases and Table 5-3 for RARV releases). These lengths are reported here as 1) the “Effects Length of Pipeline,” where simulated releases could ultimately make contact with AOIs following a release, which could include downslope and/or downstream transport or be a release directly into an AOI, and 2) the “Direct Effects Length of Pipeline,” which denotes the section of pipeline that itself crosses through AOIs. To clarify, 19.8 km (12.3 mi) of the Existing Route passes through the Reservation (i.e., direct effect), 6.4 km (4.0 mi) of pipeline has the potential for FBR releases to enter the Reservation following overland and downstream transport (i.e., indirect effect), and a total of 26.2 km (16.3 mi) of pipeline has the potential to impact the Reservation in some way (i.e., total effects length). Because none of the route alternatives cross the reservation, all of the direct effects lengths are 0.0 km (0.0 mi). Of note, many of the predicted effects lengths are the result of releases from portions of the existing pipeline on each Route Alternative that make up the total Pipeline Extent Considered, such as portions (18.5 km or 11.5 mi) of the Chequamegon-Nicolet National Forest Moquah Barrens State Natural Area between Iron River and Moquah. In addition, the total length of new construction within wetland areas for each pipeline route alternative was reported, to denote the potential for direct effects to wetlands associated with construction activities, as well as the potential for effects from an oil spill.

Table 5-2: Comparative length of each pipeline route alternative that has the potential for FBR releases under high river flow conditions to reach AOIs for the overall Pipeline Extent Considered.

Route	Total Pipeline Route Length (km)	New Construction Length of Pipeline in Wetlands (km)	Effects Length of Pipeline, km (Direct Effects Length of Pipeline, km)			
			Lake Superior*	Wild Rice Areas	Bad River Reservation	Federal, State, & County/Local** Lands
Existing Route	103.5	0	63.1 (0.0)	18.8 (0.0)	26.2 (19.8)	80.7 (27.7)
RA-01	127.2	9.45	42.5 (0.0)	4.5 (0.0)	50.0 (0.0)	102.3 (29.5)
Proposed Route	136.8	8.34	39.4 (0.0)	0.8 (0.0)	57.2 (0.0)	124.4 (37.2)
RA-02	135.0	12.59	21.5 (0.0)	5.9 (0.0)	35.5 (0.0)	126.4 (29.4)
RA-03	163.8	49.34	0.0 (0.0)	25.1 (0.0)	0.0 (0.0)	150.9 (104.7)

* Only 2.4 km (1.5 mi) of new construction on the Proposed Route (3.6%) and 7.8 km (4.8 mi) of new construction on RA-02 (7.8%) were simulated to be able to reach Lake Superior within the modeled timeframe. None of the new construction on RA-01 or RA-03 was simulated to reach Lake Superior within this same timeframe.

** While Federal and State lands are traditionally used in these assessments, additional lands associated with county/local government, as well as Forest Crop Law lands were included in the segment length analysis as a further conservative consideration, following consultation with Federal, State, and Tribal representatives. These lands were included because they are important to community, cultural, and ecological functions. Individual county and local land parcels that could be impacted, however, were not listed individually as unique AOIs because of the wide variety of land types and the overlapping nature of these resources between each dataset (e.g., contained within Federal and State lands).

Table 5-3: Comparative length of each pipeline route alternative that has the potential for RARV releases under low flow conditions to reach AOIs for the overall Pipeline Extent Considered.

Route	Total Pipeline Route Length (km)	New Construction Length of Pipeline in Wetlands (km)	Effects Length of Pipeline, km (Direct Effects Length of Pipeline, km)			
			Lake Superior*	Wild Rice Areas	Bad River Reservation	Federal, State, & County/Local** Lands
Existing Route	103.5	0	3.5 (0.0)	0.0 (0.0)	23.5 (19.8)	70.8 (27.7)
RA-01	127.2	9.45	3.5 (0.0)	0.0 (0.0)	30.8 (0.0)	86.6 (29.5)
Proposed Route	136.8	8.34	3.5 (0.0)	0.0 (0.0)	12.9 (0.0)	101.4 (37.2)
RA-02	135.0	12.59	0.0 (0.0)	0.0 (0.0)	4.3 (0.0)	96.0 (29.4)
RA-03	163.8	49.34	0.0 (0.0)	0.3 (0.0)	0.0 (0.0)	131.4 (104.7)

* No new construction on any of the route alternatives was simulated to be able to reach Lake Superior within the modeled timeframe.

** While Federal and State lands are traditionally used in these assessments, additional lands associated with county/local government, as well as Forest Crop Law lands were included in the segment length analysis as a further conservative consideration, following consultation with Federal, State, and Tribal representatives. These lands were included because they are important to community, cultural, and ecological functions. Individual county and local land parcels that could be impacted, however, were not listed individually as unique AOIs because of the wide variety of land types and the overlapping nature of these resources between each dataset (e.g., contained within Federal and State lands).

The following discussion focuses on the FBR release analysis (Table 5-2). The Proposed Route, RA-01, and RA-02 do have lengths of pipeline where hypothetical releases were predicted to reach the Reservation after some overland and/or downstream transport, but RA-03, which is outside the Bad River watershed, does not. Nearly all new pipeline construction for RA-01 (~97%) was predicted to have the potential for FBR releases to reach the Reservation due to RA-01 being located immediately adjacent to the Reservation boundary (Figure 5-2, Table 5-7). In comparison, the absolute length of the Proposed Route where FBR releases were predicted to have the potential to reach the Reservation (57.2 km or 35.5 mi) was longer than RA-01, but represented a smaller portion of the Proposed Route's new construction (87%). This was due to model-predicted release pathways that entered waterways, which flowed into the Reservation further downstream. RA-02 had an even shorter portion of pipeline that was predicted to have the potential for FBR releases to reach the Reservation, both as an absolute length (35.5 km or 22.1 mi) and as a proportion of new construction (38%), because that route is located farther from the Reservation and oil would not be predicted to enter the Reservation over the modeled 12-hour period.

The total length of pipeline with the predicted potential for releases to enter Lake Superior decreased as route alternatives shifted farther inland (away from the Lake) to the south of the existing line (Table 5-2, Table 5-3). Therefore, the Existing Route had the greatest overall length of pipeline where simulated releases were predicted to reach Lake Superior. Of note, nearly all of the Effects Lengths of route alternatives that were predicted to reach Lake Superior occurred along the existing portions of Line 5, rather than from the new construction (Figure 5-11, Figure 5-12). No simulated releases (FBR or RARV) from new construction were predicted to reach Lake Superior through the Reservation over the model time period**.**

For the Existing Route, simulated FBR releases along 18.8 km (11.7 mi) of pipeline were predicted to reach designated wild rice areas in the vicinity of the Kakagon-Bad River Slough complex. In comparison, only 4.5 km (2.8 mi) of RA-01 and only 0.8 km (0.5 mi) of the Proposed Route were predicted to have the potential for a FBR releases to impact these same areas. Outside of the Reservation, there is also a small wild rice habitat located on the White River and habitats in the Chequamegon-Nicolet National Forest and proximate to Gile Flowage (Figure 4-1). Simulated FBR releases from a 5.9 km (3.7 mi) length of RA-02 were predicted to have the potential to reach the wild rice areas within the White River, upstream of the Proposed Route crossing (Figure 4-1). For RA-03, simulated FBR releases from a 25.1 km (15.6 mi) length of pipeline had the potential to reach several wild rice areas outside the Bad River watershed, including at the edges of Gile Flowage (Figure 4-1).

