MUD LAKE CAUSEWAY ALTERNATIVES ANALYSIS

Prepared for the City of Duluth

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Contents

Executive Summary

Duluth's City Council and Parks and Recreation Commission has stated that to finalize the Western Waterfront Trail Mini-Master Plan, a scientific, comparative assessment of the different alternatives is needed. This assessment need includes habitat and human service metrics as well as cost estimates for new infrastructure and its long-term maintenance. The assessment of the costs and benefits is based on the alternative designs (listed below) from the City's draft Plan and the St. Louis River Estuary and Area of Concern conceptual habitat restoration designs for Mud Lake.

The City teamed with the MN Department of Natural Resources (MNDNR), US Environmental Protection Agency Mid-Continent Ecology Division (EPA-MED), and Barr Engineering along with other technical partners associated with the St. Louis River Estuary and the St. Louis River Area of Concern to develop, depict, and assess habitat, human services, and City-associated costs for the following causeway options:

- **Alternative 1 (Alt 1)** – *Causeway retained in current state for rail use*
- **Alternative 2 (Alt 2) –** *Causeway retained for rail use with a southern opening and a new northern opening to optimize water flow. Trail on mainland*
    - **Alternative 2 v2 (ALT 2 v2) – *considered for Habitat metrics only*** - *Causeway retained for rail use with a southern opening and a new northern opening to optimize water flow, and added river levees. Trail on mainland*
- **Alternative 3 (ALT 3) –** *Causeway retained for trail use with a southern opening and a new northern opening to optimize water flow*
    - **Alternative 3 v2 (ALT 3 v2) – *considered for Habitat metrics only*** - *Causeway retained for trail use with a southern opening and a new northern opening to optimize water flow, and added levees*
- **Alternative 4 (ALT 4) –** *Causeway eliminated to maximize water flow, vestiges retained on ends for public fishing, trail on mainland, and river levee features restored.*

A technical team of natural resource managers, ecologists and biologists met to review the existing conditions along with the City's alternatives. The team worked with the City's contractor to map the physical features associated with each alternative in order to run the quantitative and qualitative assessments used for this project. Maps for each of these alternatives are shown in Figures 1A, 2A, 2A(1), 3A, 3A(1), and 4A.

Science-based tools were then used in the areas of habitat restoration, ecosystem services, and community values, and cost estimates were generated to help decision makers process the

complexity of issues associated with a City decision on a select alternative for the Mud Lake causeway.

Ecosystem Services - Ecosystem services modelled for Mud Lake included both *supporting* and *final* ecosystem services.

- *Supporting services* provide an indirect human benefit such as fish habitat or wetlands.

  There are trade-offs for the different alternatives. For example, Alt 4 provided the greatest opportunity for deep water habitat that fish need to overwinter. On the other hand, Alt 2 v2 and Alt 3 v2 provide the greatest opportunity for providing coastal wetland sheltered habitat, which is important for waterfowl, as well as fish diversity and life stage-specific habitat needs, including spawning. The existing condition (Alt 1) provides the least supporting services.

- *Final services* are outputs of nature that provide a direct benefit to people. These services include recreational (e.g., trail, boating), subsistence (e.g., fish), and commercial beneficiaries.

  There are trade-offs for the different alternatives. For example, Alt 4 provides the greatest area for boating, combining canoeing, kayaking, and power boating. Alt 4, Alt 3 and Alt 3 v2 provide the most area for shore fishing. Other final services were similar (within 30% change) among the alternatives.

Habitat Restoration – The habitat technical team used both the quantitative (i.e., measured physical features, calculated ecosystem services) results and a qualitative approach (i.e., professional judgment) to describe, rank, and weight the habitat quality for a select set of metrics (e.g., habitat for migratory birds, wading birds, breeding birds, emergent marsh and submerged and floating leaf plant communities, fish, macroinvertebrates, invasive species). Overall, Alt 4 consistently emerged as providing the best overall habitat restoration outcome when compared to the other alternatives. This was true regardless of how the overall ranking was calculated. Alt 4 also provided the greatest potential to achieve restoration goals identified by the St. Louis River Area of Concern program. Alt 2 and 3 (both have identical habitat outcomes, differing only in the use of the causeway surface) had high rankings for a small number (2 of 9) of individual habitat components as compared to the others. Alt 2v2 and Alt 3v2 had one top rank whereas Alt 1 had none. Figure 5A is an infographic to help discern the trade-offs between the alternatives.

Community Values – Community health and well-being are a product of people's social and environmental conditions. The EPA-MED conducted a rapid community values analysis to compare the community health impacts associated with the ecosystem services provided by the four causeway alternatives. Three pathways (i.e., social and cultural; water quality and habitat; and recreation, aesthetics and engagement with nature) were analyzed to understand how the four alternatives might impact the well-being of a variety of groups that will be affected by the decision. The analysis demonstrates that every alternative produces a different mix of ecosystem services, which in turn has the potential to impact the health of several populations – current users of Mud Lake and the Lake Superior and Mississippi Railroad (LSMR), user groups and the outdoor recreation community, those who live in the Morgan Park and Gary-New Duluth neighborhoods, and the indigenous community.

All alternatives have the potential to improve outdoor recreational opportunities by improving habitat, which might positively impact bird and wildlife watchers and anglers, and by adding a trail, which will positively impact hikers and bikers. Alt 3 and Alt 3 v2 in particular will expand canoe and kayak access to all of Mud Lake, and Alt 4 would provide recreational boating and fishing opportunities throughout all of Mud Lake. Alt 4 has the greatest potential to improve habitat through the creation of a high-quality coastal wetland, which will likely positively impact indigenous communities who wish to exercise treaty rights. Further, all alternatives have the potential to offer social, historical, and cultural opportunities. However, Alt 3, Alt 3 v2 and Alt 4 would have a negative impact on the social cohesion and place attachment for the LSMR, the neighborhood that identifies with the train, and train passengers. It should be noted that this rapid assessment had a limited amount of community consultation, and therefore the assessment may not include all potentially affected groups. Recognizing that there is an attachment to place, as well as claims on the space by multiple groups, it would positively impact the mental health and social cohesion of all communities for them to participate in collaborative decision-making. This will ensure that health benefits are maximized for all communities.

Cost Estimates – High level cost estimates for the alternatives were developed by Barr Engineering for construction and annual maintenance based on a 20 year annualized cost. Assumptions have to be made when developing costs of this nature and those are detailed in the footnotes. For example, the labor cost for the railway were based on volunteer efforts, however, the estimate range of a low end to a high end project screening most likely includes the costs of contracted work should the city need to do so. On another note, the estimates did not take into account potential soil contamination issues and remedial work. This is unknown,

but likely some work will need to be done to meet the correct use (industrial vs residential) should the trail be designed with the private owners up and along the ridgeline. If the trail is moved to the base of the hillside, costs will likely increase for permitting and construction due to the wet areas.

Overall Alt 4 is the least costly in the short and long term followed by Alt 3 and last by Alt 2. Figure 1D is an infographic to help discern the trade-offs between the alternatives.

Assessing Habitat Differences of Alternative Concept Designs

Discussions of habitat restoration needs and opportunities at Mud Lake have been occurring formally and informally for many years. Following the designation of the St. Louis River Area of Concern (AOC) in 1987, the Mud Lake area was identified as requiring both remediation and restoration in the St. Louis River Remedial Action Plan (RAP) in 2013 (MPCA 2013). In particular, management actions in the project area are necessary to help correct two beneficial use impairments (BUIs). One of these BUIs is the loss of fish and wildlife habitat. The other is restrictions on dredging, a BUI directly related to contaminated sediments in West Mud Lake. Defining the habitat or sediment variables that can be measured (metrics) is important for designing a project to achieve specified goals for clean-up and habitat improvement and to assess post project success over time.

Sediment quality metrics use analysis of various chemicals of concern in the sediment (e.g., metals, volatiles, toxicants) to determine the need for remediation. Identifying habitat quality metrics can be more complex. Measures of two metrics (benthic macroinvertebrates and aquatic vegetation assemblages) indicate that much of the open water areas of Mud Lake do not differ significantly from other sites in the estuary that are considered least-impaired. However, other habitat metrics still need to be considered to meet other goals in the RAP. These include habitat for various species of fish, birds, and mammals which are more difficult to measure. Mostly, these metrics focus on the depth, exposure to wind and waves, bottom composition, and other physical habitat features.

The Lower St. Louis River Habitat Plan (SLRCAC 2002) identifies strategies needed to restore habitat in the estuary, including at Mud Lake. The Habitat Plan Strategies Implementation Planning Worksheet (SLRA 2011) for Mud Lake (Figure 6A) provided an initial direction for this project site.

Habitat restoration planning and strategy development at Mud Lake have relied on historical and recent resource assessments completed throughout the St. Louis River Estuary. These assessments include regular and long term population assessments for taxa such as fish (e.g., MNDNR 2019, Piszczek, et al. 2016), occasional or site-specific monitoring surveys for taxa such as birds (e.g., Bracey, et al. 2016), aquatic macrophytes (e.g., Reschke, et al., 2016), aquatic macrophytes (e.g., Brady, et al. 2016), and invasive species (e.g., Jensen 2018, St. Louis County Board 2015). Restoration planning also relies on information gleaned from historic maps such as the original navigation chart of the St, Louis River (Figure 7A), and air photos from both past (Figure 8A) and present (Figure 9A). In addition to these documents, maps, and images, the professional expertise of natural resource managers are used to advise on design strategies to help correct degraded conditions.

Alternatives Examined

For this assessment, natural resource managers, ecologists, biologists, and St. Louis River (SLR) AOC partners associated with the estuary examined several conceptual restoration project alternatives. These alternatives were based on conceptual designs established over the past several years to restore habitat functions and values at Mud Lake. The alternatives were compared to each other and to the current physical conditions to evaluate habitat benefits and tradeoffs between the conceptual designs.

1) **Existing conditions** – The existing physical condition at Mud Lake (ALT 1) is a benchmark condition and was used for comparison purposes. It was considered representative of the habitat values and benefits of the site now and in the near future if no action is taken to restore the loss of fish and wildlife habitat at Mud Lake. To provide a basis for comparison, the existing conditions were mapped and modeled by MNDNR and EPA- MED using the same methods as the other alternatives. Figure 1A illustrates a combined topographic and bathymetric map of ALT 1 as it was used in this analysis.
2) **Adding an opening in the causeway** – The second design alternative (ALT 2 and ALT 3) includes several human use variations, however, the underlying habitat design strategy that forms the basis of ALT 2 and ALT 3 is improvement to the hydrologic connection between the western portion of Mud Lake and the larger estuary by creating an additional opening in the causeway. The objective of this additional opening is to enhance the volume and rate of water exchange, restoring the estuarine processes to the area cut off by the causeway.

   This alternative comes from the conceptual plan developed by AOC partners and presented to MPCA in a 2013 report "Preliminary Restoration Elements for Mud Lake" (Figure 10A).

   ALT 2 and ALT 3 include limited impact to the existing causeway. Alteration of the causeway for the purposes of habitat restoration is restricted to adding an opening in the northern portion of the project site. This opening is presumed, for the purposes of this assessment to be a bridge. It is important to note that this and the other alternatives involving restoration actions will require fine-scale design considerations and this may result in some differences between these conceptual designs and the final implemented project.

   Because ALT 2 and ALT 3 include limited impact to the causeway it allows for continued use as a travel corridor. To ensure that habitat and ecosystem services values between different causeway uses were considered, these alternatives were

mapped and modeled based on a future use as a railway (ALT 2) and as a pedestrian and bicycle trail (ALT 3).

In addition two variations of ALT 2 were mapped and modeled. This was done to include potential habitat enhancements identified as part of ALT 4 to ensure that the assessment of any one conceptual design was not unduly influenced by the presence or absence of design features that could potentially be included but that had not been part of the original concept design. These variations of Alternative 2 (Alt 2 version 2, labeled ALT2 v2v2, and Alt 3 version 2, labeled ALT3 v2 differ from the original versions of the alternatives by including the restoration of river levee features along the main channel of the St. Louis River on the eastern side of the project site.

3) **Causeway removal** -- The final major conceptual design alternative is labeled Alternative 4 (ALT 4). This alternative incorporates removing significant portions of the causeway to remove the physical barrier between the east and west basins in Mud Lake and allow for greater hydrologic connectivity to the greater estuary. This alternative also incorporates restoration of the river levees that formed bay-mouth bar like features that were historically present along the eastern portion of the project site, and provides a larger area of off-channel, deep water habitat.

   A conceptual plan for this alternative was developed by the City of Duluth and AOC partners as part of a coordinated effort that considered strategies that best remediated, restored and revitalized the St. Louis River corridor. This cooperative project incorporated other planning efforts to improve and extend the Western Waterfront Trail while meeting AOC goals to remediate contaminated sediment and restore lost fish and wildlife habitat. The *Mud Lake Conceptual Restoration Design* (Figure 11A) was included in the Draft Western Waterfront Trail plan.

Refining alternatives

To compare the alternatives it was necessary to establish a common mapping framework by clearly mapping the physical features associated with each of the alternatives and their respective variations. A technical team of natural resource managers, ecologists and biologists participated in a workshop to consider the existing conditions and alterations to those conditions necessary to accomplish the restoration design concepts in both the 2013 (ALT 2 – Figure 10A) and 2017 (ALT 4 – Figure 11A) plans. This workshop resulted in the development of the topography/bathymetry maps

for each of the alternatives under consideration. The City of Duluth used their contractor to create digital elevation models for the alternatives. These models were used to measure habitat features for all the various alternatives. They were also used by EPA's Midcontinent Ecology Division (EPA-MED) lab in Duluth to quantify predicted habitat conditions though the use of ecosystem models calibrated for the St. Louis River estuary (Hoffman and Angradi 2019).

To ensure that the effects of specific physical alterations included in the alternatives were examined, elements of ALT 4 were added as a variation to the ALT 2 scenarios. This arose from concern that leaving the potential restoration of the river levee features out of the analysis may be viewed as an intentional effort to favor one alternative over another. While the river levee feature had not been a component of the 2013 concept design, it was added as "version 2" of ALT 2 and ALT 3 for the analysis.

The alternatives are summarized as follows:

- **Alternative 1 (ALT 1)** – *Causeway retained in current state for rail use*
- **Alternative 2 (ALT 2) –** T*rail on the mainland and causeway retained for rail with southern opening and a new northern opening to optimize water flow*
- **Alternative 2 V2 (ALT 2 V2) -** *Trail on the mainland and causeway retained for rail with southern opening and a new northern opening to optimize water flow with river levee between Mud Lake east and St. Louis River*
- **Alternative 3 (ALT 3) –** *Causeway retained for trail with a southern opening and a new northern opening to optimize water flow*
- **Alternative 3 (ALT 3 V2) -** *Causeway retained for trail with a southern opening and a new northern opening to optimize water flow with river levee between Mud Lake east and St. Louis River*
- **Alternative 4 (ALT 4) –** *Causeway eliminated to maximize water flow, vestiges retained on ends for public fishing, trail on mainland, river levee features restored.*

Modeling for Aquatic Vegetation

Maps of the six alternatives were produced by EPA-MED to depict water depths based on the current International Great Lakes Datum (IGLD85) low water level of 601.1 feet above sea level. (Figures 11-16). Water depths in 2-foot classes (i.e., 0-2 feet deep, 2-4, 4-6, and greater than 6) are shown over an aerial photo base map. These depth classes are biologically relevant due to the way different groups of plants respond to water

depth in the St. Louis River estuary.

Submerged aquatic vegetation (SAV) includes plants such as water celery (*Vallisneria* spp.) and some pondweed (*Potamogeton* spp.) that have stems and leaves that grow entirely underwater, although some may also have floating leaves. Flowers and seeds on short stems that extend above the water may also be present. They are important food sources for migratory waterfowl and provide food and cover for many types of fish and other aquatic organisms. Submerged plants also occur mixed with floating-leaf vegetation and emergent vegetation.

Floating–leaf vegetation (FLV) favors somewhat shallower water than SAV. It is a group that includes species such as water lilies (such as *Nuphar variegata* and *Nymphaea odorata*) that are rooted in the bottom but have most of their leaves and flowers at the water surface. They also provide important food and cover to a variety of fish and other aquatic organisms. This habitat also includes submerged aquatic plants, and occasionally some emergent vegetation.

In the 0-2 foot deep range vegetation trends toward emergent aquatic species and is most likely to be exposed above water during periods of low lake level. In the 2-4 foot depth range, floating-leaf vegetation tends to become more dominant, especially in areas sheltered from wind and wave energy. Submerged aquatic vegetation grows best in the estuary at depths less than 6 feet since sunlight does not penetrate far enough in the estuary's dark waters to support much plant life. Water deeper than 6 feet is very important habitat for fish seeking cooler water during hot summer periods and for overwintering.

The depths shown on the ALT 1 map (Figure 12A) are based on the most current bathymetric surveys for the project area. Those shown on the other alternatives use a combination of the current bathymetry in unchanged areas along with proposed new bathymetry in areas designed to achieve depth outcomes desired for the alternative.

Table 1. Summarizes the differences in depth classes between the alternatives on an acre-for- acre basis and as a percentage of the overall project area.

Table 1. Depth classes

	Current Condition	Retain Rail use	Rail to Trail Conversion	Retain Rail use - Version 2	Rail to Trail Conversion - Version 2	Remove Causeway
	(Alt 1)	(Alt 2)	(Alt 3)	(Alt 2 v2)	(Alt 3 v2)	(Alt 4)
Acres 0-2 feet deep	33.0	35.1	35.1	33.3	33.3	33.8
Acres 2-4 feet deep	58.2	65.3	65.3	62.6	62.6	56.6
Acres 4-6 feet deep	42.8	41.2	41.2	41.0	41.0	42.5
Acres greater than 6 feet deep	33.2	37.1	37.1	36.5	36.5	51.1
percent of project area 0-2 feet deep	20	20	20	19	19	18
Percent of project area 2-4 feet deep	35	37	37	36	36	31
Percent of project area 4-6 feet deep	26	23	23	24	24	23
Percent of project area greater than 6 feet deep	20	21	21	21	21	28

The percent area in each depth class was calculated to provide a measure of how much the depths would change for each of the alternatives. The difference between alternatives in the 0- 2 foot category is small and ranges from 18% of the total area for ALT 4 to 20% for the ALT 1 and ALT 2/3. The change in the 2-4 foot depth classes ranges from 31% for ALT 4 to 37% for ALT 2/3. In the 4-6 foot depth class the range is from 23% for ALT 3 to 26% for ALT 1. The largest difference among the depth classes is seen in the greater than 6 feet deep class. ALT 4 has 28% of the project area in this depth class where other alternatives have 20-21%.

For all the alternatives, the most prevalent depth class is 2-4 feet and the least prevalent class is 0-2 feet, although in the case of the current condition (ALT 1), the greater than 6 foot class is tied to least prevalent. Note, this does not include the existing areas of invasive cattail marsh present in the larger project area. The invasive cattail marsh aquatic habitat, where no changes are proposed to bathymetry, was not included in this analysis.

Tables 2. Summarizes the differences in model outputs for different types of aquatic vegetation between the alternatives. The values in this table are based on the computer models developed by EPA-MED for the St. Louis River Estuary. These models combine the effects of several physical environmental parameters such as water depth, wind exposure and wave energy to help predict how different types of plants will respond to current and potential future habitat conditions.

Table 2. Vegetation types						
	Current Condition (Alt 1)	**Retain Rail use** (Alt 2)	**Rail to Trail Conversion** (Alt 3)	**Retain Rail use - Version 2** (Alt 2 v2)	**Rail to Trail Conversion - Version 2** (Alt 3 v2)	**Remove Causeway** (Alt 4)
Submerged Vegetation (SAV)						
Acres Sparse cover (0-25%)	19.4	18.0	18.0	17.9	17.9	19.1
Acres Patchy cover (25-75%)	23.2	22.5	22.5	22.4	22.4	27.1
Acres Dense cover (75-100%)	75.9	84.3	84.3	79.3	79.3	73.3
Acres Total SAV	158.9	169.3	169.3	163.5	163.5	174.9
Floating Leaf Vegetation (FLV)						
Acres sparse and patchy cover (0-50%)	125.1	127.5	127.5	115.6	115.6	181.1
Acres dense cover (50-100%)	42.2	51.2	51.2	57.9	57.9	2.9
Acres Total FLV	167.3	178.7	178.7	173.4	173.4	184.0

The models were built from acoustic data obtained by EPA. In this case, the acoustic data collection system is "pinging" multiple times per second along a transect and classifying a ping as plant presence/absence. Because the system is continuously sampling for frequency along a transect, it can appropriately be thought of as an estimate of cover (Angradi et al., 2013). Results from the models estimate the percentage of an area that would likely have vegetation present during a typical growing season. For submerged aquatic vegetation (SAV), the results were categorized into classes of "Sparse" vegetation with 0-25% cover, "Patchy" vegetation with 25-75% cover, and "Dense" vegetation with 75-100% cover.

The alternatives did not differ significantly with respect to the area of sparse SAV cover. The range of areas with Sparse SAV was 17.9 acres to 19.4 acres, or a difference of 1.5 acres between the highest (ALT 1) and lowest (ALT 2 v2/3 v2) values. There was a difference of 4.7 acres between the highest (Alt 4) and lowest (ALT 2 v2/3 v2) values in the Patchy SAV cover class. There was a difference of 11 acres between the highest (ALT 2/3) and lowest (ALT 4) values in the Dense SAV cover class. When all classes are combined, ALT 4 had the greatest number of acres of SAV habitat (174.9) and ALT 1 had the least (158.9).

The categories for floating leaf vegetation (FLV) are broader and include a "Sparse and Patchy" class that has 0-50% cover and a "Dense" cover class with 50-100% cover.

ALT 4 had the greatest number of acres in the Sparse and Patchy FLV cover class for with 181.1. ALT 2 v2/3 v2 had the least with 115.6 acres. The opposite pattern was seen for acres of Dense FLV. ALT 4 had the least (2.9 acres) while ALT 2 v2/3 v2 had the greatest (57.9 acres). When both classes are combined, ALT 4 had the greatest number

of acres of FLV habitat (184) and Alt 1 had the least (167.3).

Other Modeled Features

Table 3 summarizes other habitat features relevant for assessing differences in quality between the alternatives.

Table 3. Other measures of habitat condition

	Current Condition	Retain Rail use	Rail to Trail Conversion	Retain Rail use - Version 2	Rail to Trail Conversion - Version 2	Remove Causeway
	(Alt 1)	(Alt 2)	(Alt 3)	(Alt 2 v2)	(Alt 3 v2)	(Alt 4)
Highly Sheltered Bay (acres)	23.4	26.5	26.5	30.9	30.9	9.8
Moderately Sheltered Bay (acres)	29.8	28.2	28.2	42.6	42.6	21
Fill in Public waters (lineal feet of artificial structures)	4,894	4,782	4,782	4,782	4,782	3,067
Hardened shoreline (lineal feet)	4,379	4,107	4,107	4,107	4,107	1,302
Off-channel overwintering fish habitat (acres)	33.2	37.1	37.1	36.5	36.5	51.1

"Fill in Public Waters" in Table 3 is the lineal feet of artificial structures in the river which is closely related to the measure of "Hardened Shoreline" at this project site. For both measures, a lower value indicates better habitat condition. Both measures are strongly influenced by the physical size and composition of the railroad causeway and how it relates to the physical habitat of the aquatic habitat types adjacent to it. ALT 1 has the highest value for both of these measures. There is some reduction in the measure for the various versions of ALT 2 due to the small area removed to create a second opening in the causeway. ALT 4 has a substantially lower number in these measures due to removal of the fill and the associated riprap on the shoreline of the causeway.

Off-channel overwintering fish habitat is identified as a habitat metric to be addressed in the RAP and is also assessed herein all the design concepts and goals. It differs from other deep water habitats in the estuary which tend to have greater water velocity in the river's main- channel areas and a higher frequency of disturbance by watercraft in the navigation channel areas. Deep water habitat quality is also influenced by adjacency to aquatic vegetation beds and the position of underwater slopes where fish can find suitable depths depending on seasonal or daily requirements. It is important also as a cool-water refuge for fish during hot summer conditions. This habitat measure is closely linked at this project site to the number of acres deeper than 6 feet. ALT 4 has the highest value (51.1 acres) and ALT 1 has the lowest (33.2 acres).

While the measured and modeled habitat values provide some means to objectively compare alternatives, it is interactions between these values that influence how well a particular area meets the requirements of a particular species or group of species. In addition, habitat conditions suitable for one group of organisms may be very unsuitable for another. For example, deep water habitat is important for several species of fish at certain times of the year but it provides relatively poor habitat for SAV or benthic macroinvertebrates.

To compare the alternatives with respect to the interactions between multiple habitat values for a set of high priority ecological functions and values, the habitat team identified 9 habitat quality metrics based on site-specific and AOC-wide habitat restoration goals. Metrics were then ranked relative to each other based on the measureable factors that influence those metrics at this project site.

The measured and modeled results of ALT 2 and 3 did not differ from each other. The primary difference between these two alternatives pertains to the human use of the causeway. Neither the ecological models nor the physical habitat conditions measured are sensitive to this difference in use. Similarly, the measured and modeled values for ALT 2 v2 and 3 v2 did not differ from each other. Therefore the ranking of habitat metrics combined Alt 2 and Alt 3. This combined set of alternatives is labeled ALT 2/3. ALT 2 v2 and ALT 3 v2 were also combined into one set and is labeled ALT 2 v2/3 v2.

Table 4 summarizes the habitat metrics and their relative ranks. In Table 4, a rank of "1" is the highest rank and represents the best alternative for each habitat metric when compared to each of the other alternatives. Table 5 describes the metrics in more detail

Table 4. Habitat quality ranking (1 is highest, 4 is lowest)

	Alt 1	Alt 2/3	Alt 2 v2/ 3 v2	Alt 4
Breeding Bird habitat	4	3	1	2
Wading Bird Habitat	4	3	2	1
Migratory Waterfowl Habitat	3	1	2	4
Emergent Marsh Plant Community	4	2	3	1
Submerged and Floating Leaf Plant Community	3	1	2	4
Fish Habitat	4	2	2	1
Benthic Macroinvertebrates	4	2	3	1
Hydrology	4	2	3	1
Non-native Plant Management	4	2	3	1
TOTAL	**34**	**18**	**21**	**16**
Total with one bird (averaged)habitat metric*	**27**	**13**	**18**	**11**
Total number of top-rank scores	**0**	**2**	**1**	**6**

*Average of the three bird habitat values was used to prevent over-weighing results toward one taxa.

and identifies the primary factors used to establish the ranks during a resource managers/ecologists/biologists workshop on March 1, 2019.

Table 5. Factors used to rank habitat metrics

Breeding Bird Habitat
• Increased length of edge • Increased area of emergent vegetation for feeding   ○ E.g. the north channel to be created through the cattails west of the causeway
Wading Bird Habitat
• Increased length of shoreline • Increased area of submergent vegetation (approx. 0-2 feet) • Soft shoreline (as opposed to riprap shoreline) • Continuous habitat connection better (vs. broken by artificial structures)
Migratory Bird
• Increased area of submerged vegetation as food source
Emergent Marsh
• Increased area of emergent vegetation • Connection with estuarine hydrologic process
Submerged and Floating-Leaved Plant Community
• Increased area of submerged and floating leaf vegetation
Fish Habitat Restoration Opportunity
• Increased area of deep water
Benthic Macroinvertebrates
• Increased area of submerged aquatic vegetation • Increased area of novel habitat (beta-diversity) • Total water
Hydrology
• Restoration of estuarine hydrology
Non-Native Plant Management Risk (risk of colonization) vs. Opportunity (for removal)
• Increased water depth to flood out non-native cattail

Birds

Three bird habitat metrics were included in the analysis as different types of birds require different habitat features for optimal habitat. For the purpose of this analysis, the three bird habitat metrics were used both as separate scores and averaged into one score. This was done to assess the impact of multiple metrics on the overall outcome and to ensure that results would not be over-weighted toward one group of organisms. Both the total score and the total calculated with the average of the three ranks is presented in Table 4. Using the average score for the three bird habitat metrics did not change the overall rank order of the alternatives.

Habitat Ranks

To determine the overall rank order of alternatives, three different approaches were used. First and overall rank was calculated by adding up the ranks for all metrics. Second, the total score was calculated after averaging the bird habitat metrics into one. Third, the number of top rankings for each alternative achieved was tallied. The overall rank order of alternatives was consistent with all of the approaches. In all cases, ALT 4 had the highest overall rank. Alt 2/3 was second followed by ALT 2 v2/3 v2. ALT 1 had the lowest overall rank. ALT 4 received six top rankings for individual metrics. These metrics included Wading Bird Habitat, Emergent Marsh Plant Community, Fish Habitat, Benthic Macroinvertebrates, Hydrology, and Non-native Plant Management. ALT 2/3 had two top rankings. These included Migratory Waterfowl Habitat and Submerged and Floating Leaf Plant Community. ALT 2 v2/3 v2 had one top ranking, which was for Breeding Bird Habitat. Finally, ALT 1 had no metrics with top rankings for any individual habitat metrics.

Overall, ALT 4 provided the most habitat benefit of the alternatives assessed. Additionally, it scored the highest combined rank for metrics associated with AOC RAP habitat restoration goals identified for the site which included:

- Establish more vital hydrologic connection
- Restore wetland habitat including wild rice, and
- Establish deep water.

The metrics corresponding to these habitat goals included Hydrology, Emergent Marsh Community Habitat, and Fish Habitat. For each of these metrics, ALT 4 received the top rank.

The RAP also identifies a goal of remediating contaminated sediments at Mud Lake. This analysis assumed that all restoration alternatives will adequately address the needs to remediate contaminated sediments and that following restoration, substrates will be safe and suitable for supporting the types of plant and animal communities that can occur in the resulting depths and energy environments.

The goals in the Habitat Plan Strategies Implementation Planning Worksheet for Mud Lake (Attachment 1) identify three habitat restoration goals:

- Establish a more vital connection between the estuary and the wetlands north of the railroad causeway
- Enhance wetlands for migratory birds at Mud Lake, and
- Establish wild rice beds within wetland north of the railroad causeway.

ALT 4 scored the top rank for two of the three of these goals, Hydrology and

Emergent Marsh Plant Community. It scored the lowest rank for Migratory Waterfowl habitat. ALT 2/3 scored the highest rank for Migratory Waterfowl Habitat and mid-rank scores for the other planning worksheet goals.

References:

Angradi, T., M. Pearson, D. Bolgrien, B. Bellinger, M. Starry, and C. Reschke. 2013. Predicting submerged aquatic vegetation cover and occurrence in a Lake Superior estuary. Journal of Great Lakes Research 39 (2013) 536-546.

Bracey, A., J. Chatterton, and G. Niemi. 2016. St. Louis River AOC R2R Support Projects: Ecological Monitoring and Assessment (CR#6403) Final Report. Sample Birds at R2R and Reference Locations. Report submitted to MPCA. Natural Resources Research Institute, University of Minnesota Duluth.

Brady, V.J., J. Dumke, G. Niemi, A. Bracey, G. Host, C. Reschke, N. Johnson, and J. Austin. 2016. St. Louis River AOC R2R Support Projects: Ecological Monitoring and Assessment. Final report to Minnesota Pollution Control Agency (CR#6403). Report submitted to MPCA. Natural Resources Research Institute, University of Minnesota Duluth.

Hoffman, J. and T. Angradi. 2019. Ecosystem Services Providing Area Analysis for Habitat Restoration Alternatives at Mud Lake on the St. Louis River, Minnesota. U.S. Environmental Protection Agency, Office of Research and Development. Technical Brief.

Jensen, D. 2018. Non-Native Species Introductions into the St. Louis River Estuary Compared to Lake Superior 1883-2018. Presented at St. Louis River Estuary Summit, March 13, 2018.

MNDNR. 2019. Fisheries Lake Surveys, St. Louis River Estuary (69129100). URL: https://www.dnr.state.mn.us/lakefind/showreport.html?downum=69129100, accessed April, 2019.

MPCA. 2013. St. Louis River Area of Concern Implementation Framework: Roadmap to Delisting (Remedial Action Plan Update), July 15, 2013. 78 pages.

Piszczek, P, A. Nelson, M. Wedge, A. Varian, and B. Borkholder. 2016. 2015 St. Louis River Lake Sturgeon Survey Summary. St. Louis County, Minnesota and Douglas County, Wisconsin. Wisconsin Waterbody ID Code (WBIC): 2843800.

Reschke, C., and G. Host. 2016. St. Louis River AOC R2R Support Projects: Ecological Monitoring and Assessment (CR#6403). Aquatic Macrophyte Sampling and Analysis. Draft Final Report submitted to MPCA. Natural Resources Research Institute, University of Minnesota Duluth.

St. Louis River Alliance (SLRA). 2011. Lower St. Louis River Habitat Plan Appendix 9 Strategies
Implementation Planning Worksheets.

St. Louis River Citizens Action Committee (SLRCAC). 2002. Lower St. Louis River Habitat Plan. St. Louis River Citizens Action Committee, Duluth, MN.

St. Louis County Board. 2015. Aquatic Invasive Species Prevention Plan, St. Louis County Minnesota. St. Louis County board Approved May 12, 2015.

Figures: Assessing Habitat Differences of Alternative Concept Designs

Figure 1A. Topography and Bathymetry – Existing Conditions

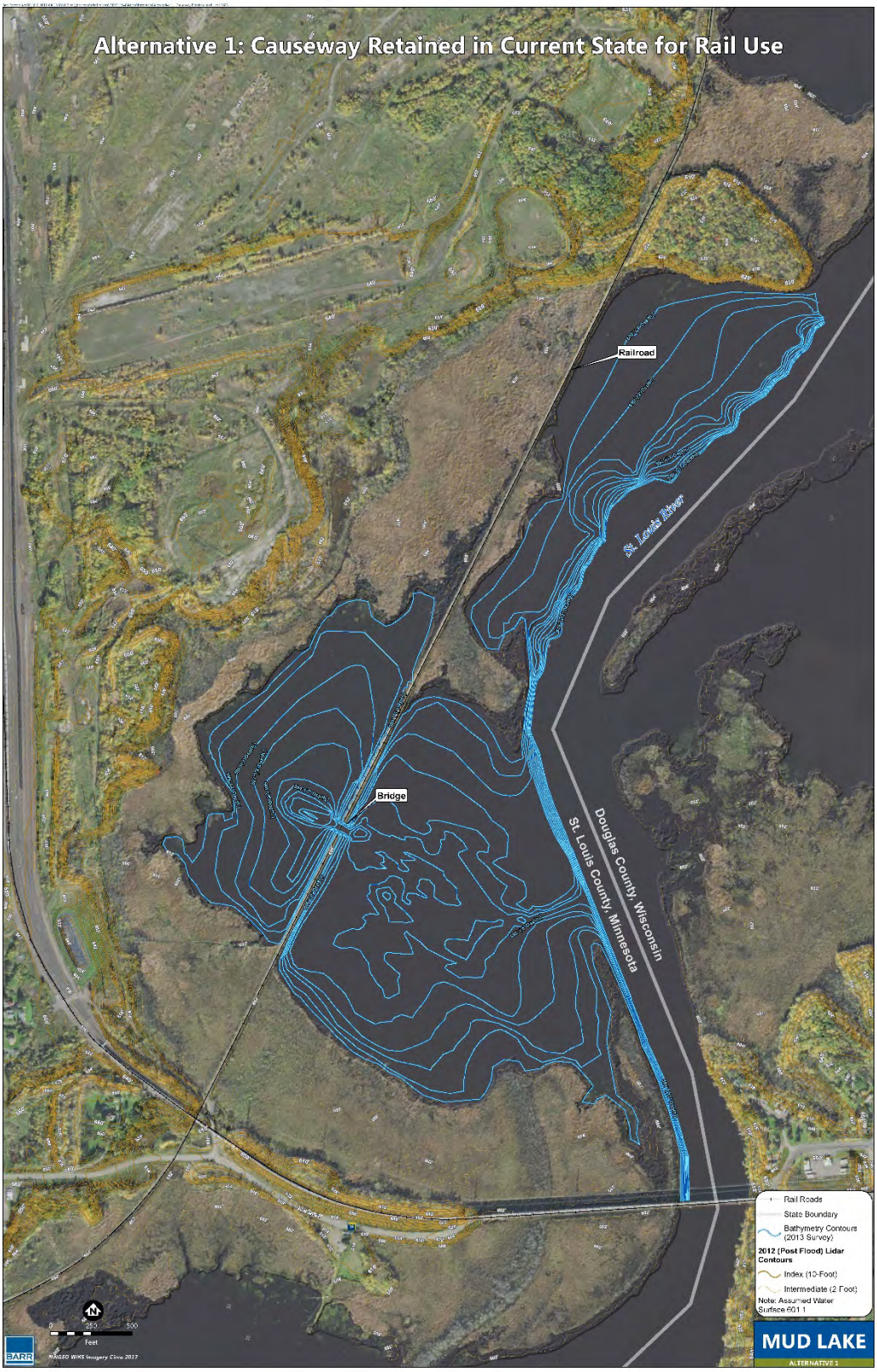

Figure 2A. Topography and Bathymetry - Causeway opening added in north with rail use.

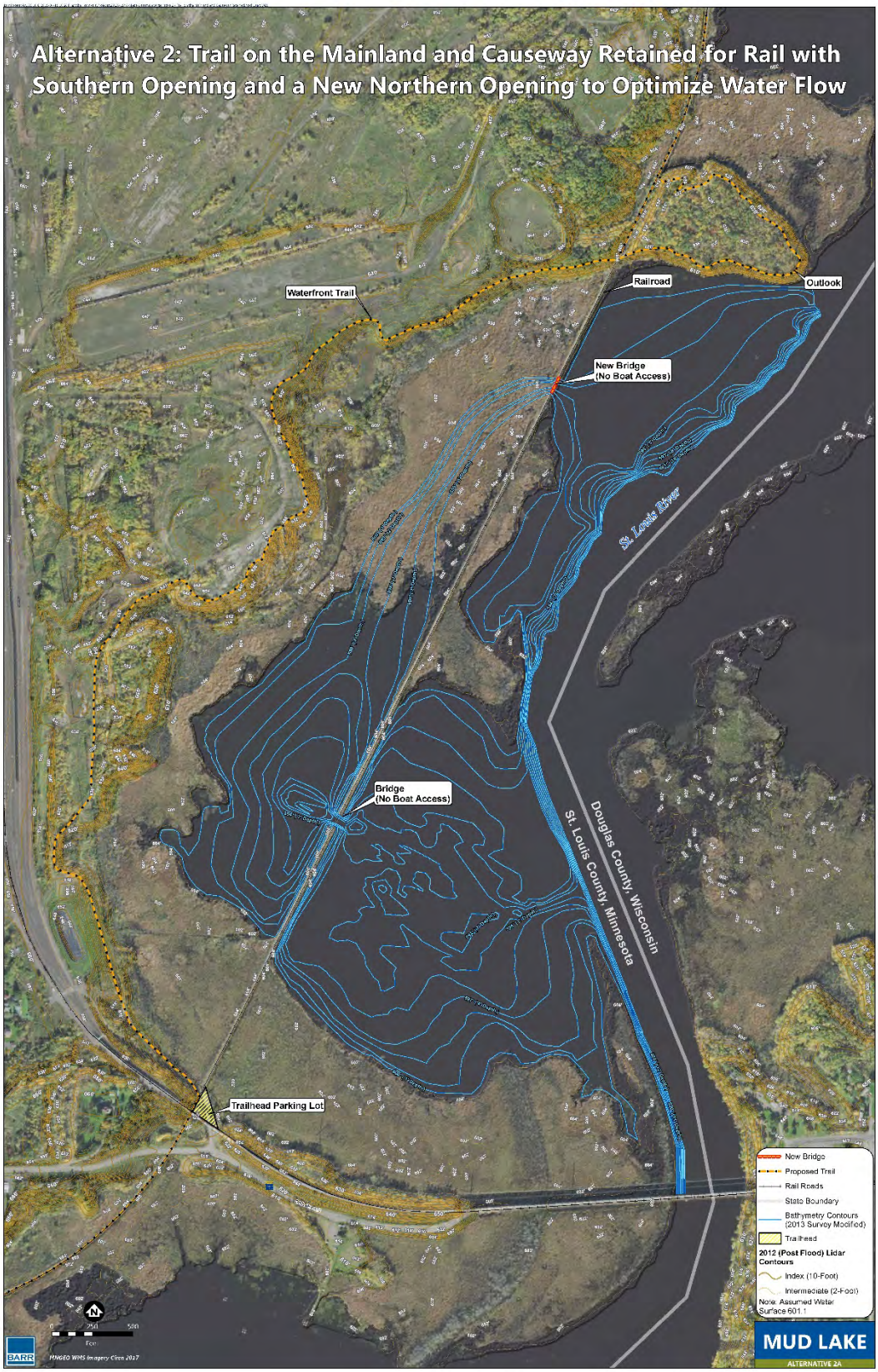

Figure 2A(1). Topography and Bathymetry - Causeway opening added in north with rail use.

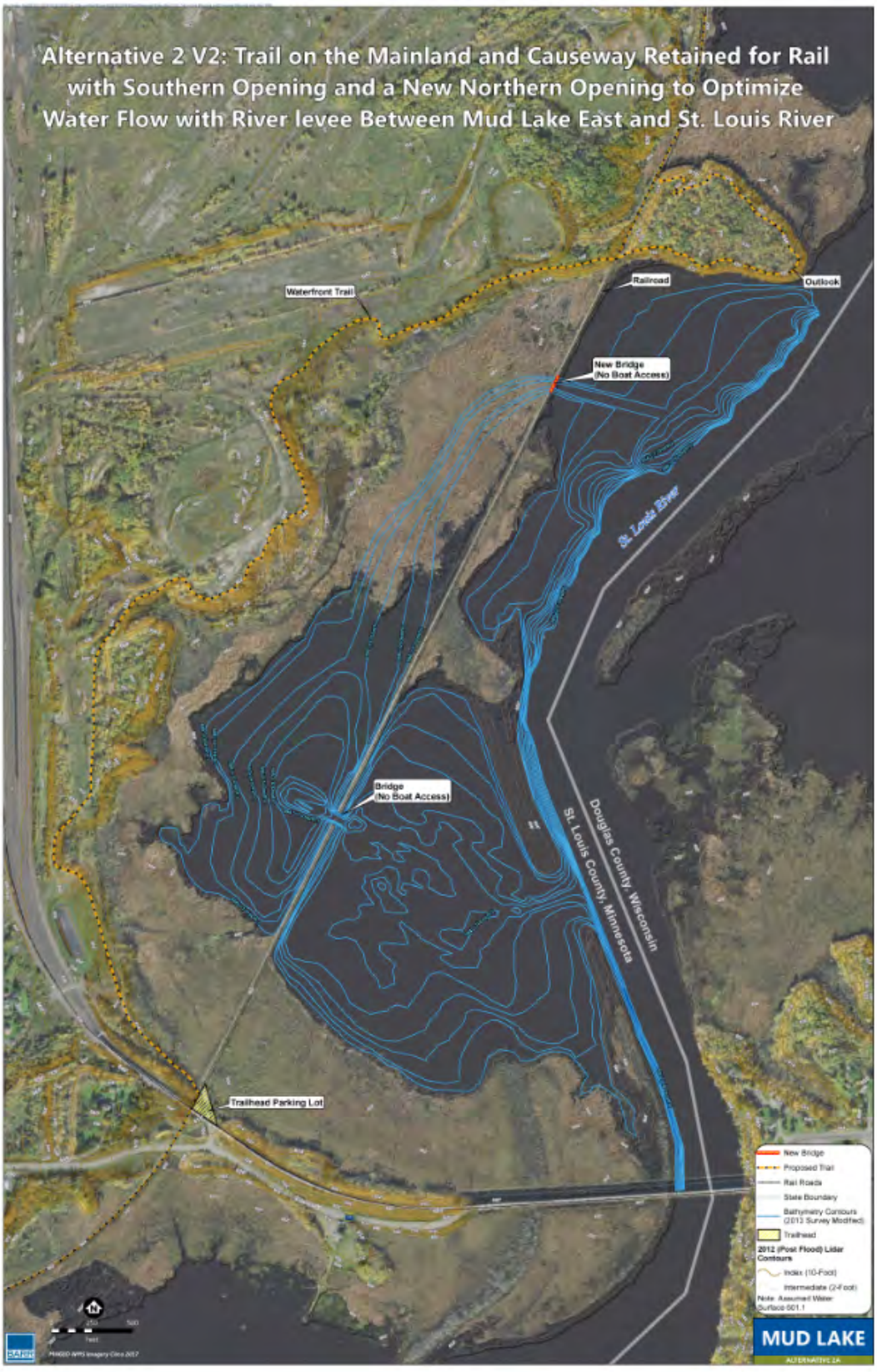

Figure 3A. Topography and Bathymetry - Causeway opening added in north with trail use.