Generally, the RARV releases had shorter Effects Lengths for all AOIs (Table 5-3) because of the more limited transport due to the smaller release volumes and slower river flow in these simulations. Note that the Direct Effects Lengths were the same for both types of releases, as they are defined as occupying the same location as a receptor and are therefore not dependent on release volume nor transport. Notably, the Proposed Route had a shorter length of pipeline with the potential to reach the Reservation, when compared to RA-01, as the Proposed Route was a greater distance from the Reservation.

A list of each unique area of State or Federal Land that had the potential to be impacted by hypothetical FBR releases is provided in Table 5-4. This list includes the direct effects that would be predicted by a pipeline route alternative crossing the receptor and indirect effects from potential downslope and/or downstream transport within the modeled timeframe. As the total pipeline length increased for each route alternative, the number of unique areas with the potential to be impacted also increased (Table 5-4), as well as the total length of pipeline that had the potential to impact these areas (Table 5-2, Table 5-3). In addition, because RA-03 is outside of the Bad River Watershed, the State and Federal Lands that would have the potential to be impacted would be almost entirely new for the pipeline and different from each of the other route alternatives.

Table 5-4: Unique Federal and State AOIs predicted to be impacted by FBR releases for each Route Alternative.

Impact	Existing Route	RA-01	Proposed Route	RA-02	RA-03
State Lands Directly Crossed by Pipeline Route	• South Shore Lake Superior Fish and Wildlife Area (SSLSFA) - Fish Creek Unit • Statewide Wetland Mitigation Program - NOR	• SSLSFA - Fish Creek Unit • White River Wildlife Area-Ashland • Copper Falls State Park • Town of Morse State Habitat Area	• SSLSFA - Fish Creek Unit	• SSLSFA - Fish Creek Unit • White River Fishery Area-Bayfield	• Caps Creek Fishery Area • Forest Legacy Program • Great Northern Conservation Easement • Island Lake Hemlocks State Natural Area
State Lands Reached by Potential Release	• SSLSFA - Fish Creek Unit • SSLSFA - Iron River Unit • Statewide Wetland Mitigation Program - NOR	• SSLSFA - Fish Creek Unit • SSLSFA - Iron River Unit • Copper Falls State North Country Trail Area • Copper Falls State Park • Town of Morse State Habitat Area • White River Wildlife Area-Ashland	• SSLSFA - Fish Creek Unit • SSLSFA - Iron River Unit • Copper Falls State North Country Trail Area • Copper Falls State Park • White River Fishery Area-Bayfield • White River Wildlife Area-Ashland	• SSLSFA - Fish Creek Unit • SSLSFA - Iron River Unit • Copper Falls State North Country Trail Area • Copper Falls State Park • Devil's Creek Fishery Area-Ashland • Rem-Devils Creek • SSLSFA - Fish Creek Unit • White River Fishery Area-Bayfield	• Big Brook Fishery Area • Brule River State Forest • Caps Creek Fishery Area • Clam Lake Fishery Area • Forest Legacy Program • Gile Flowage Public Access • Great Northern Conservation Easement • Island Lake Hemlocks State Natural Area • Namekagon River Fishery Area • State Owned Islands
Federal Lands Directly Crossed by Pipeline Route	• Chequamegon-Nicolet National Forest	• Chequamegon-Nicolet National Forest	• Chequamegon -Nicolet National Forest	• Chequamegon-Nicolet National Forest	• Chequamegon-Nicolet National Forest • Saint Croix National Scenic Riverway
Federal Lands Reached by Potential Release	• Chequamegon-Nicolet National Forest	• Chequamegon-Nicolet National Forest	• Chequamegon -Nicolet National Forest	• Chequamegon-Nicolet National Forest	• Chequamegon-Nicolet National Forest • Saint Croix National Scenic Riverway

Two additional analyses and comparisons were conducted for each route alternative based on the OILMAPLand model results. The first included concerns over the timing that an unmitigated oil spill may arrive at the boundary of the Reservation (Table 5-5). The trajectory information from each pipeline route alternative was analyzed to return the shortest period of time for any single, unmitigated oil spill with an FBR release volume under high river flow conditions to reach the Reservation. As expected, the farther a pipeline route alternative is from the Reservation, the longer it will take for oil to potentially reach the Reservation. Note that these times are generally shorter than those predicted specifically for the Bad River and White River (Appendix B) because this route assessment included other watercourse crossings that were nearer to the Reservation and because these simulations were conducted using faster (95th percentile) river flow conditions to conservatively predict the shortest period of time for potential downstream movement.

Table 5-5: Shortest time after unmitigated releases of oil to reach the Bad River Reservation under 95th percentile river flow rates.

Route	Shortest Time to Reach Bad River Reservation (min)
Existing Route	Immediate (located in Reservation)
RA-01	16.2
Proposed Route	50.4
RA-02	147
RA-03	N/A (never reaches Reservation)

The second additional analysis included the assessment of the relative portion of each pipeline route alternative that had the potential for a unmitigated FBR releases to impact a waterbody (Table 5-6). The total number of releases simulated along each pipeline route alternative was compared to the total number of unmitigated releases that were predicted to reach one or more waterbodies. Between 55.5-82.7% of simulated release points along each route alternative were predicted to reach at least one body of water (e.g., a stream, river, pond) within the simulated unmitigated 12-hour timeframe. In general, the Existing Route, Proposed Route, and RA-01 and RA-02 were quite similar in total number and percentage of releases predicted to reach water. RA-03 had a comparable number of releases reaching water, but due to its longer length had a smaller percentage of the total pipeline able to reach waterways. In addition, because RA-03 is outside of the Bad River Watershed, the waterways that would have the potential to be impacted would be almost entirely new and different from each of the other route alternatives over the Pipeline Extent Considered.

Table 5-6: Total number of releases modeled for each route alternative and the corresponding number and percentage that were predicted to reach at least one body of water.

Route	Total Releases Modeled Along Route Alternative	Releases Reaching Water	Percent of Releases Reaching Water	Length of Pipeline with Potential for Releases to Reach Water (km)
Existing Route	1,052	816	77.6%	76.3
RA-01	1,330	1,100	82.7%	101.8
Proposed Route	1,452	1,187	81.7%	109.2
RA-02	1,426	1,189	83.4%	110.1
RA-03	1,688	937	55.5%	93.5

5.1.2 HCA Analysis

An HCA analysis was conducted along each pipeline route alternative in the same way the AOI analysis was completed, to determine the HCA “could-affect” segments. Could-affect segments are defined as portions of the pipeline that, should there be a hypothetical release of oil (i.e., the simulated, unmitigated FBR), would have the potential to impact an HCA. Five types of HCAs were included in the assessment, as defined in 49 CFR § 195.450 and 49 CFR § 195.6, which include: CNW, HPA, OPA, DW, and ESA.