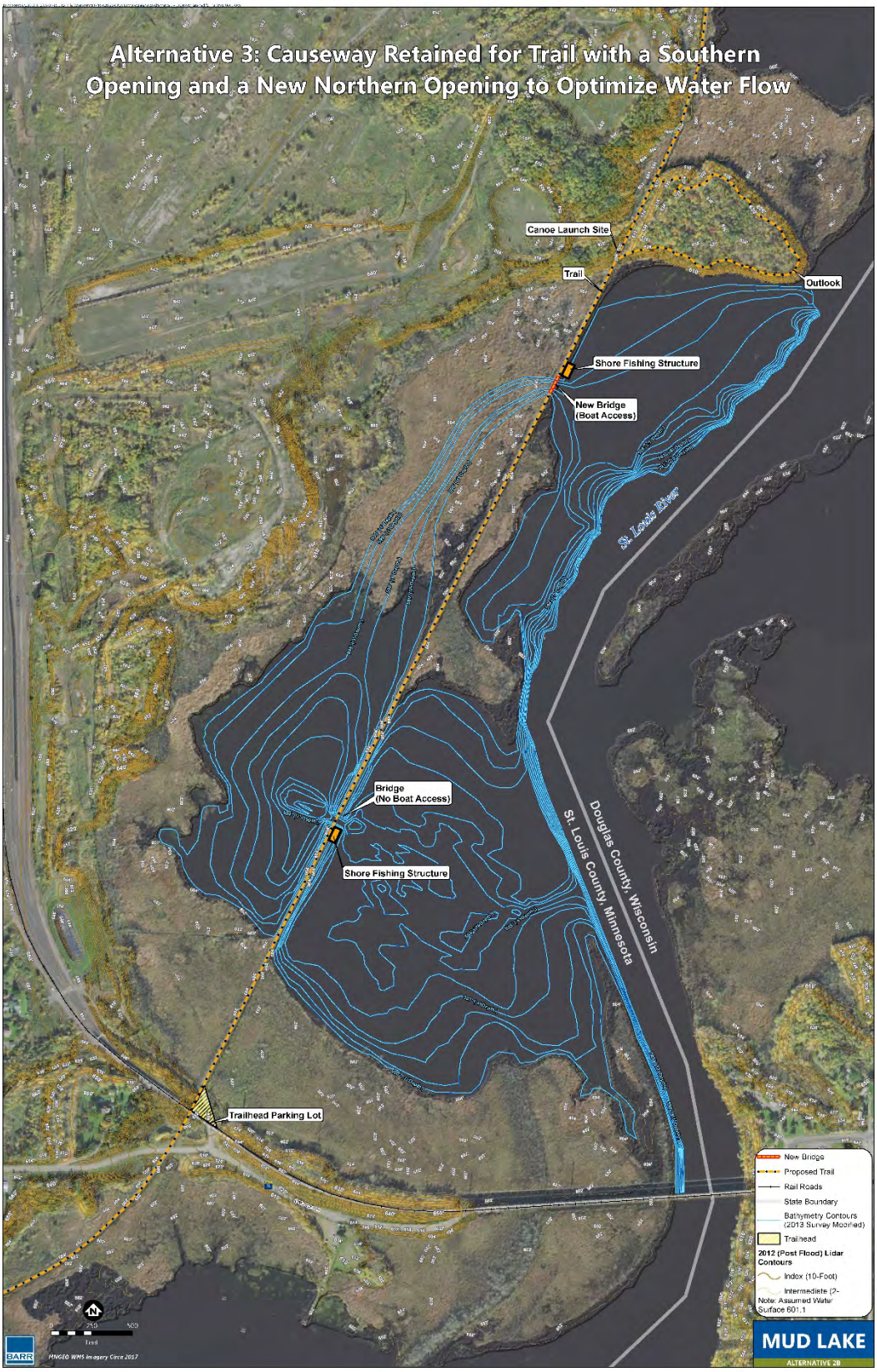

Figure 3A(1). Topography and Bathymetry - Causeway opening added in north with trail use.

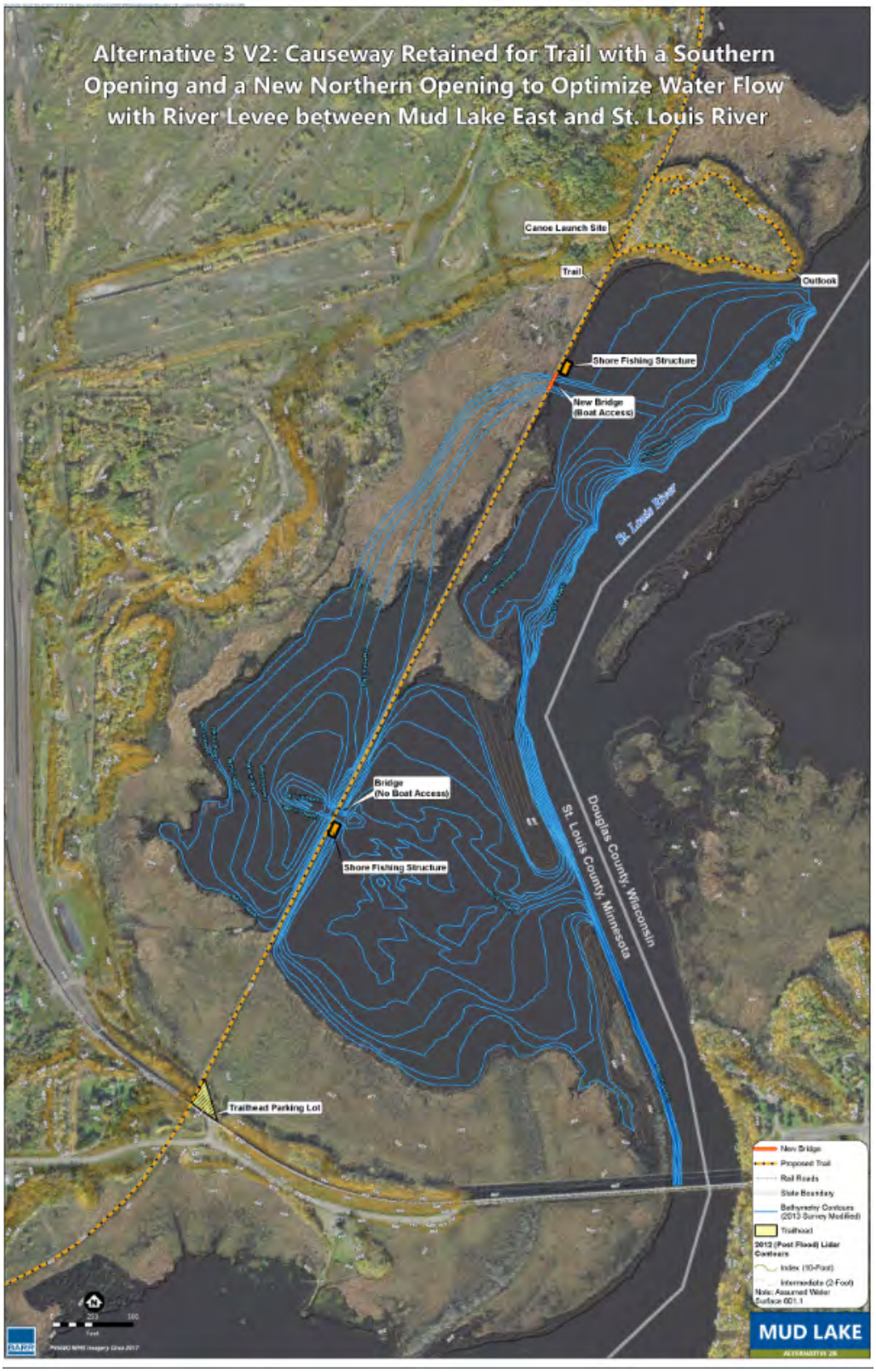

Figure 4A. Topography and Bathymetry - Causeway largely removed, levees restored.

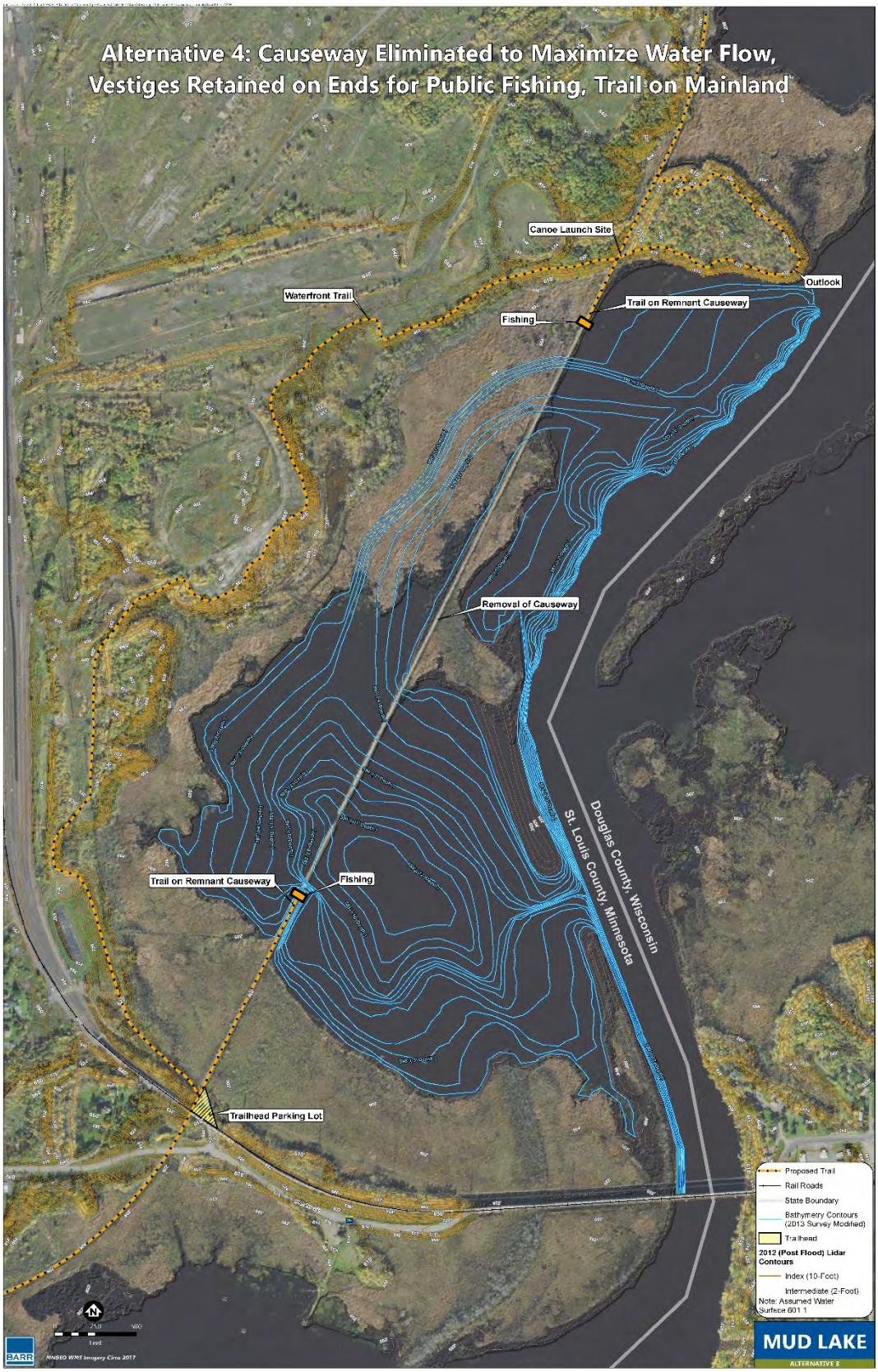

Figure 5A. Mud Lake Alternatives Analysis - Habitat Ranking

Habitat Quality Ranking

Ranking Key: 4 (Lowest Score) → 1 (Highest Score (Best))

Ranking Category	Ranked Causeway Design Alternatives			
	Alt 1	Alt 2 & ALT 3	Alt2 V2 & Alt3 V2	Alt 4
Migratory Waterfowl, Wading, & Breeding Bird Habitat (average of 3 metrics)	4	3	1	2
Plant Community Quality - Emergent Marsh	4	2	3	1
Plant Community Quality - Submerge & Floating Leaved	3	1	2	4
Fish Habitat Restoration	4	2	2	1
Benthic Macroinvertebrate Habitat	4	2	3	1
Hydrologic Connectivity	4	2	3	1
Non-Native Plant Management (invasive species)	4	2	3	1

Top Ranked

ALT 4

- Best wading bird habitat
- Greatest area of emergent marsh
- Most deep water fish habitat
- Greatest diversity of benthic macroinvertebrate habitat
- Most improvement in hydrologic connectivity
- Highest potential for removal and control of invasive species

Alt 2 & Alt 3

- Greatest area of submerge and floating leaved plant communities
- Best migratory waterfowl habitat

Alt 2 V2 & Alt 3 V2

- Best breeding bird habitat

Ranking Criteria

On 3/1/2019 the Habitat Restoration Technical Team completed a ranking exercise using EPA-MED modeled data, where values were scored for each of the habitat category listed below. As part of the exercise the team assigned qualitative weights to the habitat metrics for use in evaluating the ranks when combining the metrics. Weights were based on a combination of factors that included their relationship to habitat components identified in past Mud Lake design concepts and the relative importance of the metric as a driver for achieving beneficial outcomes across all the measured values and habitat metrics.

	Breeding Bird Habitat	Wading Bird Habitat	Migratory Bird Habitat	Emergent Marsh	Submerged & Floating-Leaved Plant Community	Fish Habitat Restoration Opportunity	Benthic Macroinvertebrates	Hydrology	Non-Native Plant Management
									
Why Important	Breeding birds need safe places for building nests, incubating eggs and their young birds to develop.	Wading birds rely heavily on natural shorelines and wetland habitats including emergent marshes and wooded swamps. Wading birds consume fish, aquatic and terrestrial invertebrates, amphibians, reptiles, and crustaceans found in these shorelines and wetland areas.	Birds migrating need places to stop and re-fuel along the way that are relatively free from predators and have abundant, diverse food supplies to enable them to complete their long journeys.	Emergent marsh is a shallow-water wetland characterized by emerging vegetation. This community type occurs in areas up to 4 feet deep on gently sloping bottoms of sand, gravel or silt. Emergent plants serve as spawning habitat for fish and amphibians, shelter for a wide range of species, and as nesting habitat for birds.	Submerged and floating plants provide essential habitat for fish and aquatic wildlife. Every species of fish relies on submerged aquatic plant species for either food, spawning habitat, or shelter. In addition waterfowl feed on submerged or floating plants directly or eat the fish, macroinvertebrates, and crustaceans that live among the plants.	Fish need a range of habitat types. Each species of fish feeds on different food sources and goes through different year cycles of habitat use. Fish find cover from aerial predators in deeper water. In the heat of the summer fish seek the cooler conditions in deep water habitats. Deep water away from the river's main channel also provides winter refuge habitat for fish.	Benthic or aquatic macroinvertebrates are organism without backbones that live in the sediment and on the bottoms of lakes rivers and streams. Examples of benthic macroinvertebrates include immature forms of beetles, mayflies, caddisflies, stoneflies, and dragonflies. They are vitally important at the base of the aquatic food web.	In estuaries, water flow and the natural movement of sediments are important for maintaining high-quality shallow water habitats. The natural rise and fall of water levels due to seiche results in higher plant diversity in estuarine wetlands compared to inland wetlands.	Non-native cattails are prolific and can quickly dominate wetland plant communities. Monotypic stands of cattails reduce overall habitat value and reduce the local plant diversity.
Criteria Measured	• Increased length of edge • Increased area of emergent vegetation for feeding fledglings	• Increased length of shoreline • Increased area of submergent vegetation(approx. 0-2'). • Soft natural shoreline (as opposed to rip rap) • Continuous habitat connection	• Increased area of submerged vegetation as food source	• Increased areas of emergent vegetation • Connection with estuarine hydrologic process	• Increased area of submerged and floating leaf vegetation	• Increased area of deep water	• Increased area of submerged aquatic vegetation • Increased area of novel habitat (beta-diversity) • Total water	• Restoration of estuarine hydrology	• Increased water depth to flood out non-native cattail

Figure 6A.

Lower St. Louis River Habitat Plan Strategies Implementation Planning Worksheet for Mud Lake

PROJECT 2-8: Sheltered Bays/Shallow Wetlands – Mud Lake Hydrologic Reconnection

Background: Mud Lake is a shallow sheltered bay located on the Minnesota side of the estuary downstream of the Oliver Bridge and adjacent to the USX Superfund Site and other industrialized land. A Northern Pacific Railroad causeway bisects the bay, reducing seiche affect and habitat function in its northwest section. The causeway also reduces boat-based fishing opportunities for anglers.

Problem Statement: Habitat function and recreational opportunity has been reduced in the northwest portion of Mud Lake due to a Northern Pacific Railroad causeway.

Goals:

- Establish a more vital connection between the estuary and the wetlands north of the railroad causeway
- Enhance wetlands for migratory birds at Mud Lake
- Establish wild rice beds within wetland north of the railroad causeway

Beneficial Use Impairment(s): BUI #2 – Loss of Fish and Wildlife Populations; BUI #4 – Degradation of Benthos; BUI #6 – Excessive Loading of Sediments and Nutrients to Lake Superior; BUI #8 – Degradation of Aesthetics; and BUI #9 – Loss of Fish and Wildlife Habitat.

Priority: Medium/High
Task Duration: 2-5 years
Potential Mechanism: SLRIDT (NRDA), USX (NRDA), GLNPO, MnDNR, FMC Corps Bird and Habitat Conservation Fund, Private biological/engineering contractor, Unified Request for Proposals, North American Wetlands Conservation Fund.
Partnering Organization(s): NRDA Trustees, MnDNR, Fond du Lac
Estimated Cost: $500,000 - $750,000

Comments: Need more detail: restoration actions required. Remove slag fill. This could be part of the NRDA settlement with US Steel. NRDA Trustees could coordinate the form of this project as part of the NRDA phase of the US Steel Superfund process. More detailed analysis of potential contaminated sediments is necessary.

Special Considerations: Potential for contaminated sediments.
Accomplishments: Some initial scoping of this project has been completed through the NRDA phase of the Interlake Superfund process.
Measure(s) of Success: Increased angling recreational use.
SLRCAC Primary Contact: John Lindgren, MnDNR 218-525-0853.

Figure 7A. Mud Lake as charted in 1861

Figure 8A. Aerial Photo of Mud Lake 1961

Figure 9A. The current condition - Google Earth Image from 2017

Figure 10A. Sketch of design concept to address hydrologic connectivity (from 2013 LimnoTech report "Preliminary Restoration Elements for Mud Lake"

Figure 6: Water Circulation Restoration Concept for Discussion by AOC Coordinators

Figure 11A. Concept sketch with causeway removal and bay mouth bar restoration.

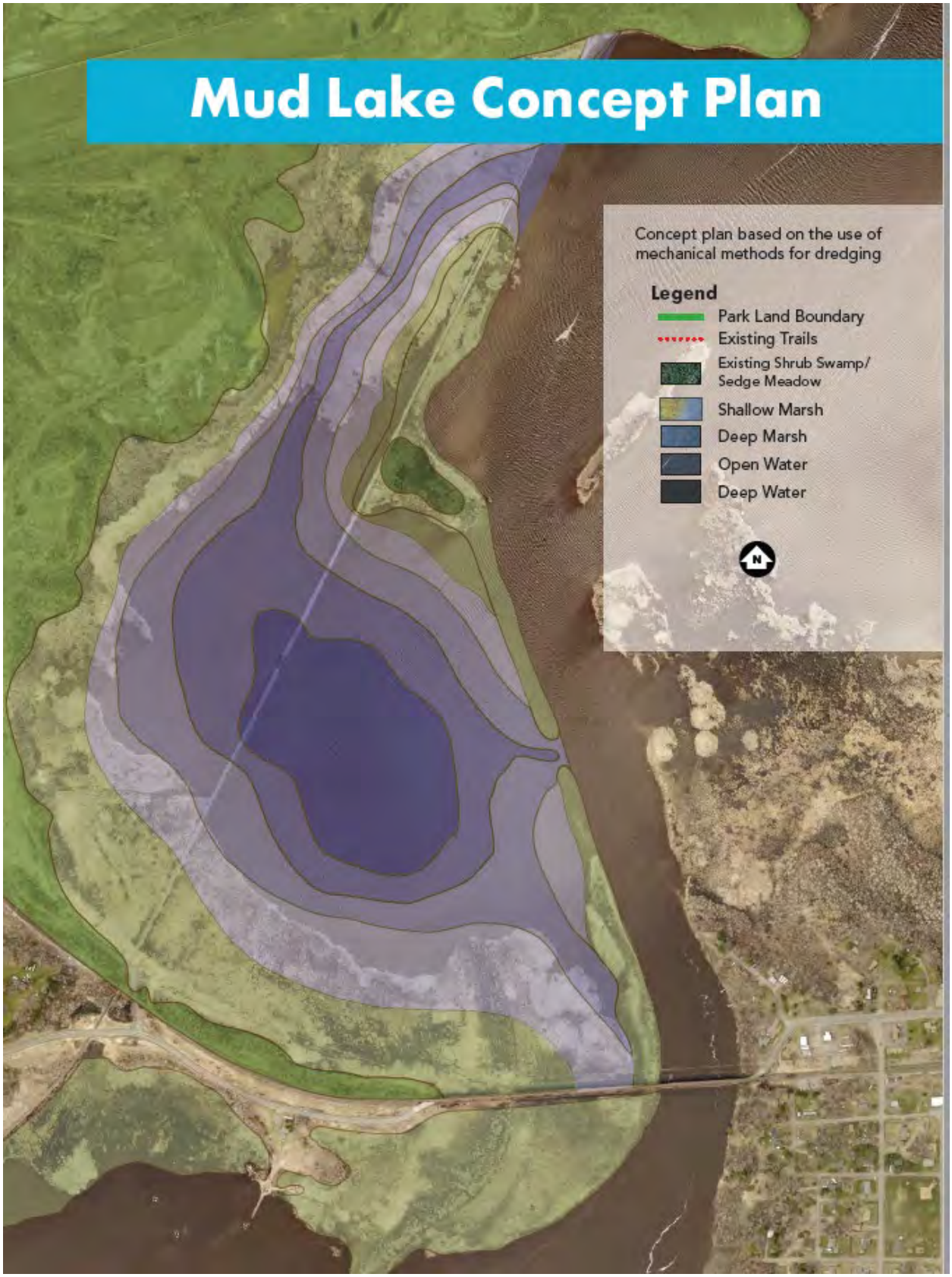

Figure 12A.