The results of the HCA Analysis were summarized in the same manner as the AOI Analysis to facilitate additional comparisons between the pipeline route alternatives, for both the FBR releases under high river flow conditions (Table 5-7) and the RARV releases under low river flow conditions (Table 5-8). The lengths of each pipeline route within the Pipeline Extent Considered that had the potential to affect an HCA (“could-affect” segments) were reported by individual HCA category, as well as together. None of the route alternatives were predicted to result in impacts to any HPA, so that category was not reported.

Table 5-7: Length of pipeline with the potential for FBR releases under high flow condition to impact HCAs for the overall Pipeline Extent Considered for each route alternative.

Route	Total Pipeline Route Length (km)	Overall HCA Could-Affect** Direct and Indirect (Direct Only) (km)	HCA Could-Affect by Category Direct and Indirect (Direct Only) (km)*			
			OPA	DW	ESA	CNW
Existing Route	103.5	76.4 (5.8)	27.5 (3.1)	44.5 (3.7)	62.2 (0.0)	40.0 (0.0)
RA-01	127.2	67.0 (6.9)	14.9 (3.7)	25.1 (3.8)	42.4 (0.0)	30.6 (0.0)
Proposed Route	136.8	59.9 (1.5)	23.6 (1.3)	25.8 (0.8)	36.7 (0.0)	28.2 (0.0)
RA-02	135.0	77.6 (8.4)	45.4 (8.4)	46.9 (0.0)	19.2 (0.0)	15.2 (0.0)
RA-03	163.8	39.2 (4.0)	37.4 (4.0)	3.1 (0.0)	9.8 (0.0)	0.0 (0.0)

* None of the pipeline route alternatives were predicted to affect an HPA; therefore, that category was not reported.

** Note that the overall HCA could-effect length is not equal to the sum of the individual category lengths; this is because individual HCA could-affect segments may impact multiple HCA types.

Table 5-8: Length of pipeline with the potential for RARV releases under low river flow conditions to impact HCAs for the overall Pipeline Extent Considered for each route alternative.

Route	Total Pipeline Route Length (km)	Overall HCA Could-Affect** Direct and Indirect (Direct Only) (km)	HCA Could-Affect by Category Direct and Indirect (Direct Only) (km)*			
			OPA	DW	ESA	CNW
Existing Route	103.5	24.0 (5.8)	10.3 (3.1)	21.7 (3.7)	4.3 (0.0)	4.5 (0.0)
RA-01	127.2	22.5 (6.9)	14.2 (3.7)	17.8 (3.8)	3.4 (0.0)	4.5 (0.0)
Proposed Route	136.8	26.0 (1.5)	17.8 (1.3)	17.9 (0.8)	3.4 (0.0)	4.5 (0.0)
RA-02	135.0	33.2 (8.4)	28.2 (8.4)	15.1 (0.0)	0.0 (0.0)	0.0 (0.0)
RA-03	163.8	15.0 (4.0)	13.6 (4.0)	2.7 (0.0)	0.0 (0.0)	0.0 (0.0)

* None of the pipeline route alternatives were predicted to affect an HPA; therefore, that category was not reported.

** Note that the overall HCA could-effect length is not equal to the sum of the individual category lengths; this is because individual HCA could-affect segments may impact multiple HCA types.

The following discussion focuses on the FBR release analysis (Table 5-7). The Proposed Route had the second shortest overall could-affect segment length for FBR releases, and generally had shorter direct and indirect effects by HCA type, when compared to other routes. The Proposed Route's direct could-affect segments were shorter (or <1 km) for all categories, but the indirect could-affect lengths were in some cases higher relative to RA-01 or RA-02. RA-03 did have the lowest overall could-affect segment length, as well as the lowest in the DW, ESA, and CNW categories. However, this low value was the result of much of this pipeline route alternative passing through uncategorized forested land (Chequamegon-Nicolet National Forest), which was assessed in the AOI analysis (see Section 5.1.1).

Generally, the RARV releases had shorter could-affect lengths for all HCAs (Table 5-8) because of the more limited transport due to smaller release volumes and slower river water conditions. As was noted previously, direct effects were the same for both types of releases, as they are defined solely by location, irrespective of release volume or transport.

A list of each unique HCA that had the potential to be impacted by hypothetical FBR releases is provided by route alternative (Table 5-9). The number of unique areas with the potential to be impacted generally increased with the increase in total pipeline length. Overall, the Proposed Route and RA-01 had fewer predicted could-affect HCAs than other pipeline routes and were quite similar to each other, which is consistent with their proximity and positioning within the watershed. The Existing Route had similar predicted HCAs to the Proposed Route and RA-01, but also other HCAs located in the downstream portions of the Bad River watershed. RA-02 and RA-03 had a larger and different set of HCAs, with overlap in the eastern portions, where those pipeline routes run through the same area near Ironwood and Gile Flowage. The fewest DW HCAs were predicted for RA-03. All pipeline routes had the potential to indirectly affect the Great Lakes and connecting waters ESA, and all but RA-03 had the potential to indirectly affect Lake Superior. These findings were largely due to the eastern and western sections of the existing Line 5 that would still be operational under each of the different route alternatives. No simulated releases from new construction on route alternatives were predicted to be able to reach Lake Superior via the Reservation (i.e., near the mouth of the Bad River) within the modeled timeframe.

Table 5-9: Unique HCAs predicted to be impacted by FBR simulations for each Route Alternative.

	Existing Route	RA-01	Proposed Route	RA-02	RA-03
Direct	• Ashland City (OPA) • Birch Hill CDP (OPA) • 3 DW HCAs	• Ashland City (OPA) • Marengo CDP (OPA) • 1 DW HCA	• Ashland City (OPA) • 1 DW HCA	• Hurley City (OPA) • Iron Belt CDP (OPA) • Ironwood (OPA) • Montreal City (OPA) • Pence CDP (OPA)	• Hurley City (OPA) • Montreal City (OPA) • Pence CDP (OPA)
Indirect	• Ashland City (OPA) • Birch Hill CDP (OPA) • Diaperville CDP (OPA) • New Odanah CDP (OPA) • Odanah CDP (OPA) • 14 DW HCAs • 1 Agency provided ESA HCA • Great Lakes and connecting waters (ESA) • Lake Superior (CNW)	• Ashland City (OPA) • Marengo CDP (OPA) • 8 DW HCAs • 1 Agency provided ESA HCA • Great Lakes and connecting waters (ESA) • Lake Superior (CNW)	• Ashland City (OPA) • Marengo CDP (OPA) • Mellen City (OPA) • 9 DW HCAs • 1 Agency provided ESA HCA • Great Lakes and connecting waters (ESA) • Lake Superior (CNW)	• Hurley City (OPA) • Iron Belt CDP (OPA) • Ironwood (OPA) • Marengo CDP (OPA) • Mellen City (OPA) • Montreal City (OPA) • Pence CDP (OPA) • 9 DW HCAs • Great Lakes and connecting waters (ESA) • Lake Superior (CNW)	• Brule CDP (OPA) • Cable CDP (OPA) • Clam Lake CDP (OPA) • Glidden CDP (OPA) • Hurley City (OPA) • Ironwood (OPA) • Montreal City (OPA) • Pence CDP (OPA) • 5 DW HCAs • Great Lakes and connecting waters (ESA)

5.2 High-Resolution Segment Analysis

A high-resolution (10-m) segment analysis was conducted to determine the total length of pipeline at specific watercourse crossings that would have the potential for a FBR release to enter that crossing directly. This high-resolution segment analysis was conducted for the White River and Bad River for the Proposed Route, RA-01, and RA-02. RA-03 was not assessed because it would not cross the White River or Bad River. The identified segments were used in the Probability Assessment described in Technical Appendix A. Simulation results were categorized into one of four categories:

1. the release reached the river "at" the crossing, entering the river within approximately 100 meters (328 ft) from the location where the pipeline and river centerline cross;
2. the release reached the river "upstream or downstream" of the crossing, entering the river within approximately 500 meters (1,640 ft) from the location where the pipeline and river centerline cross;
3. the release reached the river "away" from the crossing, entering the river greater than approximately 500 meters (1,640 ft) from the crossing; or
4. the release remained on land.

The lengths of pipeline over which releases were predicted to reach each of the six crossings, either "at" or "upstream or downstream" of the crossing, were calculated from the high-resolution OILMAPLand results (Table 5-10). The length of the potential impact segment for releases that reached the river "at" each crossing varied from 90-600 meters (295-1969 ft; sum of left bank and right bank). For releases that reached the watercourse "upstream or downstream" of the crossing, the total length increased to a range of 720-5,550 m (2,362-18,045 ft). The variability is the result of complex and variable topography, river channels, and pipeline corridors. This variability is highlighted by the predicted distance inland for a release to reach "at" the crossing ranging from 10 m up to 570 m (33-1,870 ft) depending on the specific watercourse crossing and specific bank (Figure 5-13 through Figure 5-18). For context, the Existing Route had a FBR potential impact segment length of 260 m (Horn et al., 2022).

Table 5-10: Length of pipeline over which simulated FBR releases were predicted to reach the watercourse crossing for each route, either "at" or "upstream or downstream" of the crossing.

		Length of Pipeline where FBR Releases were Predicted to Reach Watercourse Crossing (m)	
Route	Crossing	At crossing	Upstream or downstream of crossing
RA-01	White River	280	2,450
	Bad River	330	720
Proposed Route	White River	600	2,000
	Bad River	110	1,040
RA-02	White River	210	5,550
	Bad River	90	1,640

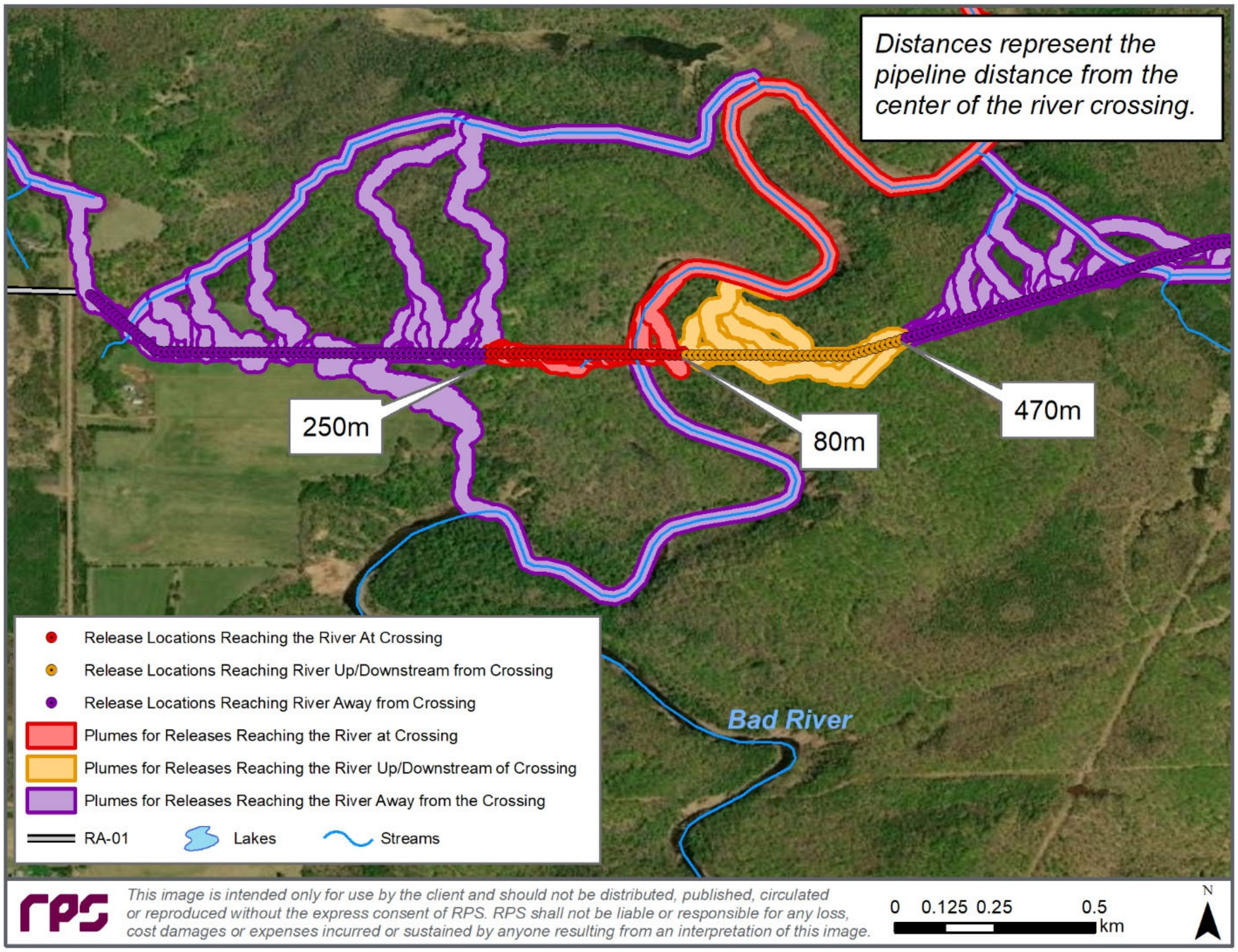

Figure 5-13: FBR releases from RA-01 that had the potential to reach the Bad River Crossing using a high-resolution segment analysis.