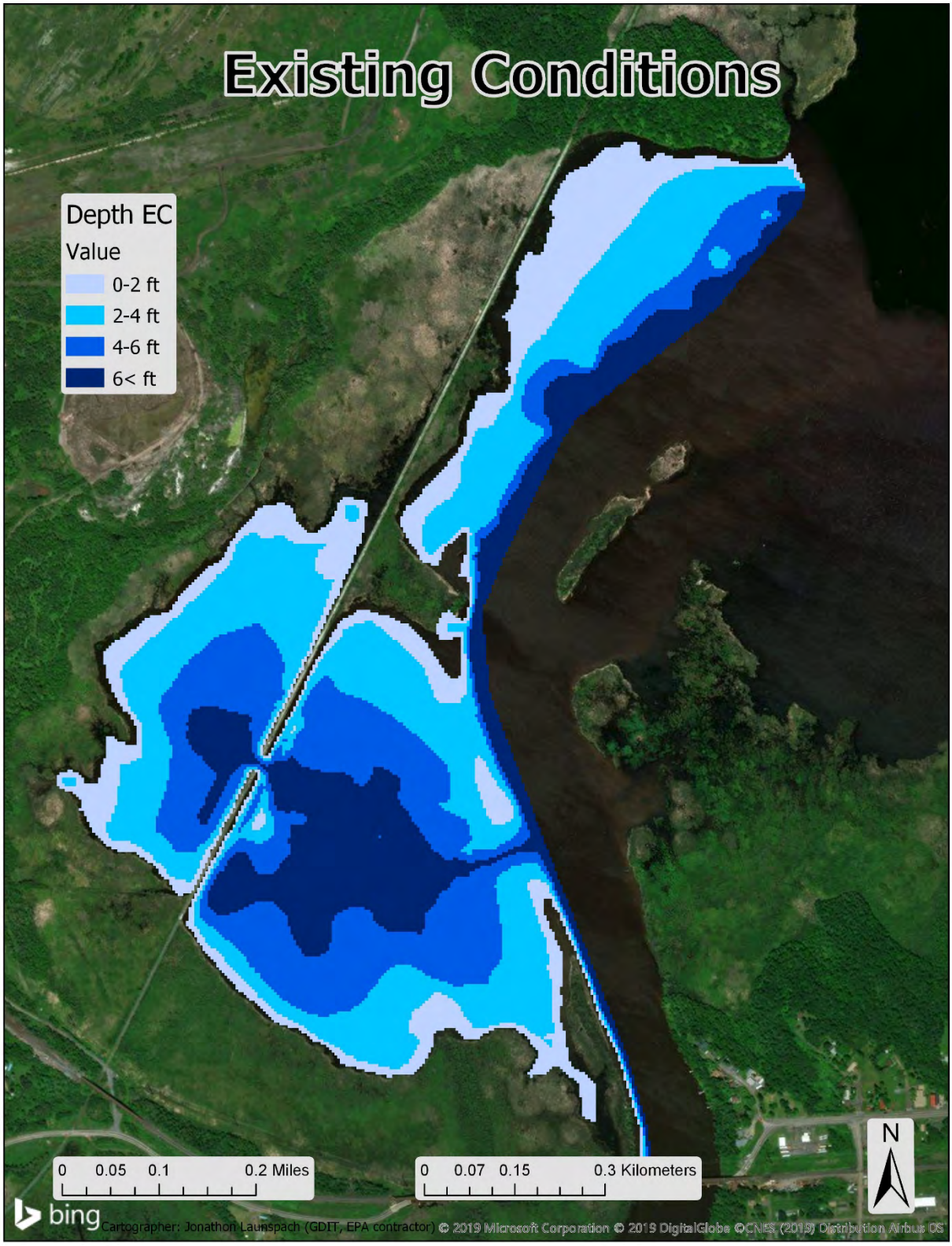
Existing Conditions
Depth EC
Value
0-2 ft
2-4 ft
4-6 ft
6< ft
0 0.05 0.1 0.2 Miles
0 0.07 0.15 0.3 Kilometers
N
bing
Cartographer: Jonathon Laumspach (GDIT, EPA contractor) © 2019 Microsoft Corporation © 2019 DigitalGlobe ©CNES (2019) Distribution Airbus DS

Figure 13A.

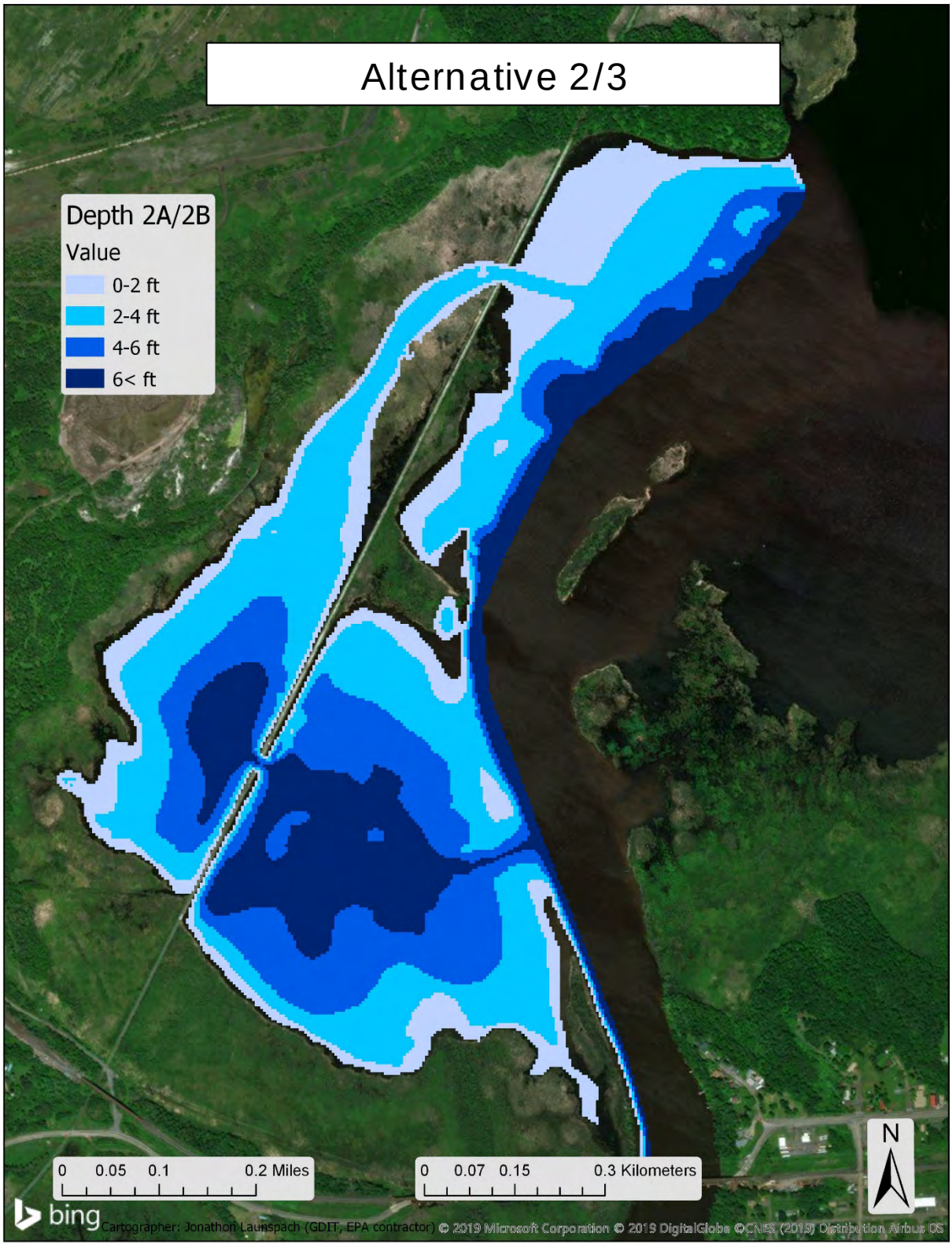
Alternative 2/3
Depth 2A/2B
Value
0-2 ft
2-4 ft
4-6 ft
6< ft
0 0.05 0.1 0.2 Miles
0 0.07 0.15 0.3 Kilometers
N
bing
Cartographer: Jonathon Launspach (GDIT, EPA contractor) © 2019 Microsoft Corporation © 2019 DigitalGlobe ©CNES (2019) Distribution Airbus DS

Figure 14A.

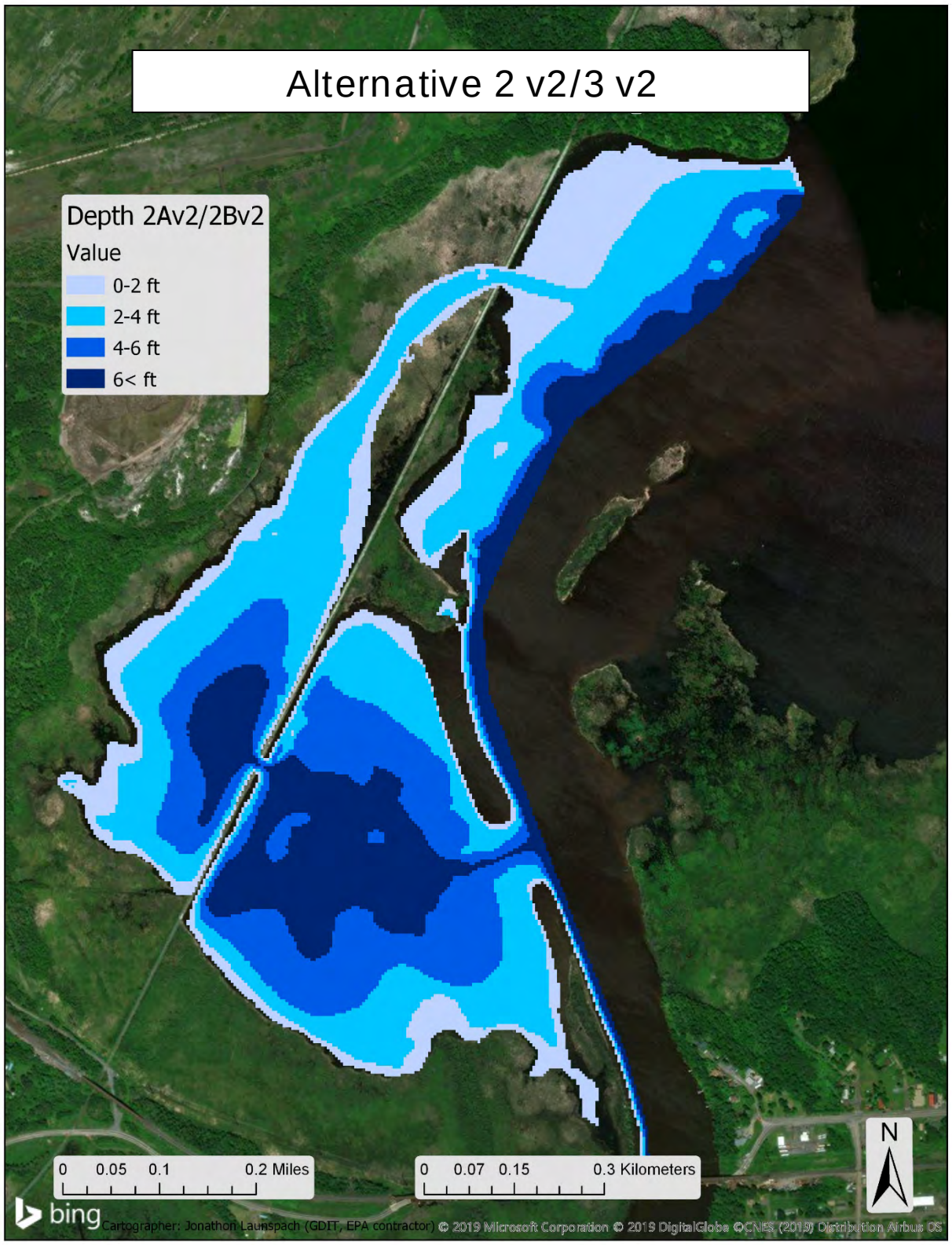
Alternative 2 v2/3 v2
Depth 2Av2/2Bv2
Value
0-2 ft
2-4 ft
4-6 ft
6< ft
0 0.05 0.1 0.2 Miles
0 0.07 0.15 0.3 Kilometers
N
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Figure 15A.

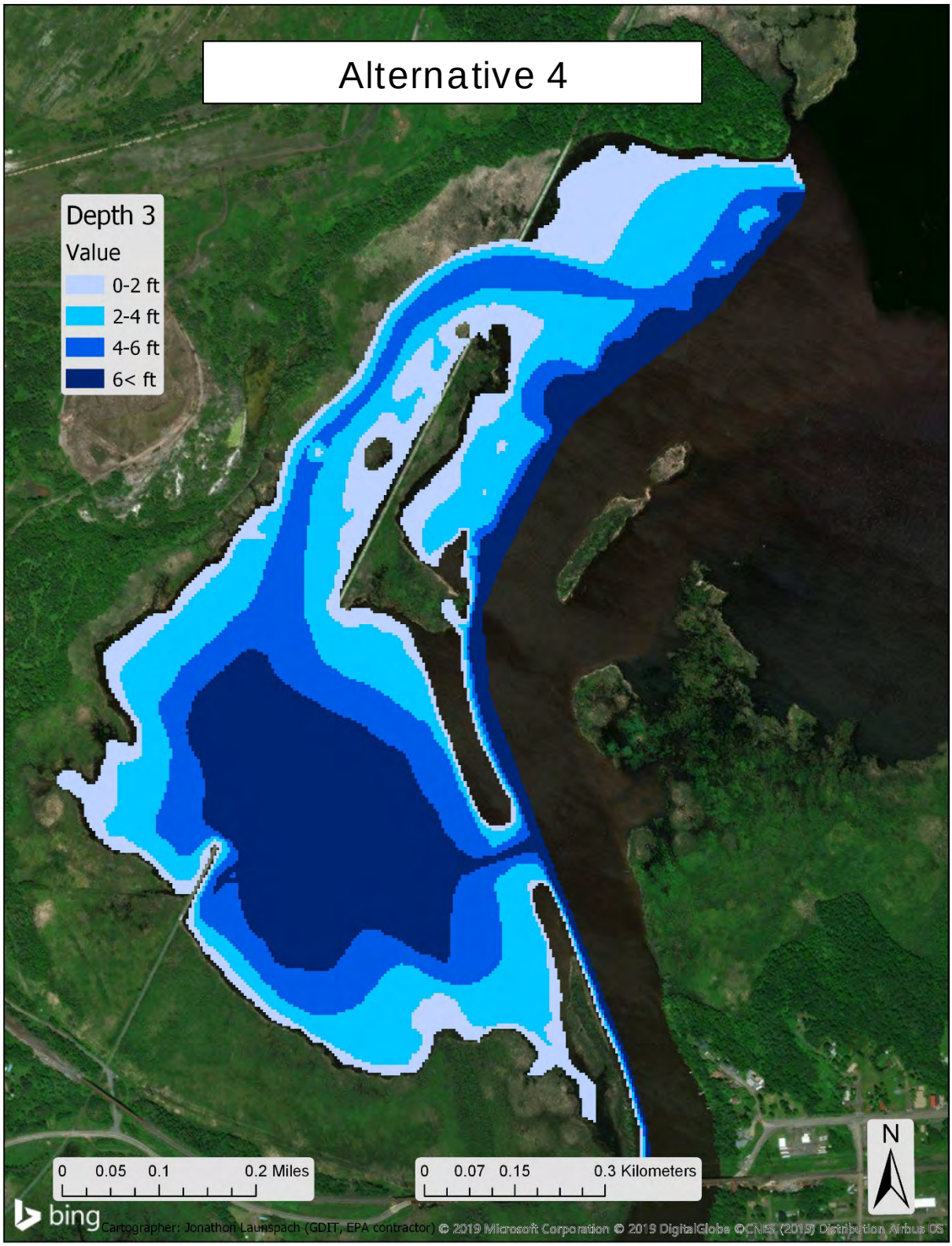
Alternative 4
Depth 3
Value
0-2 ft
2-4 ft
4-6 ft
6< ft
0 0.05 0.1 0.2 Miles
0 0.07 0.15 0.3 Kilometers
N
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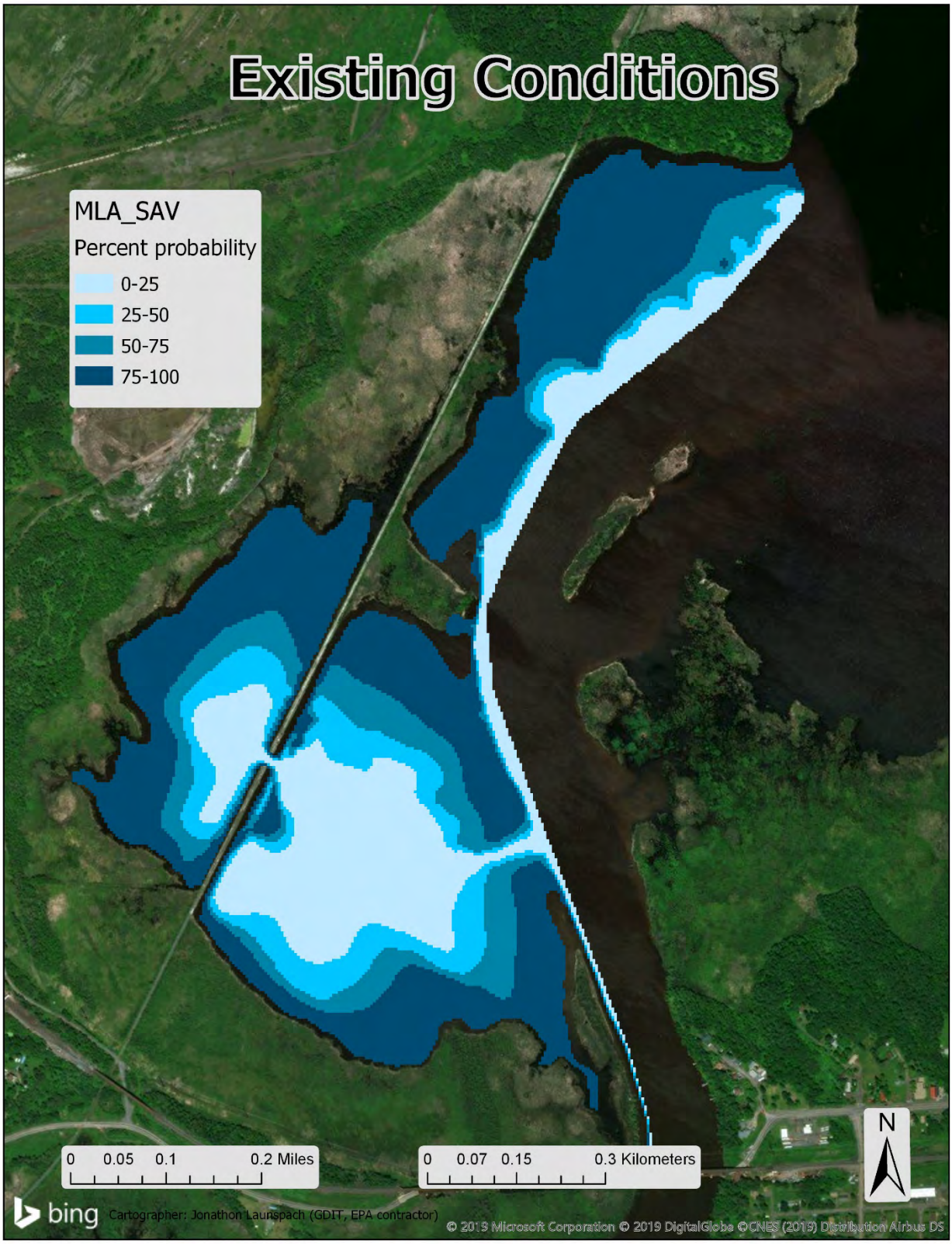
Figure 16A.