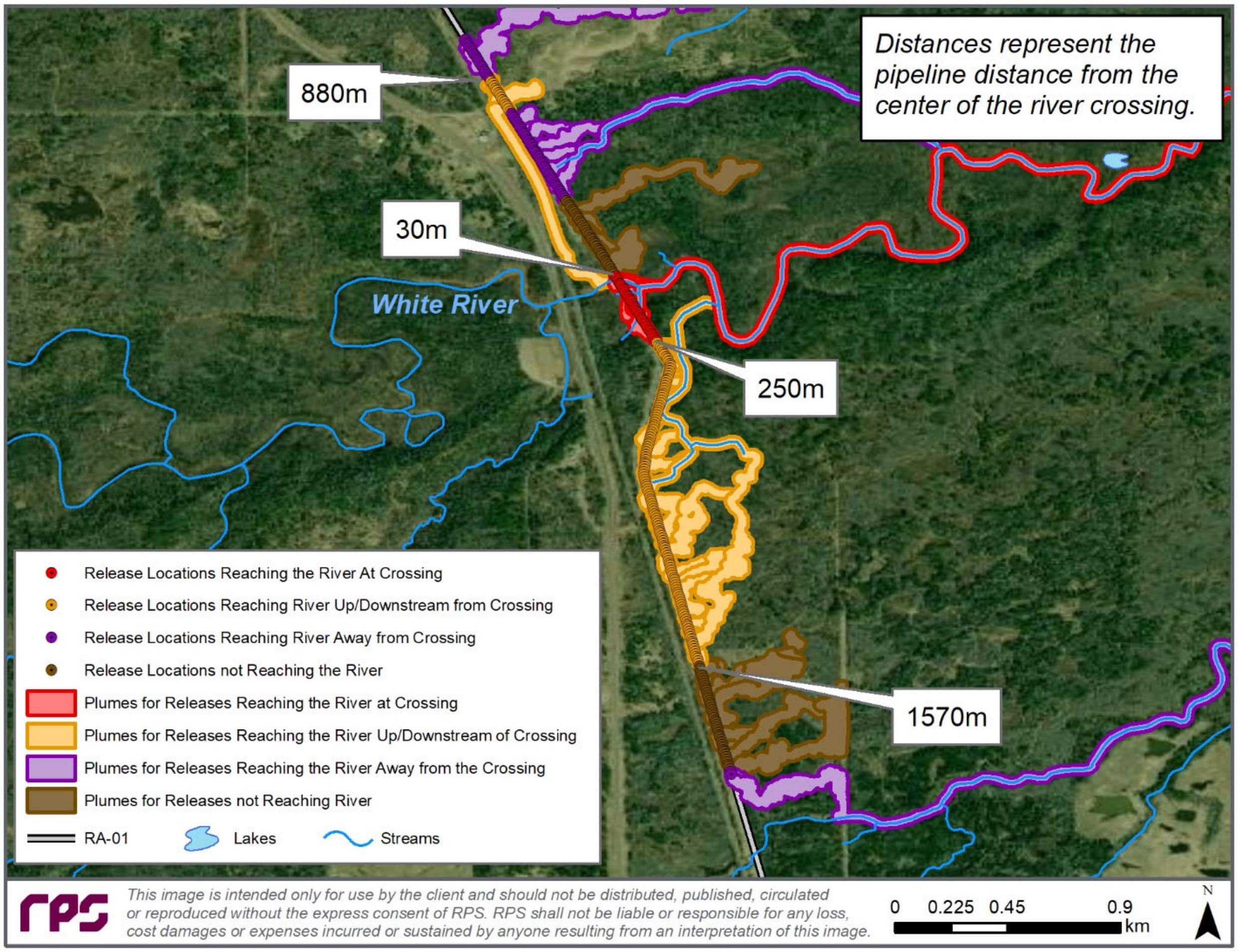

Figure 5-14: FBR releases from RA-01 that had the potential to reach the White River Crossing using a high-resolution segment analysis.

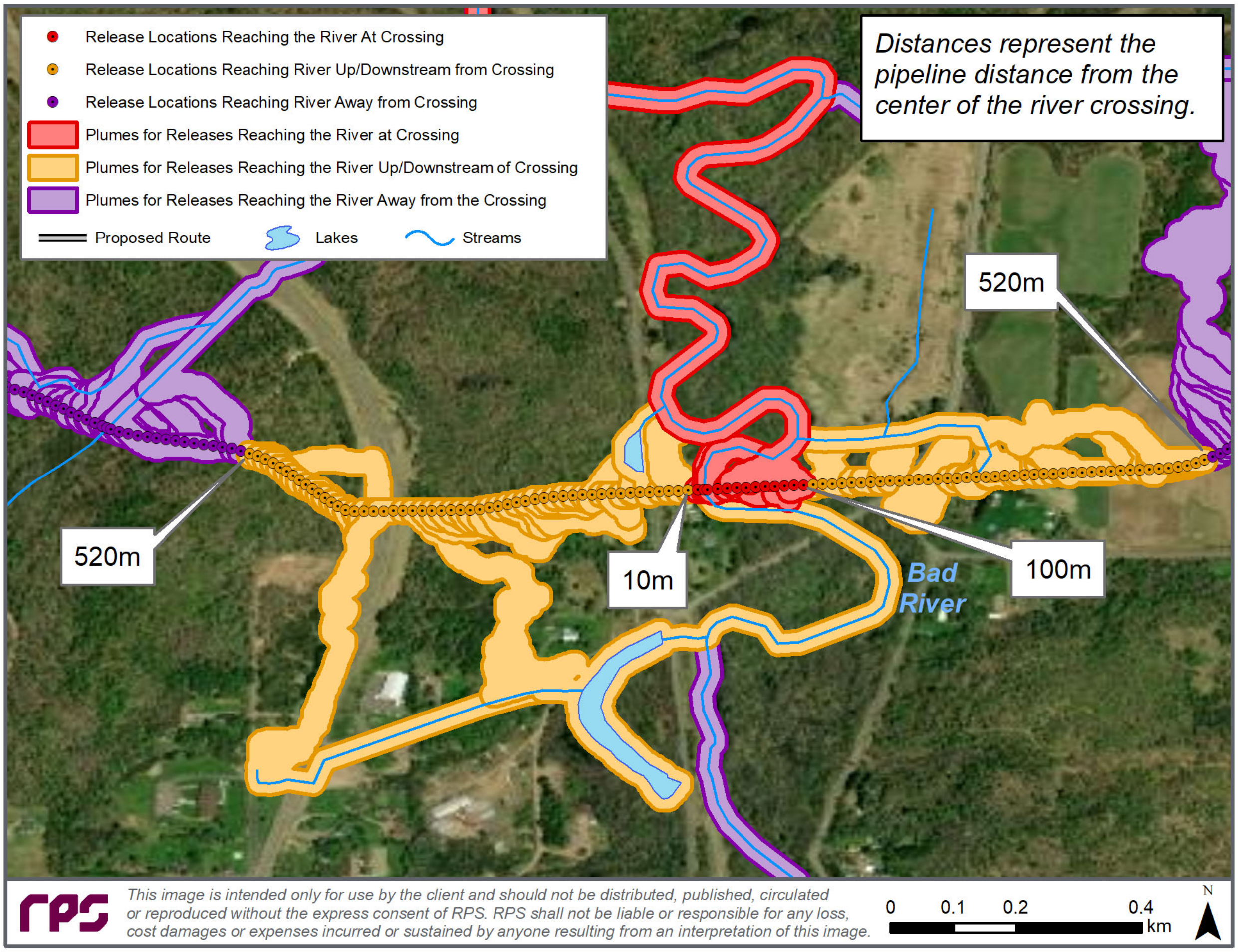

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Figure 5-15: FBR releases from the Proposed Route that had the potential to reach the Bad River Crossing using a high-resolution segment analysis.

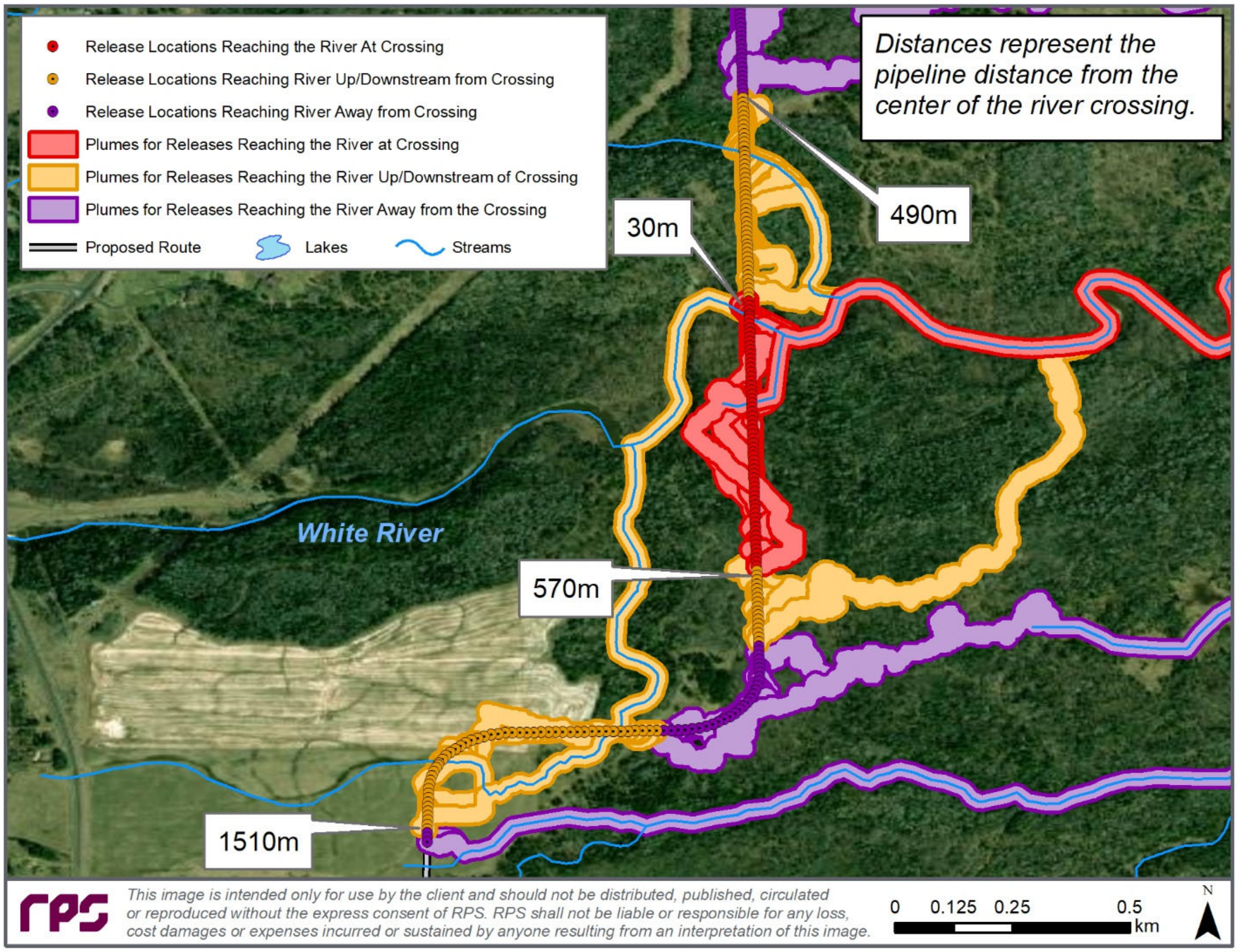

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Figure 5-16: FBR releases from the Proposed Route that had the potential to reach the White River Crossing using a high-resolution segment analysis.