Existing Conditions
MLA_SAV
Percent probability
0-25
25-50
50-75
75-100
0 0.05 0.1 0.2 Miles
0 0.07 0.15 0.3 Kilometers
N
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Cartographer: Jonathon Launspach (GDIT, EPA contractor)
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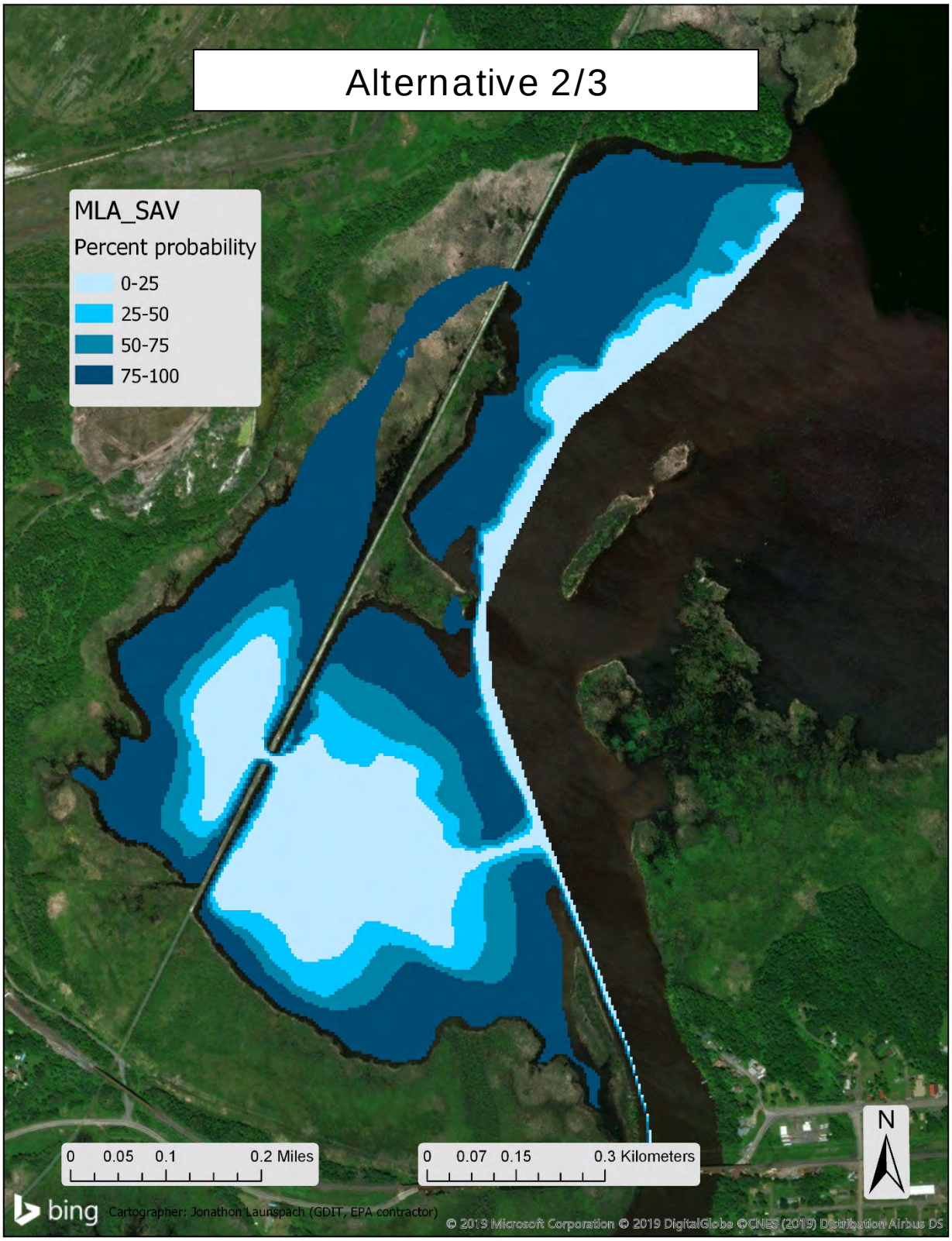
Figure 17A.


Alternative 2/3
MLA_SAV
Percent probability
0-25
25-50
50-75
75-100
0 0.05 0.1 0.2 Miles
0 0.07 0.15 0.3 Kilometers
N
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Cartographer: Jonathon Launspach (GDIT, EPA contractor)
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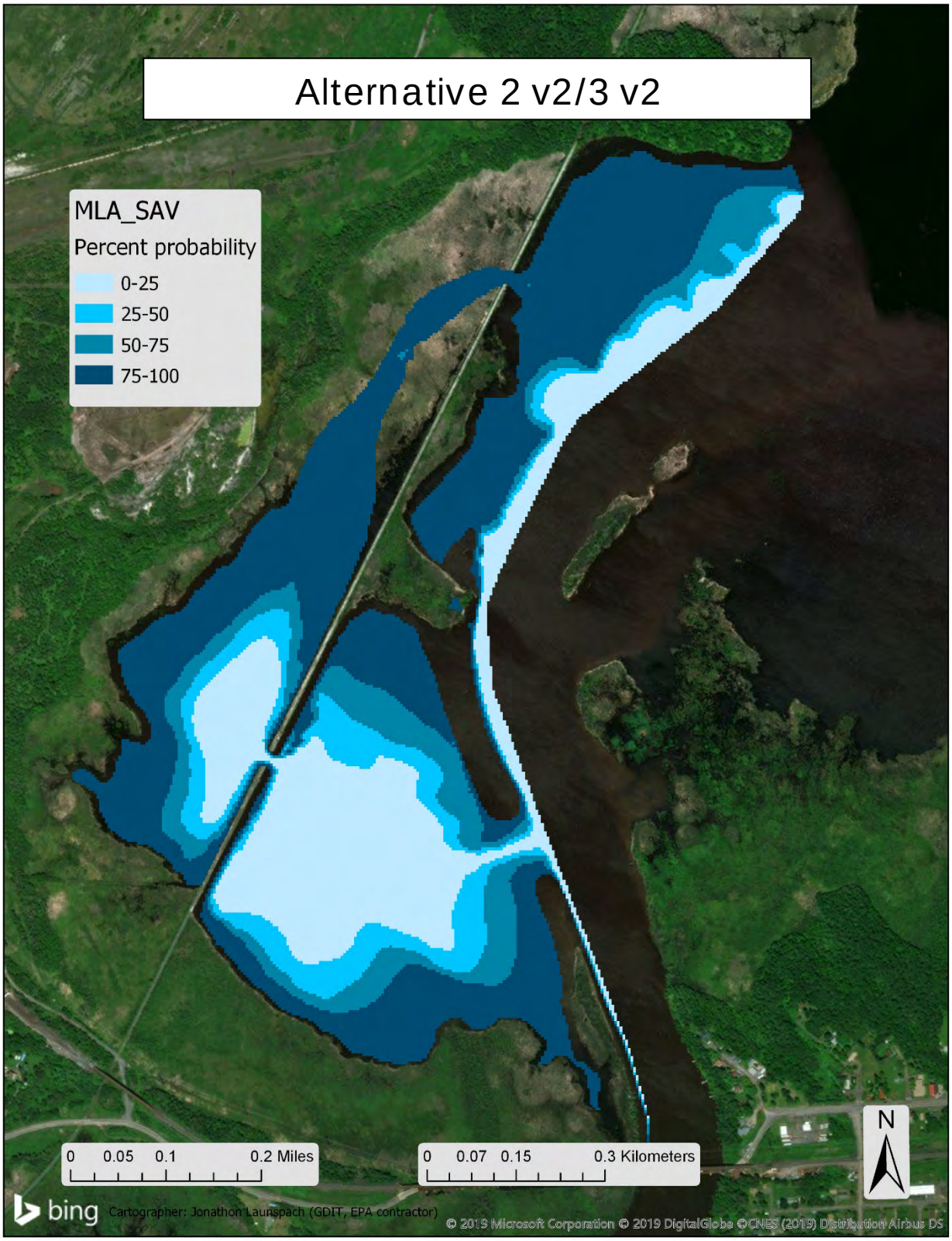
Figure 18A.


Alternative 2 v2/3 v2
MLA_SAV
Percent probability
0-25
25-50
50-75
75-100
0 0.05 0.1 0.2 Miles
0 0.07 0.15 0.3 Kilometers
N
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Cartographer: Jonathon Launspach (GDIT, EPA contractor)
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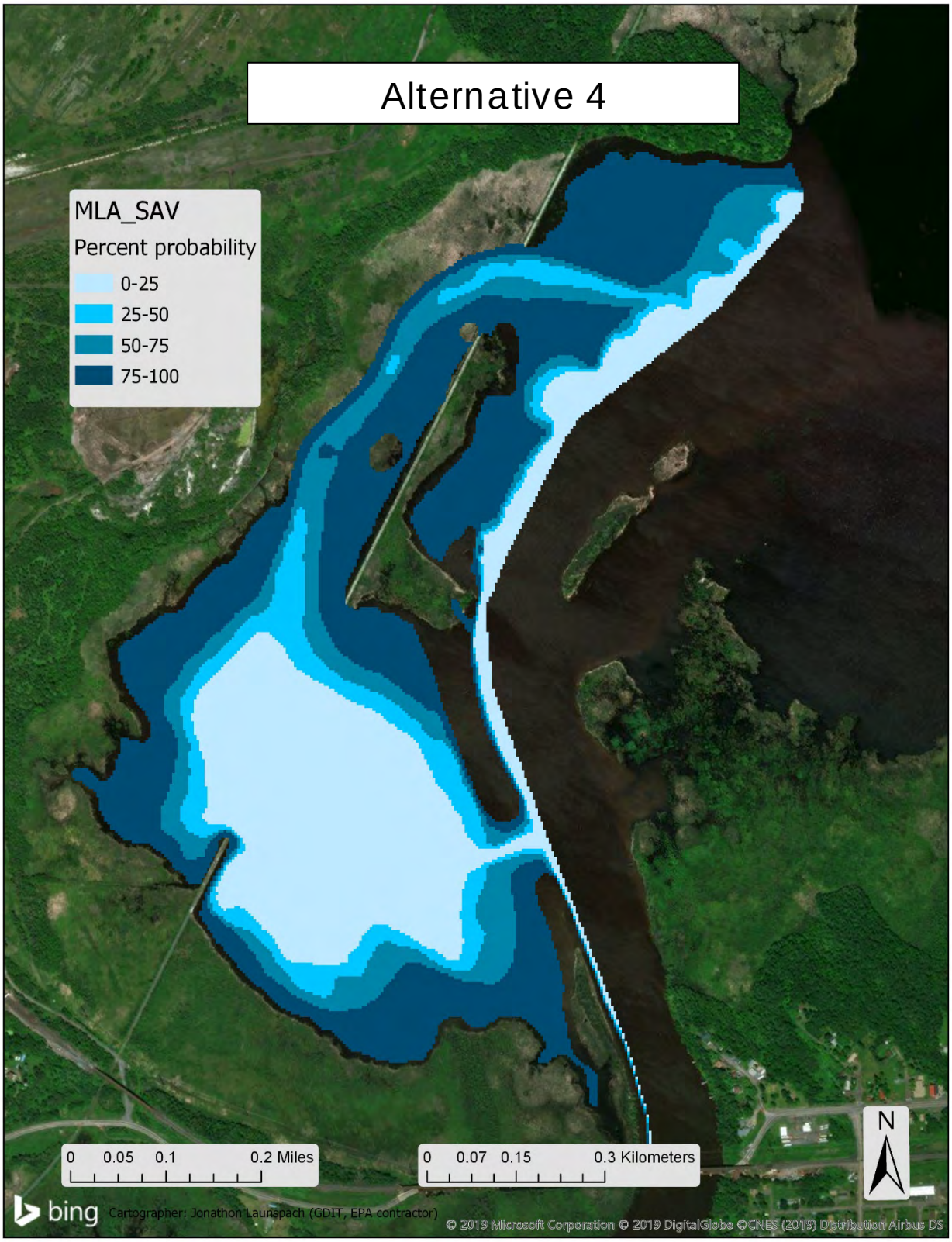
Figure 19A.


Alternative 4
MLA_SAV
Percent probability
0-25
25-50
50-75
75-100
0 0.05 0.1 0.2 Miles
0 0.07 0.15 0.3 Kilometers
N
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Cartographer: Jonathon Launspach (GDIT, EPA contractor)
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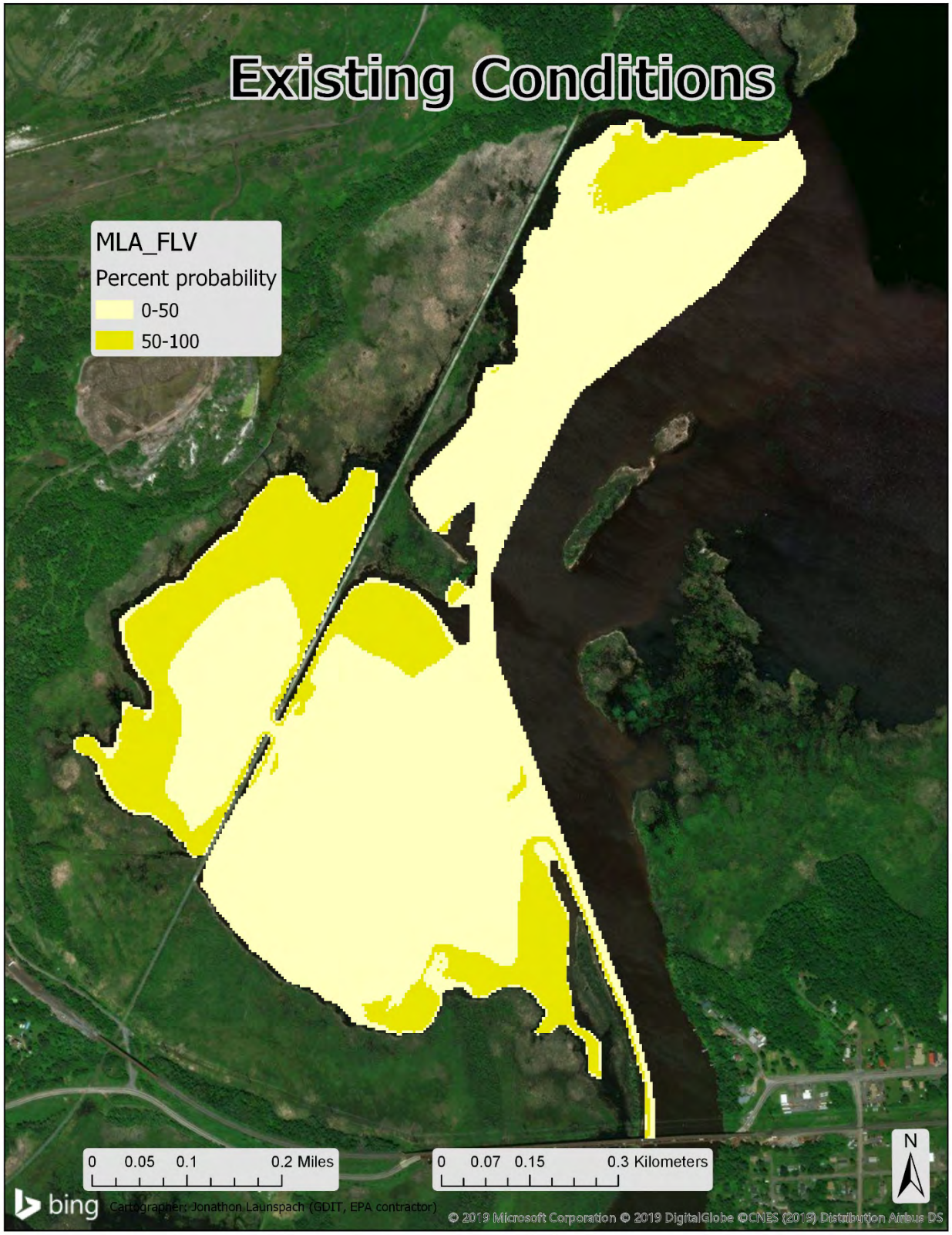
Figure 20A.


Existing Conditions
MLA_FLV
Percent probability
0-50
50-100
0 0.05 0.1 0.2 Miles
0 0.07 0.15 0.3 Kilometers
N
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Cartographer: Jonathon Launspach (GDIT, EPA contractor)
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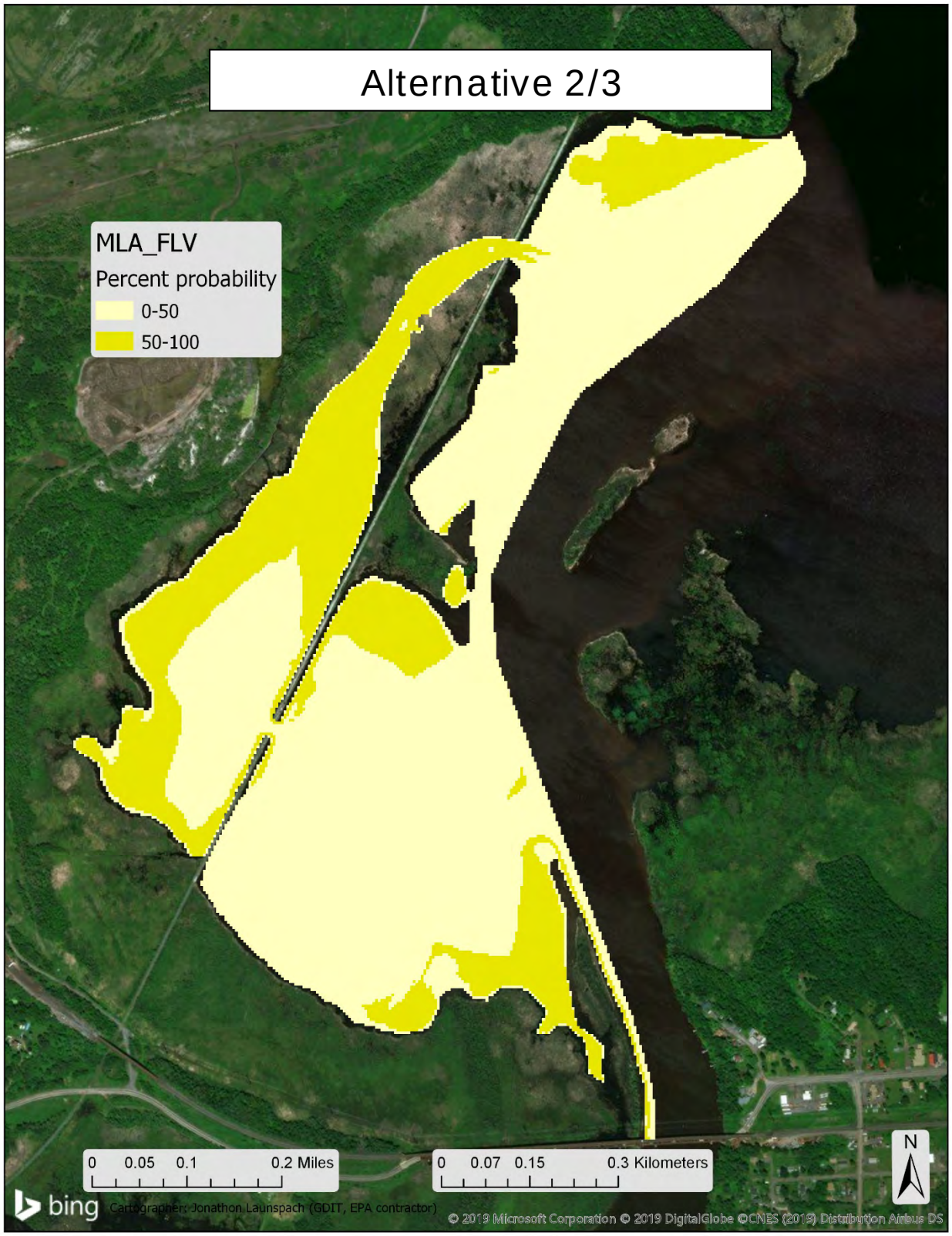
Figure 21A.


Alternative 2/3
MLA_FLV
Percent probability
0-50
50-100
0 0.05 0.1 0.2 Miles
0 0.07 0.15 0.3 Kilometers
N
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Cartographer: Jonathon Launspach (GDIT, EPA contractor)
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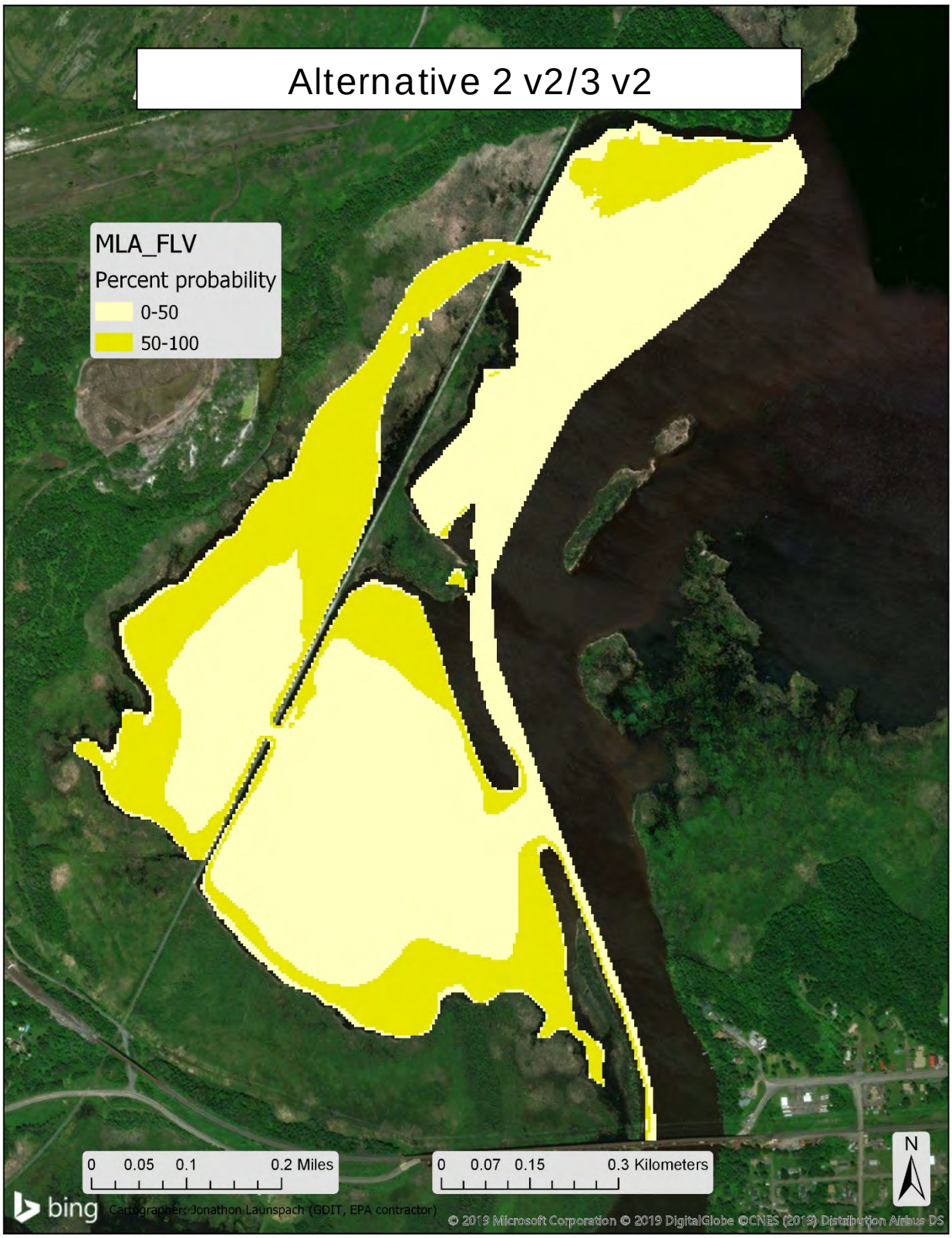
Figure 22A.