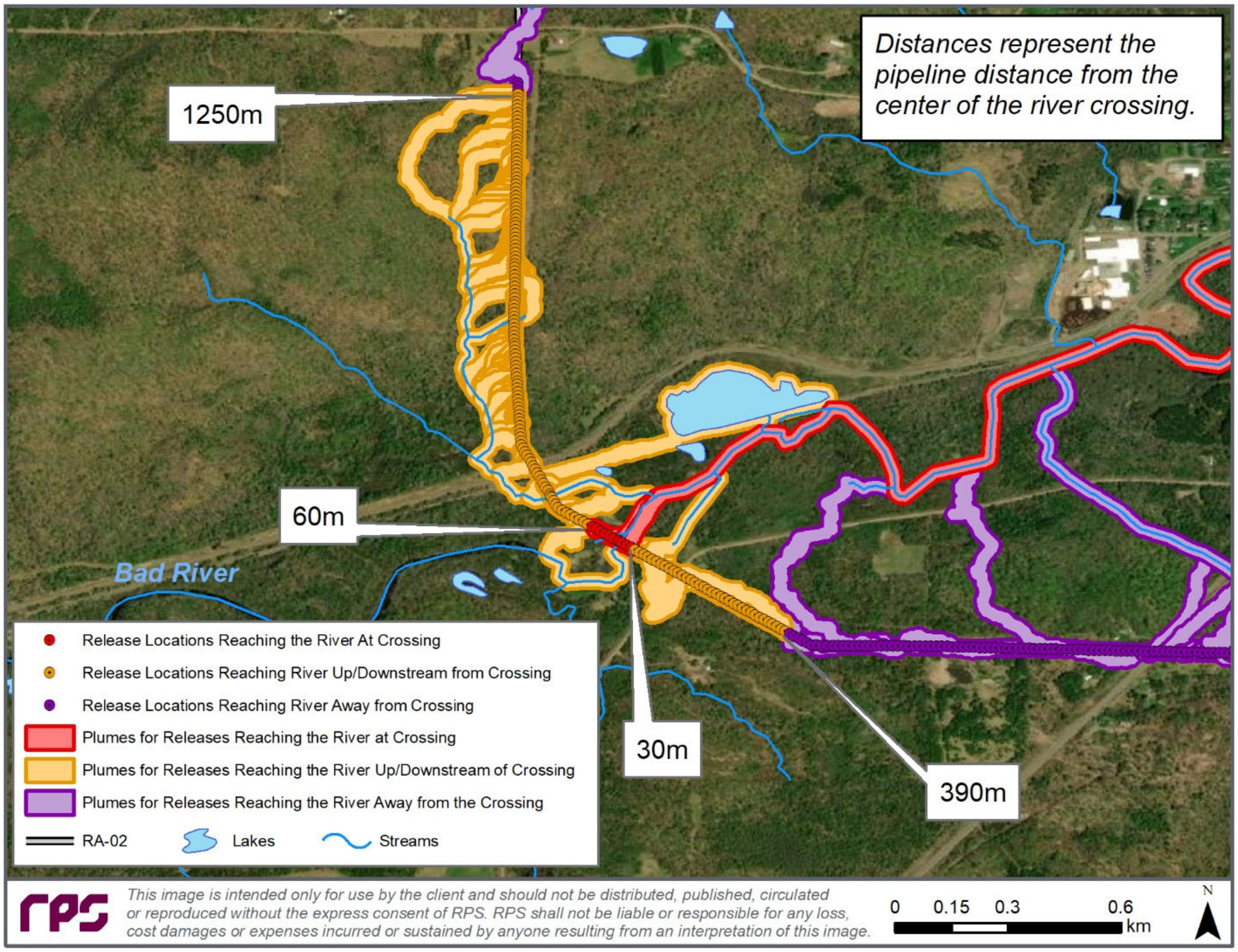

Figure 5-17: FBR releases from RA-02 that had the potential to reach the Bad River Crossing using a high-resolution segment analysis.

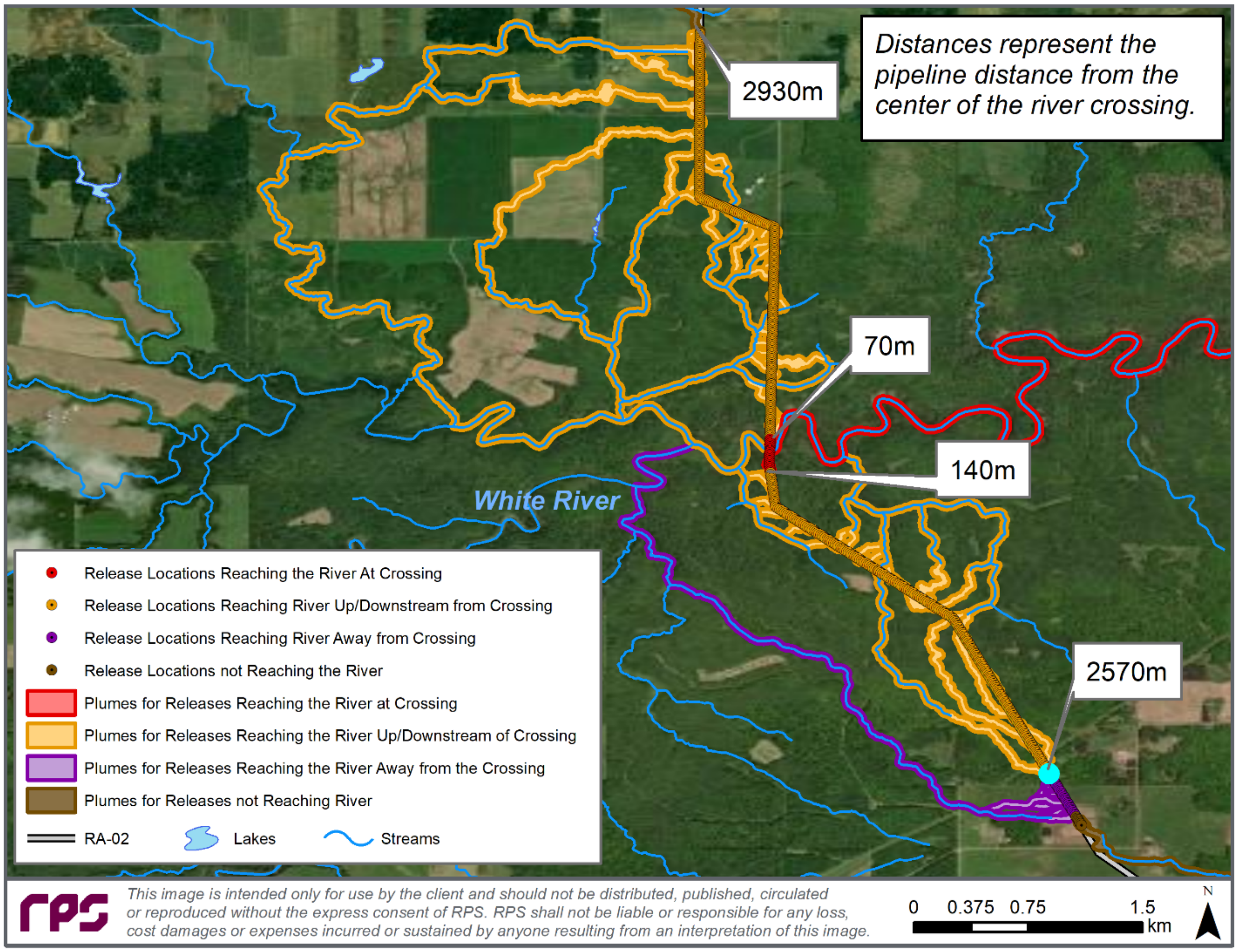

Figure 5-18: FBR releases from RA-02 that had the potential to reach the White River Crossing using a high-resolution segment analysis.

6 CONCLUSIONS

RPS conducted a route alternatives analysis of the Existing, Proposed, and Route Alternatives to assess the range of predicted overland and downstream movement and behavior of hypothetical hydrocarbon releases and receptors that may be impacted from releases along each pipeline. The four route alternatives vary in the degree of divergence from the existing pipeline route. The path of RA-01 would be most similar to the existing line, with the shortest overall length among the route alternatives. The deviation away from the existing line increases from RA-01 to the Proposed Route, followed by RA-02, and finally RA-03. However, the total length of the line actually increases from RA-01 to RA-02, followed by the Proposed Route, and finally RA-03. RA-03 would involve the largest deviation and the longest overall length, as the route would be almost entirely outside of the Bad River watershed.

As the relocation moves farther from the existing pipeline, the likelihood of impacts from a potential release to the Reservation and Lake Superior decreases. This is because of the greater distance from the hypothetical release points to the Reservation and Lake Superior, which provides additional time for oil spill response activities to halt the downstream transport of the released product before it reaches those areas, or in the case of large sections of RA-03, the released product would travel away from the Bad River entirely due to it being in another watershed.

A comparative ranking assessment was undertaken using the FBR release modeling to most conservatively and qualitatively rank overall segment analysis risk scores for each pipeline route alternative. Essentially, the values for each criteria assessed in this Technical Appendix (e.g. total length of pipeline route and length of pipeline with potential to impact various receptors) were compared between pipeline routes (Table 6-1). A lower score represents a less impactful pipeline route alternative, or one that was predicted to collectively have the potential to impact sensitive receptors from shorter stretches of the pipeline. However, it is important to note that this ranking does not mean that any specific hypothetical release would be more or less impactful to any single resource identified in the ranking. Rather, if one was to consider the entire pipeline route alternative (and hypothetical releases along the entire pipeline), the segment analysis ranking identifies a non-dimensional value of total resources that would have the potential to be affected, relative to the other pipeline alternatives. No weighting was used to compare different ranking criteria, meaning no single receptor was assumed to be more important than any other.