Alternative 2 v2/3 v2
MLA_FLV
Percent probability
0-50
50-100
0 0.05 0.1 0.2 Miles
0 0.07 0.15 0.3 Kilometers
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Cartographer: Jonathon Launspach (GDIT, EPA contractor)
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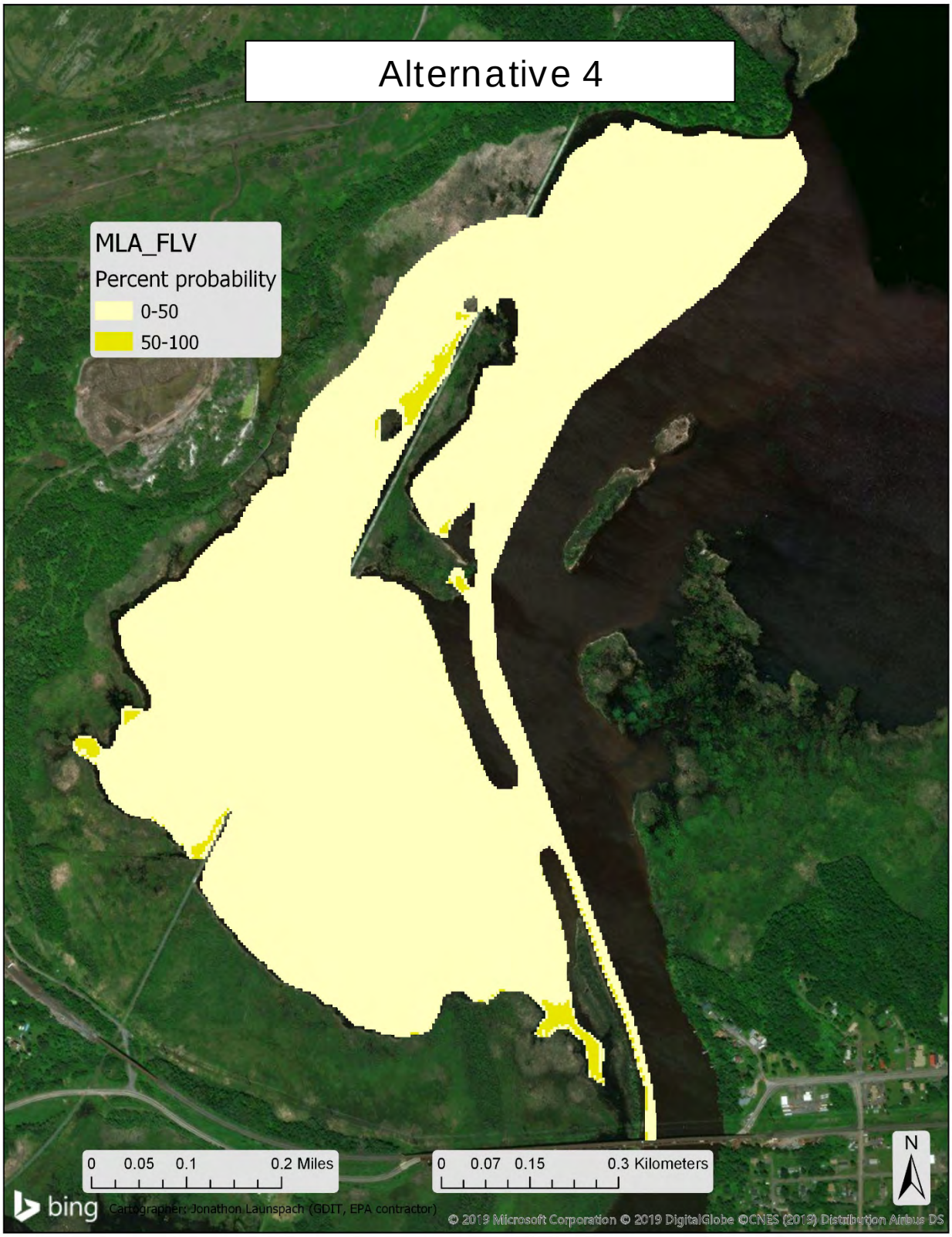
Figure 23A.


Alternative 4
MLA_FLV
Percent probability
0-50
50-100
0 0.05 0.1 0.2 Miles
0 0.07 0.15 0.3 Kilometers
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Cartographer: Jonathon Launspach (GDIT, EPA contractor)
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Figure 24A.


Existing Conditions
MLA_Sheltered_ Bays
Percentiles
25
50
0 0.05 0.1 0.2 Miles
0 0.07 0.15 0.3 Kilometers
N
bing
Cartographer: Jonathon Launspach (GDIT, EPA contractor)
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Figure 25A.


Alternative 2/3
MLA_Sheltered_ Bays
Percentiles
25
50
0 0.05 0.1 0.2 Miles
0 0.07 0.15 0.3 Kilometers
N
bing
Cartographer: Jonathon Launspach (GDIT, EPA contractor)
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Figure 26A.


Alternative 2 v2/3 v2
MLA_Sheltered_ Bays
Percentiles
25
50
0 0.05 0.1 0.2 Miles
0 0.07 0.15 0.3 Kilometers
N
bing
Cartographer: Jonathon Launspach (GDIT, EPA contractor)
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Figure 27A.


Alternative 4
MLA_Sheltered_ Bays
Percentiles
25
50
0 0.05 0.1 0.2 Miles
0 0.07 0.15 0.3 Kilometers
N
bing
Cartographer: Jonathon Launspach (GDIT, EPA contractor)
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technical BRIEF
INNOVATIVE RESEARCH FOR A SUSTAINABLE FUTURE

Ecosystem Services Analysis for Habitat Restoration Alternatives at Mud Lake on the St. Louis River, Minnesota

The purpose of this analysis was to compare the ecosystem services associated with each of the six different alternatives selected by the City of Duluth, Minnesota, for the restoration of habitat at Mud Lake on the St. Louis River. Specifically, the alternatives were analyzed to map indicators related to ecosystem services at Mud Lake (i.e., the service providing areas) and to estimate the area or extent associated with each service. The ecosystem service metrics were either suggested by local stakeholders or were based on metrics described by Angradi et al. (2016; Table 1). The area or extent of each service was then tabulated for each alternative (Table2).

Ecosystem services analyzed for Mud Lake included both supporting and final ecosystem services. Supporting services provide an indirect human benefit such as fish habitat or wetlands; final services are outputs of nature that provide a direct benefit such as fish or wild rice (Boyd and Banzhaf 2007). The final services provided by Mud Lake benefit a variety of people, including recreational, subsistence, and commercial beneficiaries.

Supporting ecosystem services

The analysis shows that there are service trade-offs among (Table 2). Alternative 3 (remove causeway) provides the greatest opportunity for increasing deep water habitat and restoring connectivity between the east and west sides of Mud Lake. Deep water habitat that does not freeze to the bottom or become hypoxic during winter is important for fish overwintering in the river. Hydrologic connectivity is important to maintain coastal wetland vegetation communities, and their associated fauna (Albert et al. 2005). Because they increase connectivity, Alternatives 2Av2 and 2Bv2 provide the greatest opportunity for providing coastal wetland sheltered habitat, which is important for a wide diversity of wildlife and fish species (Niemi et al. 2007).

Alternatives 2A and 2B provide slightly more area of dense submerged aquatic vegetation (SAV), though the absolute difference in area among alternatives is small (ca. 11 acres). Areas with dense SAV are favored as nursery habitat for many fish species and provide food and cover for a variety of fish and wildlife (Cvetkovic and Chow-Fraser 2011).

The current condition (i.e., keeping Mud Lake as is) has the least supporting service providing area among the alternative analyzed.

Final ecosystem services

As with supporting ecosystem services, trade-off among alternatives was apparent for final ecosystem services (Table2). For both power and human-powered boating, Alternative 3 provided the greatest area because removal of the causeway and the creation of the northern channel allowed for the greatest boatable area. It also provided, along with Alternative 2B and 2Bv2, the most area for shore fishing due to the number of designated shore-based fishing areas included in this alternative.

Alternatives 2A and 2B provided the greatest amount of Northern Pike and Muskellunge (Esocid fishes) spawning habitat owing to the extensive shallow, moderately-vegetated habitat preferred by these fish for spawning, created by these alternatives. However, it should be noted that the absolute difference among alternatives (ca. 10 acres) for this service is small relative to the project area.

Alternative 3 (current conditions) provides the least habitat area for semi-aquatic mammals because removing the causeway decreases the length of riparian shoreline available. Again, it should be noted that the absolute difference in shoreline area (ca. 15 acres) is small relative to the project area.

Limitations

A hydrodynamic model of current velocities and wetland water residence time was not available to include in the analysis of the various alternatives. All aquatic vegetation models assumed that current velocity will be like conditions in other sheltered bays in the river, such that establishment of vegetation is likely. Low current velocity could promote aggradation of wetlands, whereas high water velocity could scour existing wetland habitat. Also, upland vegetation plans were not included with the alternatives. Whether the adjacent riparian corridor includes shrubs or mature upland trees will influence availability of habitat for wildlife, waterfowl, and migratory birds. All models were based on a water elevation of 601.1 ft, and therefore habitat values do not reflect high water conditions (ca. 603 ft) or low water conditions (ca. 599 ft).

Summary

The largest differences among the Mud Lake restoration alternatives are for overwinter fish habitat (highest for Alternative 3 because it includes the most open water dredging) and boating and fishing (also highest for Alternative 3 because the amount of aquatic habit is increased by causeway removal). On the other hand, the amount of sheltered bay habitat, shoreline, and floating leaved vegetation is lower for Alternative 3 than for the other alternatives.

This analysis is based on area or extent of services and all the services are assumed here to have equal per area benefit quality or "value." The true relative value of the different services (e.g., fishing vs. wetland habitat vs. wildlife) will likely vary among human beneficiaries.

Without reliable estimates of relative valuation for each service, it may be useful to consider the scarcity of the relevant Mud Lake habitats in the context of the entire St. Louis River Estuary ecosystem.

References

Albert, D.A., D.A. Wilcox, J. Ingram, T.A. Thomson (2005) Hydrogeomorphic classification for Great Lakes coastal wetlands. J. Great Lakes Res. 31 (S1):129–146.

Angradi, T.R., Pearson, M.S., Bolgrien, D.W., Bellinger, B.J., Starry, M.A. and Reschke, C., 2013. Predicting submerged aquatic vegetation cover and occurrence in a Lake Superior estuary. J. Great Lakes Res., *39*, 536-546.

Angradi, T.R. (2014) A predictive model for floating leaf vegetation in the St. Louis River Estuary. EPA report for Minnesota Pollution Control Agency. 16p.

Angradi, T.R., D.W. Bolgrien, J.L. Launspach, B.J. Bellinger, M.A. Starry, J.C. Hoffman, M.E. Sierszen, A.S. Trebitz, T.P. Hollenhorst. (2016) Mapping ecosystem services of a Great Lakes estuary can support local decision-making. J. Great Lakes Res 42:717-727.

Boyd, J., S. Banzhaf (2007) What are ecosystem services? The need for standardized environmental accounting units. Ecol. Econ. 63:616-626.

Cvetkovik, M., P. Chow-Fraser (2011) Use of ecological indicators to assess the quality of Great Lakes coastal wetlands. Ecol. Indic. 11:1609–1622.

Niemi, G.J., J.R. Kelly, N.P. Danz (2007) Environmental Indicators for the coastal region of the North American Great Lakes: introduction and prospectus. J. Great Lakes Res. 33(SI3):1–12.

Contacts

Joel Hoffman, US EPA Mid-Continent Ecology Division, 6201 Congdon Blvd, Duluth, MN 55803
hoffman.joel@epa.gov

Ted Angradi, US EPA Mid-Continent Ecology Division, 6201 Congdon Blvd, Duluth, MN 55803
angradi.theodore@epa.gov

Table 1. Ecosystem services analyzed for Mud Lake, including beneficiaries, associated subcategories, and ecosystem service source

Ecosystem Service (units)	Beneficiary	Subcategories	Description	Source
River greater than 6 feet deep (acres)	Indirect (Habitat)	Off-channel deep habitat	Potential for overwintering fish habitat	Suggested by stakeholders
Highly-sheltered bay (acres)	Indirect (Habitat)	Back bay habitat	Relative amount of highly-sheltered aquatic habitat relative to reference bays*	Angradi et al. 2016
Moderately-sheltered bay (acres)	Indirect (Habitat)	Back bay habitat	Relative amount of moderately-sheltered aquatic habitat relative to reference bays*	Angradi et al. 2016
Fill in public waters (lineal feet)	Indirect (Habitat)	Loss of connectivity	Distance of artificial structures within project area	Suggested by stakeholders
Protected shoreline (feet)	Indirect (Habitat)	Loss of connectivity	Distance of protected (rip rap) within project area	Suggested by stakeholders
75-100 percent probability of vegetation occurrence (acres)	Indirect (Habitat)	Submerged aquatic vegetation (SAV)	Area with dense SAV (e.g., eelgrass, coontail) cover based on predictive models	Angradi et al. 2013
25-75 percent probability of vegetation occurrence (acres)	Indirect (Habitat)	Submerged aquatic vegetation (SAV)	Area with moderate SAV cover based on predictive models	Angradi et al. 2013
50-100 percent probability of vegetation occurrence (acres)	Indirect (Habitat)	Floating leaf vegetation (FLV)	Area with moderate to dense FLV vegetation cover based on predictive models	Angradi 2014
Power boating (acres)	Recreational	Boaters, Anglers, Experiencers and Viewers	Area of a suitable depth for power boating (motorized)	Angradi et al. 2016
Human-power boating (acres)	Recreational	Boaters, Anglers, Experiencers and Viewers	Area of a suitable depth for canoes and kayaks	Angradi et al. 2016
Esocid spawning (acres)	Recreational, Subsistence	Anglers	Area of habitat suitable for Northern Pike and Muskellunge spawning	Angradi et al. 2016
Designated shore fishing (acres)	Recreational, Subsistence	Anglers, Food extractors, Food subsisters	Area designated and suitable for shore-fishing	Angradi et al. 2016
Boat/ice fishing (acres)	Recreational, Subsistence	Anglers, Food extractors, Food subsisters	Area of a depth suitable for ice- or boat-based fishing+	Angradi et al. 2016
Trapping (acres)	Recreational, Commercial	Hunters, Pelt Extractors	Area of habitat suitable for semi-aquatic mammals (e.g., river otters, beavers)	Angradi et al. 2016

* Sheltered bay morphology is based on the relative exposure index (REI) and is measured as the number of acres below the mean relative exposure index (Angradi et al. 2016) for reference bays including Duck Hunter Bay, Radio Tower Bay, Stryker Bay, and Rask Bay.

+ Dependent on accessibility of western Mud Lake

Table 2. Ecosystem services providing areas and extent for Mud Lake. The cells are color coded to help indicate relative change from current condition among alternatives: yellow = less than a 30% change from current conditions; blue = at least a 30% increase in area or extent from current conditions; pink = at least a 30% decrease from current conditions. For fill, a decrease in length is a positive change because it increases aquatic habitat connectivity. A decrease in protected shoreline increases connectivity but decreases shoreline habitat.

Ecosystem Service (units)	Current Condition (Alt 1)	Retain Rail, North Opening (Alt 2A)	Rail to Trail, North Opening (Alt 2B)	Retain Rail, North Opening, Bay Mouth Bar (Alt 2Av2)	Rail to Trail, North Opening, Bay Mouth Bar (Alt 2Bv2)	Remove Causeway, North Opening, Bay Mouth Bar (Alt 3)
River greater than 6 feet deep (acres)	33.2	37.1	37.1	36.5	36.5	51.1
Highly-sheltered bay (acres)	23.4	26.5	26.5	30.9	30.9	9.8
Moderately-sheltered bay (acres)	29.8	28.2	28.2	42.6	42.6	21.0
Fill in public waters (lineal feet)	4894	4782	4782	4782	4782	3067
Protected shoreline (lineal feet)	4379	4107	4107	4107	4107	1302
75-100 percent probability of SAV occurrence (acres)	75.9	84.3	84.3	79.3	79.3	73.3
25-75 percent probability of SAV occurrence (acres)	42.7	40.5	40.5	40.4	40.4	46.2
50-100 percent probability (acres) of FLV occurrence (acres)	42.2	51.2	51.2	57.9	57.9	2.9
Power boating (acres)	75.9	75.9	75.9	75.9	75.9	110.9
Human-power boating (acres)	129.7	129.7	173.4	129.7	173.4	184.0
Esocid spawning (acres)	75.7	84.0	84.0	78.9	78.9	72.9
Designated shore fishing (acres)	0.0	0.0	1.0	0.0	1.0	1.2
Boat/ice fishing (acres)	144.6	153.5	153.5	149.2	149.2	160.6
Trapping (acres)	133.6	124.7	124.7	128.2	128.2	118.7

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Mud Lake Future Alternatives Community Values and Health Impact Analysis

The goal of this analysis was to utilize elements of the systematic and science-based health impact assessment (HIA) methodology to conduct a community values analysis to compare the health impacts and ecosystem services associated with four different alternatives selected by the City of Duluth, Minnesota, for the restoration of habitat at Mud Lake on the St. Louis River.

This approach was chosen because the process objectively and transparently considers the best-available qualitative and quantitative evidence to identify potential direct and indirect health impacts and help assess the trade-offs inherent in the decision process.

Ecosystem Services

Ecosystem services are products of nature that when used, consumed, or experienced by people provide some sort of direct benefit (Boyd and Banzhaf 2007). In conjunction with this analysis, a separate ecosystem services analysis was conducted to compare the amount of ecosystem services associated with the alternatives under consideration (see Angradi and Hoffman 2019).

Health Impact Assessment

Community health and well-being are a product of one's environment and the social and environmental conditions that exist there. These social and environmental determinants of health (i.e., factors or conditions that can directly or indirectly influence human health) include access to public services and infrastructure; adequate living and working conditions; and social, economic, and political factors (Figure 1).

Figure 1. Determinants of health, from Human Impact Partners (2011)

HIA is a science-based approach that considers input from stakeholders and uses a variety of analytical tools and methods to determine the potential effects of a proposed project on the health of a population. An HIA is neutral to the decision result; its purpose is to advocate for health and wellness through the consideration of potential health impacts.

The HIA process is a systematic, six-step process that includes screening, scoping, assessment, recommendations, reporting, and monitoring and evaluation (Human Impact Partners 2011; National Research Council 2011).

Screening for an HIA

Decision context. The design alternatives focus on Mud Lake; however, the site is connected to overlapping decision contexts, including the:

- Comprehensive approach to the St. Louis River Corridor
- Options for extending the Western Waterfront Trail from its current terminus to Chambers Grove Park
- Initiatives to improve options for outdoor recreation and create or enhance regional amenities
- Other plans, including:
  - St. Louis River Water Trail
  - Duluth Natural Areas Plan
- City of Duluth Comprehensive Plan
  - Green space
  - Economic development
  - Housing
- St. Louis River Area of Concern
- Habitat restoration plans

Decision alternatives. The City of Duluth identified six potential alternatives for Mud Lake[1]:

- Alternative 1 (Alt 1) – Causeway retained in current state for rail use
- Alternative 2 (Alt 2) – Causeway retained for rail with a southern opening and a new northern opening to optimize water flow. Trail located on the mainland.
    - Alternative 2 v2 (Alt 2 v2) –Causeway retained for rail with a southern opening and a new northern opening to optimize water flow, with an added levee. Trail located on the mainland. The alternative was considered for habitat metrics only.
- Alternative 3 (Alt 3) – Causeway retained for trail with a southern opening and a new northern opening to optimize water flow.
    - Alternative 3 v2 (Alt 3 v2) –Causeway retained for trail with a southern opening and a new northern opening to optimize water flow, with an added levee. The alternative was considered for habitat metrics only.
- Alternative 4 (Alt 4) – Causeway eliminated to maximize water flow, vestiges retained on ends for public fishing, and trail located on the mainland.

These alternatives focus on the section of the rail through Mud Lake, from Boat House Point to Boy Scout Landing.

Feasibility and Value of an HIA

EPA's Mid-Continent Ecology Division (MED) evaluated whether an HIA was feasible and would add value to the project. It was decided that elements of an HIA could be used to scope the problem, identify the social and environmental determinants of health and populations potentially impacted by the alternatives, and assess the impact of the decision alternatives on health, but not all six steps of the HIA process would be conducted.

To facilitate the analysis, the research team made several assumptions:

- It is feasible to remediate and restore Mud Lake to a standard that would allow people to safely use the area.
- The rail will continue to operate from their station near the Lake Superior Zoo to Boat House Point.
- If left in place, the railroad would continue to run and maintain the causeway and tracks to a working condition that meets operational standards.
- The City of Duluth would adequately maintain any infrastructure or features built as a result of the Western Waterfront Trail extension.

Scoping the Problem: Community Values, Pathways of Impact, and Impacted Populations

The scoping phase of the analysis included identifying the social and environmental determinants of health most important to the community, the pathways through which the decision could impact health, and the impacted populations.

Social and environmental determinants of health. A stakeholder meeting was held on March 4, 2019 at the Goodfellowship Community Center in the Morgan Park neighborhood to identify the social and environmental determinants of health most valued by the community. Twenty-nine people attended the meeting representing environmental nonprofit organizations, community groups, natural resource agencies, and businesses.

The comments collected through stakeholder input exercises were analyzed to identify what services Mud Lake provides to the participants and what Mud Lake means to them (Table 1). Several potential Mud Lake user groups were identified that were not in attendance at the meeting, including organized outdoor recreation groups. It was important to identify the values of this group of users because they too will be impacted by the City's decision.

To fill this gap, a content analysis was conducted of Duluth news articles related to outdoor recreation (Table 2).

Pathways of Impact. The dimensions identified as significant to the community represent three distinct pathways that were analyzed to understand how changes at Mud Lake will impact health (USEPA 2019):

- Social and Cultural
- Water Quality and Habitat
- Recreation, Aesthetics, and Engagement with Nature

[1] In the original stakeholder consultation exercise, there were six alternatives which were numbered differently. This reflects the current numbering and list of alternatives. The current (old) alternatives are: Alternative 1 (same); Alternative 2 (2A/2Av2); Alternative 3 (2B/2Bv2); Alternative 4 (Alternative 3).

Impacted populations. The populations that will be impacted by decisions at Mud Lake are diverse and include residents, organizations, and other groups:

- Current users of Mud Lake area
- Train passengers
- Morgan Park residents
- Gary-New Duluth residents
- Indigenous community
- Businesses
- Others (i.e., user groups, including outdoor recreation groups)

A baseline health assessment for the impacted populations indicates that these populations have distinct connections to Mud Lake.

Current users. Some users volunteer to run a passenger train that travels to the Mud Lake area, while others forage, trap, fish and use it as a natural area. Mud Lake serves as a site for personal and organizational identity and has historical and cultural value. Furthermore, Mud Lake is a site important for social cohesion and historical preservation.

The rail on the causeway is a remnant of the Lake Superior and Mississippi Railroad (LSMR), which was completed in 1870 and provided the first transportation link between St. Paul and Duluth. It served as an important economic link to expand the mining, fishing, manufacturing, and timber industries. The rail is currently preserved by a nonprofit that provides historical information about the surrounding neighborhoods.

Train passengers. According to a brief analysis of social media about the LSMR passenger train, the train is valued because of the experience it provides. There was an emphasis on the scenic views, natural experience, and the dedication of the volunteers. Riders also noted the affordability and accessibility of the train.

Morgan Park and Gary-New Duluth residents. These are two of the neighborhoods surrounding the Mud Lake area that would be impacted by decisions made at the site. The health status of residents in the Morgan Park and Gary-New Duluth neighborhoods was examined in comparison to the health of residents in the City of Duluth as a whole:

- Residents in the adjacent neighborhoods report better well-being behaviors (i.e., >7 hours of sleep and leisure time activity) than the City of Duluth as a whole;
- Poverty in Morgan Park is higher than the City of Duluth, but in Gary-New Duluth is lower than the rate for the City as a whole;
- Rates of diabetes, high blood pressure, and obesity are higher in these neighborhoods than rates for the City of Duluth (CDC 2016).

Indigenous community. The St. Louis River estuary is the ancestral home of the Anishinaabe people. Spirit Island, just downstream from Mud Lake, is the sixth stopping place on their westward migration. It was the first place they encountered the food that grows on water – wild rice (Fond du Lac Band of Lake Superior Chippewa 2018). The St. Louis River is also an important place to exercise treaty rights (1854 Treaty Authority 2017). Maple sugar camps and burial grounds are found on Spirit Mountain, the hill that runs parallel to the St. Louis River.

> *The large hill that extends for several miles along the far western end of Duluth was called Manitouahgebik (Spirit Mountain) by the Ojibwe Indians. They believed that the Great Spirit resided within the forest at the top of Spirit Mountain (Turnstone Historical Research 2015, p. 49).*

Businesses and other user groups. The scoping exercise revealed that other potentially impacted groups not present at the meeting include hikers, bikers, berry pickers, and nearby businesses. Moreover, this site was identified to be important for the extension of the Western Waterfront Trail and development of Duluth as an outdoor recreation destination and economic engine (Cities of Duluth and Superior 2017). A media analysis was conducted to better understand the general values of the outdoor recreation group (Table 2).

The outdoor recreation groups valued access to open spaces to pursue recreation and valued Duluth as a "real" outdoor recreation city (Chandler 2017). Social cohesion for this group of people means joining together to advocate in the City's decision process to expand recreation in the city. The values analysis for this group suggests their interest is less about their relationship to a particular place, but generally access to green space.

Assessing the Health Impacts of the Decision Alternatives

A rapid analysis of the impact of each alternative on the three dimensions of health determinants – Social and Cultural; Water Quality and Habitat; and Recreation, Aesthetics, and Engagement with Nature – was conducted. Table 3 summarizes the connection between these dimensions and health; the full literature reviews documenting these connections can be found in the

background research for USEPA (2019), which was conducted in Duluth as well.

Impacts of the alternatives on Water Quality and Habitat are documented in Angradi and Hoffman (2019). Table 4 summarizes the potential impacts of the alternatives on the Social, Cultural, and Recreation dimensions and on health overall.

Discussion and Summary

The proposed project has the potential to impact the health of several populations – current users of Mud Lake and the LSMR, other user groups and the outdoor recreation community, Morgan Park and Gary-New Duluth neighborhoods, and the indigenous community. The Anishinaabe are the first inhabitants of the Mud Lake area. At the same time, this site has contributed greatly over the last 150 years to the current wealth and economic base of Duluth. There is a shared and linked history to this site and those around it; thus, all populations will be affected by the decision about the future of Mud Lake.

In addition to outdoor recreational opportunities, all alternatives have the potential to offer social, historical, and cultural opportunities (e.g., spaces for socialization, social capital through rail and/or trail volunteer opportunities, maintaining the sense of place and history, cultural expression, etc.). These social and cultural dimensions can result in more positive perceptions of health, particularly mental health and stress (Kitchen et al. 2012).

Improving cultural or historical amenities can contribute to community development. However, there are cautions, as some enhancements of cultural amenities and green spaces might lead to gentrification (Gunay and Dokmeci 2012; Smiley et al. 2016) and unequal distribution of benefits (Foster et al. 2016). Policy interventions and work with community groups is likely required to prevent displacement of low-income residents (Ellen 2018). Generally, inclusivity and shared benefits of environmental renewal are created through inclusive processes (Daigneau 2015).

This analysis demonstrates that every alternative produces a different mix of ecosystem services and benefits. The realization of positive health outcomes from the ecosystem services produced is less certain because it is dependent on individual behaviors and details not contained in the alternatives (e.g., the presence of gathering spaces to encourage diverse communities to utilize natural spaces). Moreover, given uncertainty regarding water flow through Mud Lake under the various alternatives (Angradi and Hoffman 2019), the habitat and water quality improvements may not be extensive enough for the Anishinaabe people to adequately pursue treaty rights of fishing, hunting, and gathering.

The only group positively impacted in almost all alternatives is the outdoor recreation community. But, several alternatives have the potential to result in negative impacts to other groups, such as those associated with the LSMR and indigenous groups.

Recognizing that there is an attachment to place, as well as claims on the space by multiple groups, it would positively impact the mental health and social cohesion of all communities to participate in collaborative decision-making to ensure that health impacts are maximized for all communities. The City has already employed such a model in other St. Louis River Corridor projects (e.g., Quarry Park).

Limitations

This assessment is a rapid analysis of how the proposed Mud Lake future alternatives might impact the health of the community. The assessment is based on identifying the valued determinants of health and describing how those determinants will subsequently change for different populations.

The abbreviated timeframe limited the amount of community consultation. In a complete health impact assessment, considerable effort would be devoted to reaching out to community members to ensure participation. Outreach to the community was limited to a single stakeholder meeting. Despite this limitation, other impacted populations were identified and considered in the assessment through media analysis.

There were other limitations:

- Although the project alternatives do have impacts to personal and community economics, the project team did not have the time or resources to conduct an independent assessment of economic impacts. Given this limitation, we did not address several publicly-available economic studies about western Duluth, the train, or surveys conducted in relation to the expansion of the Western Waterfront Trail.
- We were unable to determine the feasibility of berry picking/jelly-making and dog training as potential uses in the future alternatives. It is plausible that the site

could continue to be used for these activities, but there is not enough information available in the alternatives to determine how the infrastructure and vegetative changes could impact the suitability of the site for these uses.

References

Angradi, T. and Hoffman, J., 2019. Mud Lake Futures Alternatives Ecosystem Services Analysis. Technical Brief. United States Environmental Protection Agency. EPA/600/F19/043

Anton, C.E. and Lawrence, C., 2014. Home is where the heart is: The effect of place of residence on place attachment and community participation. *Journal of Environmental Psychology*, *40*, pp.451-461.

Boyd, J., S. Banzhaf, 2007. What are ecosystem services? The need for standardized environmental accounting units. Ecol. Econ. 63:616-626.

Casiday, R., Kinsman, E., Fisher, C. and Bambra, C., 2008. Volunteering and health: what impact does it really have. London: Volunteering England, 9(3), pp.1-13.

Centers for Disease Control and Prevention (CDC), National Center for Chronic Disease Prevention and Health Promotion, Division of Population Health, 2016. 500 Cities Project Data [online]. https://www.cdc.gov/500cities/index.htm.

Chandler, E. 2017. Hansi Johnson on Duluth: This is Real. Northern Wilds Magazine. [online]. http://northernwilds.com/hansi-johnson-duluth/.

Cities of Duluth, MN and Superior, WI, 2017. St. Louis River Estuary National Water Trail Master Plan. [online]. http://www.duluthmn.gov/media/542220/final-water-trail-master-plan.pdf.

Daigneau, E., 2015. Just Green Enough. Governing. [online]. https://www.governing.com/topics/transportation-infrastructure/gov-green-gentrification-series.html.

1854 Treaty Authority. 2017. The Right to Hunt and Fish Theirin: Understanding Chippewa Treaty Rights in Minnesota's 1854 Ceded Territory. Report [online]. http://www.1854treatyauthority.org/images/The-Right-to-Hunt-and-Fish-Therein.final.pdf.

Ellen, I.G., 2018. "What would it take... For cities experiencing gentrification pressures to foster inclusion rather than replacement?" Harvard Joint Center for Housing Studies Symposium. Can Gentrification Be Inclusive? April 2017. Cambridge, MA. [online]. https://www.jchs.harvard.edu/sites/default/files/a_shared_future_can_gentrification_be_inclusive_0.pdf.

Fond du Lake Band of Lake Superior Chippewa. 2018. Expanding the Narrative of Tribal Health: The Effects of Wild Rice Water Quality Rule Changes on Tribal Health. Report. [online]. http://www.fdlrez.com/RM/downloads/WQSHIA.pdf.

Foster, N., Grodach, C. and Murdoch III, J., 2016. Neighborhood diversity, economic health, and the role of the arts. Journal of Urban Affairs, 38(5), pp.623-642.

Gunay, Z. and Dokmeci, V., 2012. Culture-led regeneration of Istanbul waterfront: Golden horn cultural valley project. Cities, 29(4), pp.213-222.

Human Impact Partners. 2011. A Health Impact Assessment Toolkit: Handbook for Conducting HIA, 3rd Edition. Oakland, CA: Human Impact Partners. February 2011.

Jenkinson, C.E., Dickens, A.P., Jones, K., Thompson-Coon, J., Taylor, R.S., Rogers, M., Bambra, C.L., Lang, I. and Richards, S.H., 2013. Is volunteering a public health intervention? A systematic review and meta-analysis of the health and survival of volunteers. *BMC public health*, *13*(1), p.773.

Kitchen, P., Williams, A. and Chowhan, J., 2012. Sense of community belonging and health in Canada: A regional analysis. *Social Indicators Research*, *107*(1), pp.103-126.

National Research Council, 2011. *Improving Health in the United States: The Role of Health Impact Assessment.* Washington, DC: National Academies Press.

Smiley, K.T., Rushing, W. and Scott, M., 2016. Behind a bicycling boom: Governance, cultural change and place character in Memphis, Tennessee. *Urban Studies*, *53*(1), pp.193-209.

Turnstone Historical Research. An Ethnographic Study of the Indigenous Contributions to the City of Duluth. A report to the Indigenous Commission. July 2015. [online]. http://www.duluthmn.gov/media/461501/Duluth-Ethnographic-Study-Final-July-2015.pdf.

USEPA, 2019. Kingsbury Bay and Grassy Point: A Health Impact Assessment. Report. (in preparation).

Contacts

Katie Williams, USEPA Mid-Continent Ecology Division
williams.kathleen@epa.gov

Joel Hoffman, USEPA Mid-Continent Ecology Division
hoffman.joel@epa.gov

Table 1. Dimensions or Themes Identified Through the Analysis of Input and Discussion Gathered at the Stakeholder Meeting on March 4, 2019

(The numbers in parenthesis indicate the number of comments received related to each theme. Many comments reflected more than one theme, so results should be interpreted as representing a pattern of the relative importance or significance of each theme for those stakeholders who participated.)

Social and Cultural (157)
• Identity and Place Attachment (Personal, social, and organizational attachment to Mud Lake. Most comments coded to this node than any other.)
• Governance (Focus on decisions made by the City of Duluth about Mud Lake. Participants thought changes would impact the resource.)
• Participation and Self-Determination (Desire to participate in the decision; advocating for a win-win or keep the causeway and build a trail)
• Social Cohesion (Collective action taken by community; the collective "we")
Water Quality and Habitat (80)
• Biophysical Environment (Observation and appreciation of wildlife; physical environment; movement of water)
• Safety (Perception of contamination; fear removing causeway would release contamination into the river)
Recreation, Aesthetics and Engagement with Nature (48)
• Accessibility (Train provides access to Mud Lake)
• Sustainability (Current uses of the natural features of Mud Lake: berry picking, kayaking, fishing)
• Parks and Trails (Causeway currently serves as an unofficial trail)
• Aesthetics (Beauty associated with Mud Lake; appreciation for Mud Lake as it is)

Table 2. Dimensions or Themes Identified Through an Analysis of Duluth Media Articles About the Organization of Stakeholder Groups and Development of an Outdoor Recreation Economy in Duluth

(The articles examined are related to the outdoor economy, not Mud Lake specifically. The numbers in parenthesis indicate the number of statements found related to each theme. Results should be interpreted as representing a pattern of the relative importance or significance of each theme.)

Social and Cultural (237)
• Identity and Place Attachment (Duluth as a "real" outdoor recreation city; the outdoor recreation economy; down-to-earth; enjoy outdoors)
• Participation and Self-Determination (Actions and measures taken to influence decision-making; voice opinion on topics)
• Social Cohesion (Groups or individuals coming together to advocate for a decision)
• Governance (Decisions made by City of Duluth that impact the city and natural spaces)
Water Quality and Habitat (5)
• Biophysical Environment (Presence of green space in the environment; Feasibility of new mountain bike trails)
Recreation, Aesthetics, and Engagement with Nature (62)
• Parks and Trails (Parks trails and outdoor recreation; future outdoor recreation spots)

- Accessibility (Barriers to overcome: demographics, geographic proximity, income, ability, or other structural barrier)
- Sustainability ("To make citizens healthier and happier")

Table 3. Description of Assessment Dimensions and How They Impact Health (Modified from USEPA, 2019)

Determinant of Health/Pathway	Connection to Health
Social and Cultural	Parks and green spaces provide space for socialization, which builds social capital and cohesion (the formation of social bonds and connections), spiritual reflection, and cultural resource use. The ability of the public to enjoy parks and green spaces in these capacities has been shown to improve health and well-being and reduce stress. The opportunity for public input during the planning of these spaces can also build social capital and lead to improved community health. Parks and green spaces are an important site for volunteering which can provide mental health benefits, including self-rated health, mental health, life satisfaction, social interaction, healthy behaviors and coping ability (Casiday et al. 2008; Jenkinson et al. 2013). Furthermore, people who are attached to a local area will volunteer to preserve it (Anton and Lawrence 2014).
Water Quality and Habitat	Improving water, sediment and habitat quality can potentially improve nutrition and decrease disease incidence in anglers, as well as decrease illness and skin and eye ailments in those who have contact with the water, including waders. However, at this time, it is uncertain how legacy contamination might impact fish, wildlife, or human health. Broadly, improving water quality can reduce stress, as well as improve social capital and recreational opportunities. Subsequent to improvements in water, sediment, and habitat quality, designated recreational amenities such as boat launches, canoe landings, and fishing piers can contribute to health by providing safe access to the river for the community.
Recreation, Aesthetics, and Engagement with Nature	Access to outdoor recreation areas is an important component to individual and community mental and physical well-being. Parks provide opportunities for physical activity, which is known to reduce stress, cardiovascular disease, obesity, and other chronic disease. Activities such as fishing can further impact health through consumption of the catch. Parks and aesthetically-pleasing green spaces also promote engagement with nature, which has been shown to reduce stress and improve mental and overall health and well-being. The value of these spaces can be a product of on-going contact with them.

Table 4. Health Impact Characterization Table Summarizing Potential Impacts to Health for Each Future Alternative

Alternative	Recreational Access	Uses	Description of Impacts	Impacts to Health
Alternative 1: No Change	• LSMR passenger train • Causeway is an informal trail[2] • Parking lot (on private land)	• Bird and wildlife watching • Kayaking[3] • Jelly making (berry picking) • Dog training • Fishing • Trapping	This is the baseline alternative. This alternative would result in no change to the health determinants. Current users will continue to enjoy running or riding the railroad, using the rail as an informal trail, and other uses (bird and wildlife watching, kayaking, fishing, etc.). This alternative is the least protective for water quality, which will impact indigenous communities who wish to exercise treaty rights.	The LSMR would continue to run and provide opportunities for social cohesion to its volunteers and cultural experiences for passengers. Existing opportunities for recreation and engagement with nature would continue for recreational users, bird and wildlife watchers, anglers, and others, although formal recreational access would remain limited. While these aspects would have a ***positive*** impact on health for current users, the habitat would remain impacted and could have potential ***negative*** impacts to birds, fish, and other wildlife (USEPA, 2019), as well as impact indigenous communities' rights.
Alternative 2 and Alternative 2 v2[4]: Retain Rail	• LSMR passenger train • Trail on land • Parking lot • Designated outlook • New bridge	• Bird and wildlife watching • Kayaking[3] • Fishing • Trapping • Hiking and biking	Current users will continue to enjoy running or riding the railroad and other uses (bird and wildlife watching, kayaking, fishing, etc.). These alternatives have the potential to improve habitat, which might positively impact bird and wildlife watchers, and anglers. The alternatives will also positively impact hikers and bikers through the addition of a trail on land.	These alternatives would have a ***positive*** impact on health for most impacted populations. The LSMR would continue to run and provide opportunities for social cohesion to its volunteers and cultural experiences for passengers. There would be potential improvements in water habitat and quality. Existing opportunities for recreation and engagement with nature would be preserved for recreational users, bird and wildlife watchers, and anglers, and additional recreational opportunities could be added through trail use.

[2] An informal trail is by definition an unsanctioned use. We include it here not as an endorsement, but as input offered by participants.
[3] Kayaking is limited. Stakeholders reported portaging over the tracks into West Mud Lake.
[4] The levees in the v2 alternatives provide more sheltered bay habitat (Angradi and Hoffman 2019).

Alternative	Recreational Access	Uses	Description of Impacts	Impacts to Health
Alternative 3 and Alternative 3 v2[4]: Rail to Trail	• Trail on causeway • Parking lot • Designated outlook • New bridges with kayak and canoe access • Two new shore fishing structures	• Bird and wildlife watching • Kayaking with canoe launch • Fishing • Trapping • Hiking and biking	These alternatives will result in great loss for the railroad organization in terms of social cohesion and sense of purpose and a loss for rail riders. These alternatives have the potential to improve habitat, which might positively impact bird and wildlife watchers and anglers. These alternatives will also positively impact hikers and bikers through the addition of a trail on land, and the addition of a tall bridge would provide improved access for kayakers and canoers to all of Mud Lake.	These alternatives would have a ***positive*** impact on health for recreational users, bird and wildlife watchers, and anglers through trail use and other added amenities, as well as potential improvements in water habitat and quality. They would have a ***negative*** impact on the social cohesion and place attachment for the LSMR, the neighborhood that identifies with the train, and train passengers.
Alternative 4: Remove Causeway	• Trail on land • Parking lot • Designated outlook • Fishing on causeway remnants and new fishing pier • Canoe launch and kayak landing	• Bird and wildlife watching • Canoeing and kayaking • Fishing • Trapping • Hiking and biking • Power boating	This alternative will result in great loss for the railroad organization in terms of social cohesion and sense of purpose. This alternative has the potential to improve habitat more than the other alternatives through the creation of a high-quality coastal wetland, which will likely positively impact indigenous communities who wish to exercise treaty rights, along with brid and wildlife watchers and anglers. The alternative will also positively impact hikers and bikers through the addition of the trail.	This alternative would have a ***positive*** impact on recreational users given the trail and other amenities; the Anishinaabe people as the bay is returned closer to its original state to allow for the exercise of treaty rights; anglers through more shore and boat fishing access; and boaters through more deep water. This alternative would have a ***negative*** impact on the social cohesion and place attachment for the LSMR, the neighborhood that identifies with the train, and train passengers, and bird watchers who will lose highly-sheltered shallow-water habitat and the access to the river that the causeway provides.