Table 6-1: Comparative ranking assessment of each pipeline route alternative based upon equal weighting of each criteria investigated. The segment analysis rank represents a non-dimensional number where the lowest possible score (rank of 1 in all categories) would represent the "best" route to minimize the areas of concern that may be susceptible to potential impacts following a release.

Route	Total Length (km)	New Construction (km)	New Construction Length of Pipeline in Wetlands (km)	AOI segment lengths (km)				Unique AOIs± (#)	Length with Potential to Reach Water (km)	HCA segment lengths (km)					Unique HCAs (#)
				Lake Superior	Wild Rice	Bad River Reservation	Federal, State, & County/ Local Lands			Overall	OPA	DW	ESA	CNW	
Existing	103.5	0	0	63.1	18.8	26.2	80.7	7	76.3	76.4	27.5	44.5	62.2	40	22
RA-01	127.2	50.5	9.45	42.5	4.5	50	102.3	10	101.8	67	14.9	25.1	42.4	30.6	13
Proposed	136.8	66	8.34	39.4	0.8	57.2	124.4	10	109.2	59.9	23.6	25.8	36.7	28.2	15
RA-02	135	93.4	12.59	21.5	5.9	35.5	126.4	12	110.1	77.6	45.4	46.9	19.2	15.2	18
RA-03	163.8	163.4	49.34	0	25.1	0	150.9	15	93.5	39.2	37.4	3.1	9.8	0	14

Route	Rank															Segment Analysis Rank
Existing	1	1	1	5	4	2	1	1	1	4	3	4	5	5	5	**43**
RA-01	2	2	3	4	2	4	2	2	3	3	1	2	4	4	1	**39**
Proposed	4	3	2	3	1	5	3	2	4	2	2	3	3	3	3	**43**
RA-02	3	4	4	2	3	3	4	4	5	5	5	5	2	2	4	**55**
RA-03	5	5	5	1	5	1	5	5	2	1	4	1	1	1	2	**44**

*Analyzed watercourse crossings include all crossings of the pipeline ROW (i.e., not access road or pipeyard crossings) across watercourses recorded in the NHDPlus dataset.

±Unique AOIs include the sum of (non-duplicate) Federal and State Lands and one count each for Lake Superior, wild rice, and the Reservation. Additional lands associated with county and local government, as well as Forest Crop Law lands, were not individually listed as AOIs because of the wide variety of land types and the overlapping nature of these resources between each dataset (e.g., contained within Federal and State lands).

Once the individual criteria rankings were determined, an overall segment analysis rank was calculated as the sum of the individually-ranked criteria by pipeline route. Again, the lowest segment analysis score would represent a pipeline route alternative that had the lowest potential for impact based upon the identified criteria. In general, this would imply that RA-01 (39) had the lowest score, that the Existing Route (43), Proposed Route (43) had the same scores in the mid-range, and RA-03 (44) was slightly worse, while RA-02 was the least favorable (55). If any single receptor or comparison metric was weighted as more important than another, then the overall segment analysis ranks reported here would change. For example, if a goal was made to minimize the new construction length (i.e., to reduce certain/expected effects from construction generally or specifically in wetlands) or a specific receptor (e.g., wild rice, federal & state lands, and unique AOIs) was deemed more important than another, then RA-03 would likely become far less favorable. Similarly, if a goal was made to prioritize reducing effects to Lake Superior, the Reservation (regarding both receptors and timing), releases reaching water, or OPAs, then RA-01 may be considered a less favorable route. The Existing Route would be less favorable for similar reasons, as it passes directly through the Reservation and nearer these receptors. This segment analysis score is helpful in framing route comparisons, but there are many other factors to consider for route selection, including likelihood of release (addressed in Appendix A) and potential for consequences from guaranteed events (addressed in the Construction Assessment), accidental events (addressed in Appendix B), and many others not considered in this assessment (e.g., economic, political).

RA-03 is quite unique in this analysis. RA-03 has the shortest overall length of could-affect segments (meaning lengths of pipeline where potential FBR releases could impact an HCA), but the second longest length of could-affect segments for OPA HCAs. RA-03 essentially eliminates impacts to the Reservation and Lake Superior within the Pipeline Extent Considered. However, this much longer route (with an additional net length of 60 km [37 mi] compared to the Existing Route and additional 27 km [17 mi] compared to the Proposed Route) moves potential impacts to other AOIs, including significant wild rice areas outside the Reservation, 12 Federal and State Lands, and the longest length through wetlands. These Unique AOIs include state forests and fishery areas, large portions of the Chequamegon-Nicolet National Forest (an effects length of 86.5 km [53.7 mi] or 52.3% of RA-03), the Saint Croix National Scenic Riverway, and 49.34 km (30.66 miles) of wetland areas (making up 30.1% of RA-03).

The potential impacts of each pipeline alternative route vary significantly, based on which impact metric is considered more important. Taking the full analysis into account, the Proposed Route appears to be the most favorable route alternative. The Proposed Route has a very small length of pipeline where simulated FBR releases could reach wild rice areas in the evaluated timeframe, and reduces potential impacts to Lake Superior and HCAs compared to the existing pipeline. The proximity of RA-01 to the Reservation increases the potential for effects to the Reservation, wild rice, Lake Superior, and ESAs. RA-02 received the highest overall segment analysis rank for comparative risk. RA-03 has the longest overall length of pipeline, which would maximize the potential land surface susceptible to a release and would increase the number of total receptors and new receptors that may be affected following a release. In addition, RA-03 would have the longest length of new pipe, which would maximize the guaranteed effects from construction activities through large portions of the Chequamegon-Nicolet National Forest (52.2 km [32.4 mi] of pipeline resulting in direct effects). Additionally, 49.34 km (30.66 miles) of new construction (making up 30.1% of RA-03) would take place in wetlands, again increasing the likelihood of effects from construction activities.

The high-resolution segment analysis provided the length of the pipeline crossing where a release could directly impact the White River or Bad River for each route alternative. The length of this segment varied significantly, based on the terrain in the area of the crossing. For the White River, this length varied between 210 m and 600 m (689-1,969 ft) for the three routes that cross that River (RA-01, RA-02, and the Proposed Route). For the Bad River, this length varied between 90 m and 330 m (295-1,083 ft).

The analysis presented in this Technical Appendix does not include an assessment of the likelihood of a release and subsequent impact to the AOIs or HCAs, and does not imply any actual impacts to these areas. Representative analyses of potential consequences are provided in Appendix B. In the case of a single, actual release, impacts would vary greatly, based on the location of the release, the overall release volume, and the effectiveness of response efforts. This is highlighted by the variation in trajectories between the modeled FBR and RARV scenarios under different river flow conditions. Additionally, this analysis does not evaluate impacts that might occur from hypothetical spills on the remainder of existing Line 5, outside of the Pipeline Extent Considered, as these would not change based on the route alternatives assessed here.

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