Cost Estimation for Alternative Analysis

As requested by the City of Duluth an estimate of potential costs was developed for the design and construction and annual maintenance based on a 20 year annualized cost of three alternative scenarios. The cost estimates were based on the conceptual designs developed through multi-disciplinary workshops. Costs provided are intended for planning and decision-making purposes. The alternatives are summarized as follows:

- **Alternative 1 (ALT 1)** – *Causeway retained in current state for rail use*
- **Alternative 2 (ALT 2) –** T*rail on the mainland and causeway retained for rail with southern opening and a new northern opening to optimize water flow*
- **Alternative 3 (ALT 3) –** *Causeway retained for trail with a southern opening and a new northern opening to optimize water flow*
- **Alternative 4 (ALT 4) –** *Causeway eliminated to maximize water flow, vestiges retained on ends for public fishing, trail on mainland, river levee features restored.*

Once the estimate was developed for each alternative a range of costs was applied to the total cost for each concept. The cost range was developed using recommended guidelines outlined in the AACE International Cost Estimate Classification System. The cost classification system applies a standard estimation range to attempt to account for unknowns during each phase of the design process. A concept screening level Class 5 estimate was applied to the cost estimate.

Quantities for each alternatives were based on the concept level design plans and assumed design details. The estimated costs provided are based on preliminary design features and could vary extensively depending on site conditions, final design details, material availability, site access, construction timing, and numerous other variables.
Assumptions for each alternative cost estimate was established by the City and have been detailed in the table and table notes below.

Figure 1D. Alternative Concept Cost Summary

Construction Costs

Alternative Concept	Base Total	AACE Accuracy Range				
		+100%	+30%	-20%	-50%	Range Average
1 - Retain Current Rail	**$1,469,300**	$2,938,600	$1,910,100	$1,175,400	$734,700	$1,689,700
2 - Upland Trail & Rail	**$3,602,200**	$7,204,400	$4,682,900	$2,881,800	$1,801,100	$4,142,600
3 - Rail to Trail	**$3,590,500**	$7,181,000	$4,667,700	$2,872,400	$1,795,300	$4,129,100
4 - Causeway Eliminated	**$1,979,600**	$3,959,200	$2,573,500	$1,583,700	$989,800	$2,276,600

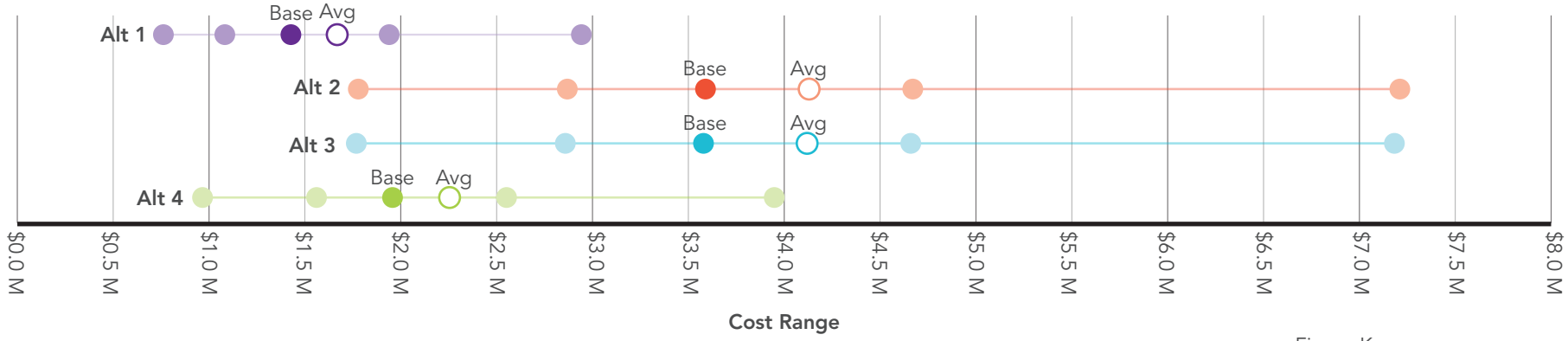
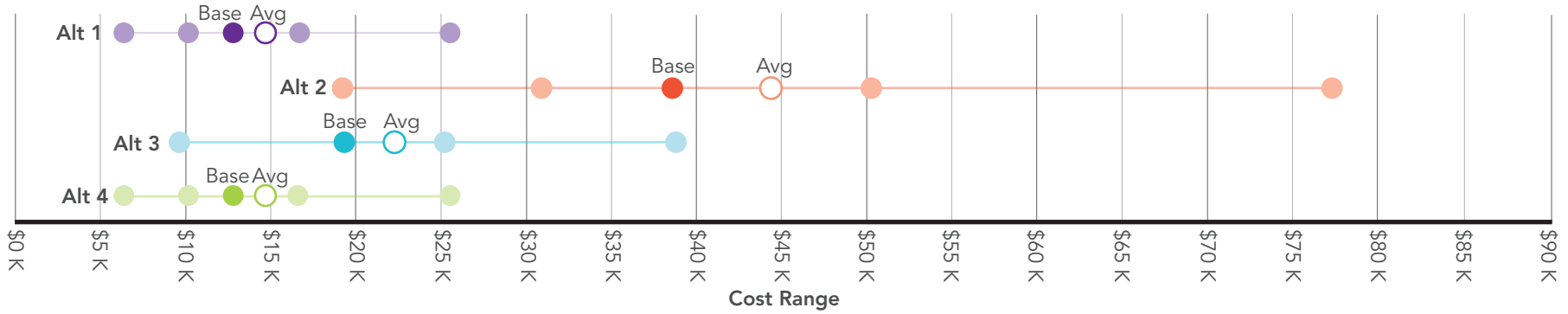


Figure Key
- Base Cost Estimate
- AACE Range Average
- AACE Screening Range

Annual Maintenance Cost (20 year annualized cost)

Alternative Concept	Base Total	AACE Accuracy Range				
		+100%	+30%	-20%	-50%	Range Average
1 - Retain Current Rail	**$38,600**	$77,200	$50,200	$30,900	$19,300	$44,400
2 - Upland Trail & Rail	**$38,600**	$77,200	$50,200	$30,900	$19,300	$44,400
3 - Rail to Trail	**$19,400**	$38,800	$25,200	$15,500	$9,700	$22,300
4 - Causeway Eliminated	**$12,800**	$25,600	$16,600	$10,200	$6,400	$14,700



Appendix A: Mud Lake - Alternatives Analysis Cost Estimation

High Level Cost Estimate for Alternative Concepts

Alternative 1- Causeway Retention in Current State for Rail Use

Construction

Item Category	Cost	
Mobilization[1]	$60,000	
Erosion Control[24]	$52,150	
Safety and Traffic Control Measures	$15,000	
Misc. Removal & Demolition (vegetation, debris, etc.)	$7,000	
Rail Road Tie Replacement[9]	$87,800	
Rip Rap Reinforcement (Along Causeway)	$943,600	
Vegetation Restoration	$6,500	
Contingency (10%)[11]	$117,200	
Project Design, Permitting and Construction Observation Fees (15% of Construction Cost)	$180,000	
Total:	**$1,469,300**	
AACE Expected Accuracy Class 5[12]		
Low End Project Screening Estimate: -20% - -50% **L:**	$1,175,400	$734,700
High End Project Screening Estimate: +30% - +100% **H:**	$1,910,100	$2,938,600
MEAN COST of ACCE Class 5 Accuracy Range	**$1,689,700**	

Annual Maintenance Cost (20 year annualized cost)

Item Category	Cost	
Replace Ties[13]	$6,000	
Surfacing Crew 1/2 Day [13]	$1,500	
Ballast Refresh - 40 CY[13]	$700	
Rip Rap Refresh - 30 CY[13]	$800	
Rotary Hyrail Dump - 1 Day[13]	$1,300	
Replace Rail[13]	$500	
Existing Rail Bridge to South Repairs[25]	$2,000	
Total:	**$12,800**	
AACE Expected Accuracy Class 5[12]		
Low End Project Screening Estimate: -20% - -50% **L:**	$10,200	$6,400
High End Project Screening Estimate: +30% - +100% **H:**	$16,600	$25,600
MEAN COST of ACCE Class 5 Accuracy Range	**$14,700**	

Alternative 2 - Trail on the Mainland and Causeway Retained for Rail with Southern Opening and a New Northern Opening to Optimize Water Flow

Construction

Item Category	Cost	
Mobilization[1,2,3]	$72,300	
Erosion Control[4]	$54,300	
Safety and Traffic Control Measures	$15,000	
Misc. Removal & Demolition (vegetation, debris, etc.)[5,6]	$39,000	
Earthwork (minor grading at trail head parking lot)[7]	$7,400	
New Rail Bridge to the North 100' (Complete) (No Boat Access)[8]	$871,000	
Rail Road Tie Replacement[9]	$87,800	
Rip Rap Reinforcement (Along Causeway)	$943,600	
Western Waterfront Trail (6,100 LF)[10,26,27]	$740,000	
Trailhead and Parking lot[18]	$14,900	
Vegetation Restoration	$6,700	
Contingency (10%)[11]	$285,200	
Project Design, Permitting and Construction Observation Fees (15% of Construction Cost)	$465,000	
Total:	**$3,602,200**	
AACE Expected Accuracy Class 5[12]		
Low End Project Screening Estimate: -20% - -50% **L:**	$2,881,800	$1,801,100
High End Project Screening Estimate: +30% - +100% **H:**	$4,682,900	$7,204,400
MEAN COST of ACCE Class 5 Accuracy Range	**$4,142,600**	

Annual Maintenance Cost (20 year annualized cost)

Item Category	Cost	
Replace Ties[13]	$6,000	
Surfacing Crew 1/2 Day[13]	$1,500	
Ballast Refresh - 40 CY[13]	$700	
Rip Rap Refresh - 30 CY[13]	$800	
Rotary Hyrail Dump - 1 Day[13]	$1,300	
Replace Rail[13]	$500	
New Rail Bridge to North Repairs[20]	$8,700	
Existing Rail Bridge to South Repairs[20,21]	$8,700	
General Repair and Maintenance (mowing, brush removal, seeding, trash removal, recovery of vandalism, snow removal, etc.)[14]	$5,500	
Minor Western Waterfront Trail Repairs (fill low spots, fill washouts, slope repair, BMP inspection and repair)[14]	$2,300	
Major Trail Repair (top dress trail, fix culverts, fix fence and gate structures)(expected every 5 years annualized over 20 years)[14]	$2,600	
Total:	**$38,600**	
AACE Expected Accuracy Class 5[12]		
Low End Project Screening Estimate: -20% - -50% **L:**	$30,900	$19,300
High End Project Screening Estimate: +30% - +100% **H:**	$50,200	$77,200
MEAN COST of ACCE Class 5 Accuracy Range	**$44,400**	

Alternative 3 - Causeway Retention for Trail with a Southern Opening and a New Northern Opening to Optimize Water Flow

Construction

Item Category	Cost	
Mobilization[1,2,3]	$83,200	
Erosion Control[4]	$54,300	
Safety and Traffic Control Measures	$15,000	
Misc. Removal & Demolition (vegetation, rail line, debris, etc.)[5,6,16]	$273,000	
Earthwork (minor grading at trail head parking lot)[7]	$7,400	
New Pedestrian Bridge to the North - 100' (Complete)[8]	$602,000	
Western Waterfront Trail (Rail to Trail, 5,750 LF, length includes bridge retrofit cost)[22,23]	$765,000	
Trailhead and Parking lot[18]	$14,900	
Fishing Structures (2)[19]	$70,000	
Reinforced Canoe Launch Site	$5,000	
Rip Rap Reinforcement (Along Causeway)	$943,600	
Vegetation Restoration	$5,000	
Contingency (10%)[11]	$283,800	
Project Design, Permitting and Construction Observation Fees (15% of Construction Cost)	$468,300	
Total:	**$3,590,500**	
AACE Expected Accuracy Class 5[12]		
Low End Project Screening Estimate: -20% - -50% **L:**	$2,872,400	$1,795,300
High End Project Screening Estimate: +30% - +100% **H:**	$4,667,700	$7,181,000
MEAN COST of ACCE Class 5 Accuracy Range	**$4,129,100**	

Annual Maintenance Cost (20 year annualized cost)

Item Category	Cost	
General Repair and Maintenance (mowing, brush removal, seeding, trash removal, recovery of vandalism, snow removal, etc.)[14]	$3,900	
Minor Western Waterfront Trail Repairs (fill low spots, fill washouts, slope repair, BMP inspection and repair)[14]	$1,700	
New Pedestrian Bridge to North Repairs[20]	$6,000	
Existing Converted Bridge to South Repairs[20]	$6,000	
Major Trail Repair (top dress trail, fix culverts, fix fence and gate structures)(expected every 5 years annualized over 20 years)[14]	$1,800	
Total:	**$19,400**	
AACE Expected Accuracy Class 5[12]		
Low End Project Screening Estimate: -20% - -50% **L:**	$15,500	$9,700
High End Project Screening Estimate: +30% - +100% **H:**	$25,200	$38,800
MEAN COST of ACCE Class 5 Accuracy Range	**$22,300**	

Alternative 4 - Causeway Eliminated to Maximize Water Flow, Vestiges Retained on Ends for Public Fishing, Trail on Mainland

Construction

Item Category	Cost	
Mobilization[1,2]	$37,500	
Erosion Control[4]	$54,600	
Safety and Traffic Control Measures	$15,000	
Misc. Removal & Demolition (vegetation, rail line, bridge, debris, etc.)[5, 6, 16]	$288,000	
Earthwork (minor grading at trail head parking lot)[3]	$7,400	
Western Waterfront Trail (Rail to Trail, 1,900 LF)[22]	$190,000	
Western Waterfront Trail (6,100 LF)[10, 26, 27]	$740,000	
Trailhead and Parking lot[18]	$14,900	
Fishing Structures (2)[19]	$70,000	
Reinforced Canoe Launch Site	$5,000	
Rip Rap Reinforcement (Along Causeway to Fishing Piers)	$140,000	
Vegetation Restoration	$2,500	
Contingency (10%)[11]	$156,500	
Project Design, Permitting and Construction Observation Fees (15% of Construction Cost)	$258,200	
Total:	**$1,979,600**	
AACE Expected Accuracy Class 5[8]		
Low End Project Screening Estimate: -20% - -50% **L:**	$1,583,700	$989,800
High End Project Screening Estimate: +30% - +100% **H:**	$2,573,500	$3,959,200
MEAN COST of ACCE Class 5 Accuracy Range	**$2,276,600**	

Annual Maintenance Cost (20 year annualized cost)

Item Category	Cost	
General Repair and Maintenance (mowing, brush removal, seeding, trash removal, recovery of vandalism, snow removal, etc.)[14]	$6,700	
Minor Western Waterfront Trail Repairs (fill low spots, fill washouts, slope repair, BMP inspection and repair)[14]	$2,900	
Major Trail Repair (top dress trail, fix culverts, fix fence and gate structures)(expected every 5 years annualized over 20 years)[14]	$3,200	
Total:	**$12,800**	
AACE Expected Accuracy Class 5[12]		
Low End Project Screening Estimate: -20% - -50% **L:**	$10,200	$6,400
High End Project Screening Estimate: +30% - +100% **H:**	$16,600	$25,600
MEAN COST of ACCE Class 5 Accuracy Range	**$14,700**	

Notes:

Topographic survey and geotechnical information were not available at the time of this estimate. Dimensions were derived from an aerial photo.

10% contingency is included as provisions to account for unforeseen circumstances that should affect construction costs.

This estimate does not include costs for survey and environmental analysis that may be necessary, permitting, design, or construction operations.

Unit prices are based on recent construction costs.

Disturbances to wetland caused by dredging will not be re-seeded and are not part of concept costs.

Estimate does not include costs for remediation and habitat restoration.

Quantities based on elevation were derived from MN DNR Post Flood LiDAR Data (fall, 2012).

Mud Lake Depths were based on DEM of Mud Lake derived from bathymetric survey completed by BARR in the summer of 2013 to obtain detailed existing condition data.

Concept location and lengths were developed through design workshops during the summer and fall of 2018 involving Barr landscape architects, MN DNR, and City of Duluth staff.

Cost estimate has been rounded to the nearest hundred value.

1. Mobilization was calculated as 5% of the total construction costs.

2. Mobilization and erosion control costs for the Western Waterfront Trail is not included in general construction costs and was excluded from overall mobilization costs. Mobilization costs for the Western Waterfront Trail are included in linear foot cost of trail construction. See note 10 and 22 below.

3. Mobilization for bridge construction in is not included in general construction costs and was excluded from overall mobilization costs. Mobilization costs for bridge construction is 15% of bridge construction costs (remote/difficult access) and is included as part of the shown cost for new bridge.

4. Erosion control costs includes erosion control Logs at the proposed parking lot, rock construction entrances, and silt curtain along open water portion of the causeway. Erosion control for trail construction is included in linear foot trail cost of trail construction. See note 10 and 22 below.

5. The excavation and removal of the north portion of the causeway (where the new rail bridge to the north is located) is considered part of the proposed restoration project.

6. Clearing and Grubbing costs for the Western Waterfront Trail are not included. Clearing and Grubbing for trail is included in the linear foot cost for trail construction. Estimates do not include costs for environmental cleanup or habitat restoration. See note 10 and 22 below.

7. Grading area assumed to be a 15 car parking lot of 7,000 square feet.

8. Bridge cost is based on the assumption that the bridge will be constructed using precast concrete. Engineering design not include as part of line item cost (see bridge design line item for engineering design assumption).

9. Repairs include replacement of 25% of the rail road ties along the length of the causeway (ties quantities based on assumption ties are evenly spaced 20" on center). Replacement cost per tie provided by David Moore of LS&M (2018).

10. Western Waterfront Trail cost estimation was provided by the City of Duluth. Linear foot prices account for mobilization, clearing and grubbing, erosion and sediment control, landscaping and minor drainage modifications. Trail install costs include fencing to provide the necessary safety barrier between the trail and steep embankments (Western Waterfront Trail, Park & Recreation Master Plan 2017 Draft). Steeper portion of trail alignments included extra assumed costs related to difficult terrain.

11. Contingencies are included as provisions to cover unforeseen circumstances that would affect the overall construction costs.

12. The anticipated cost accuracy range is a Level 5 estimate class, which is defined according to AACE RP No. 18R-97 and ASTM E2516-11 (Cost Estimate Classification System, as Applied in Engineering, Procurement and Construction for the Process Industries). A Level 5 estimate class is intended to be used for "concept screening" and the anticipated accuracy range is from -20% to -50% on the low end to +30% to +100% on the high end.

13. Annual rail road maintenance costs are directly based on estimates provided to Barr from David Moore of LS&M (2018): Replace Ties - 60/year @ $100 Installed; Surfacing - Crew 1/2 Day @ $3000; Ballast - 40 cy @ $17; Rip Rap - 30 cy @ $27; Rotary Hyrail Dump - 1 Day @ $1300; Replace Rail - LS Own; Cost are for the 1 mile (approx.) length of the causeway. All annual rail road maintenance costs assumes work would be completed by volunteer labor.

14. Annual Trail Maintenance costs were provided to Barr by the City of Duluth Parks staff. Annual maintenance costs provided were for a typical 1 mile limestone path trail segment of 10 foot width.

15. Track removal includes removal and appropriate disposal of metal rail, wood ties, and preparation of remaining ballast as trail sub-base (Track removal cost provided by LHB 2018).

16. Estimate does not include potential income from rail and tie salvage.

17. Construction and maintenance of Outlook Trail Loop north of causeway not included as part of cost estimate.

18. Parking Surface assumed 7000 sf (~15 parking stalls and a 200' long 20' wide drive lane, Parking lot disturbance area based on developed concepts (assumed extra grading surrounding parking lot for drainage and trail access).

19. ADA Accessible wood pier, 6' wide, Timber Pile with concrete footing, 42" Picket Railing, 40' long

20. Bridge Repairs represent 1% total costs for new bridge construction (complete reconstruction). This number is meant to serve as a screening level cost for annual bridge repairs. Catastrophic storm events or structural failures may result in a larger bridge repair cost not captured as part of the assumed annual 1% of total new construction cost.

21. Owner of rail road (David Moore of LS&M, 2018) provided a $2,000 lump sum a year estimation for bridge repairs. This estimate assumes volunteer labor. This $2,000 lump sum estimate was not included in annual maintenance costs sown above. See note 20 for assumed existing rail bridge repair costs.

22. Western Waterfront Trail cost estimation was provided by LHB. Linear foot prices account for mobilization, clearing and grubbing, erosion and sediment control, landscaping and minor drainage modifications. Trail install costs include fencing to provide the necessary safety barrier between the trail and steep embankments (Western Waterfront Trail, Park & Recreation Master Plan 2017 Draft).

23. Retrofit of existing rail to pedestrian trail includes extra assumed costs related to material and safety features. (Causeway Widening cost scenario, Western Waterfront Trail, Park & Recreation Master Plan 2017 Draft).

24. Erosion control costs includes rock construction entrances, and silt curtain along open water portion of the causeway.

25. Annual rail road maintenance costs are directly based on estimates provided to Barr from David Moore of LS&M (2018): Replace Ties - 60/year @ $100 Installed; Surfacing - Crew 1/2 Day @ $3000; Ballast - 40 cy @ $17; Rip Rap - 30 cy @ $27; Rotary Hyrail Dump - 1 Day @ $1300; Replace Rail - LS Own; Bridge Repairs - LS Own Labor. Cost are for the 1 mile (approx.) length of the causeway.
26. The trail alignment runs through an area of known contaminated soils and waste from historic industrial activity. The Goal of the current remedial work is preparation for industrial redevelopment. The standards for cleanup need to meet residential use along the trail route. These costs do not reflect the costs for environmental cleanup.
27. Trail alignment significantly encroaches on US Steel property that is subject to a purchase agreement with the Duluth Seaway Port Authority for the purpose of industrial redevelopment. The Trail route will need adjustment to remove encroachment that impacts redevelopment plans. Current property owner US Steel, the Port Authority and the City will need to negotiate the best place to route the trail on the ridgeline should that alternative be selected. Costs may be outside the contingency costs if the trail stays below in the wetter areas.